ISSN: 2067-3809

Universitatea Politehnica Timișoara

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering

Tome XII [2019]
Fascicule 4
[October – December]

Editura POLITEHNICA

Edited by:

UNIVERSITY POLITEHNICA TIMISOARA

with kindly supported by:

THE GENERAL ASSOCIATION OF ROMANIAN ENGINEERS (AGIR) – branch of HUNEDOARA

Editor / Technical preparation / Cover design:

Assoc. Prof. Eng. KISS Imre, PhD.
UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA

Commenced publication year:
2008

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ISSN: 2067-3809

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VARIATION IN STRENGTH PROPERTIES OF CONCRETE USING WASTE GLASS AS PARTIAL REPLACEMENT FOR DIFFERENT COARSE AGGREGATES GRADING

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Abstract: This study examined the variation in the strength properties of concrete using waste glass aggregate (WGA) as partial replacement for different coarse aggregates grading. Aggregates sizes of 20mm and 25mm were partially replaced with WGA at 10%, 20% and 30%. Physical properties such as specific gravity, bulk density, and workability of fresh concrete and the compressive strength and tensile strength of hardened concrete of grade M25 were tested after 7, 14, 28, 56 and 90 days curing. Results of the physical properties revealed that WGA exhibited lower specific gravity of 2.70, bulk density of 1364kg/m^3, as compared to granite of specific gravity of 2.74, bulk density 1660kg/m^3. At 28days the compressive strength results of 20mm and 25 mm aggregate sizes of the control mix concrete were 35.05N/mm^2 and 34.02N/mm^2 respectively, while that of 30% of 20mm and 25mm WGA partial replacement were 39.02N/mm^2 and 32.83N/mm^2 respectively. The tensile strength for all the ages reached optimum value at 10% partial replacement WGA for both 20mm and 25mm aggregate sizes. The results of the strength properties showed that the concrete grade M25 adopted was suitable for WGA partial replacement as the compressive strength results for all ages did not fall below 25N/mm^2.
Keywords: waste glass aggregate, partial replacement, workability, strength properties

INTRODUCTION

Concrete is a composite inert material comprising of binder (cement), mineral filler (body) or aggregate and water. It is the name given to a mixture of particles of stone bound together with cement. Because the major constituent of concrete is of particles of broken stones usually gravel, and sand, which is termed the aggregate usually occupying 60-70% of the total volume of concrete. Cement acts as "glue" that binds the concrete ingredients together and is very important for the strength of the composite. The great demand of concrete is due to its structural strength and stability and also its favourable properties as a structural material, among which are its high compressive strength and its property as a fire-resistant element to a considerable extent.

Glass on the other hand is a hard, usually transparent substance formed by melting and cooling without crystallizing. [1], reported that the quantities of waste glass have been on the rise in recent years due to an increase in industrialization and the rapid improvement in the standard of living. The relative abundance of glass makes it available for production of concrete, this will consequently lead to low cost of production thereby making concrete structures (buildings) relatively cheap. Unfortunately, the majority of waste glass is not being recycled but rather abandoned, and is therefore, the cause of certain serious problems such as the waste of natural resources and environmental pollution. This recycled waste glass material has been studied in concrete masonry blocks, and tests on concrete with glass aggregate, including workability, permeability, and shear strength, have been performed to determine the suitability of the material in construction.

Literature survey indicates that the use of waste glass as aggregates in concrete was first reported over 50 years ago. [2], investigated and stated that the increasing awareness of glass recycling speeds up inspections on the use of waste glass with different forms in various fields. One of its significant contributions are to the construction field where the waste glass was reused for value-added concrete production. [3] discussed the various steps that need to be taken by recyclers in the use of glass which are to collect the glass, separate it from the other materials, clean it and crush it to obtain the appropriate grading to meet the specifications for specific applications as aggregate in concrete, either in commodity products, with the only objective being to utilize as much glass as possible, or in value-added products that make full use of the physical and aesthetic properties of colour-sorted crushed glass. [4], stated in their study that the use of waste glass or glass cullet (GC) as concrete aggregate is becoming more widespread each day because of the increase in resource efficiency. In the research of [5], waste glass and stone fragments from stone slab processing are recycled as raw materials for making artificial stone slabs using vibratory compaction in a vacuum environment.

Waste glass powder (40%) and fine granite aggregates (60%) are mixed with unsaturated polymer resins (8%) as binder. Under compaction pressure of 14.7 MPa, vibration frequency of 33.3 Hz and vacuum condition at 50 mm Hg, artificial stone slabs with high compressive strength of 148.8 MPa, water absorption below 0.02%, density of 2.445, and flexural strength of 51.1 MPa are obtained after 2 min compaction.

The artificial stone slabs fabricated in the study proved to be superior to natural construction slabs in terms of strength and water absorption. [6], stated that the demand for recycled glass has considerably decreased in recent years, particularly for mixed glass. Glass is cheaper to store than to recycle, as conditioners require expenses for the recycling process. In order to provide a sustainable solution to glass storage, a potential and incentive way would be to reuse this type of glass in concretes.

Depending on the size of the glass particles used in concrete, two antagonistic behaviours can be observed: alkali–silica reaction (ASR), which involves negative effects, and pozolanic reaction,

improving the properties of concrete. Their work dealt with the use of fine particles of glass and glass aggregates in mortars, either separately or combined. [7], investigated the properties of concretes containing waste glass as fine aggregate. The strength properties and the alkali silica reaction expansion were analyzed in terms of waste glass content. An overall quantity of 80 kg of crushed waste glass was partially replacing sand at 10%, 15%, and 20% within a 900 kg of concrete mixes. The results proved 80% pozolanic strength activity given by waste glass after 28 days.

The flexural strength and compressive strength of specimens with 20% waste glass content were 10.99% and 4.23%, respectively, higher than the ordinary control specimen results at 28 days.

The mortar bar tests showed that the fine crushed waste glass helped reduce expansion of concrete by 66% as compared with the ordinary control mix. [8], investigated the effects of recycled glass cullet on fresh and hardened properties of self-compacting concrete.

Recycled glass was used to replace river sand (in proportions of 10%, 20% and 30%), and 10 mm granite (5%, 10% and 15%) in making the self-compacting concrete mixes. The experimental results showed that the slump flow, blocking ratio, air content of the recycled glass self-compacting concrete mixes increased with increasing recycled glass content. The results revealed that the compressive strength, tensile splitting strength and static modulus of elasticity of the recycled glass self-compacting concrete mixes were decreased with an increase in recycled glass aggregate content. [9], established that using waste glass gathered from coloured soda bottles as partial replacement for coarse aggregate (with proportion up to 60%) did not have a significant effect upon the workability of the concrete and only slight reduction was reported in its strength.

MATERIALS AND METHODS

— Materials

The waste glass materials used for the study were gathered from dumpsites and restaurants in Ikole-Ekiti. These materials were primarily wine bottles, soft drink bottles and alcoholic drink bottles as shown in Figure 1.

Figure 1. Waste glass collected before breaking

The waste glass materials were crushed manually using a metallic rammer and a metallic basin and were later separated into sizes of different grades using manual hand method as shown in Figure 2.

The selection of cement used involved the exact knowledge of the connection between cement and performance required and, in particular, between kind of cement and either strength or durability or both the properties of concrete [10].

Figure 2. Waste glass after being broken and separated

Type II Ordinary Portland cements, which can provide sufficient levels of strength and durability, and the most common cements used by concrete users was used with brand name Elephant. Its chemical composition was determined using X-ray florescence technique. Natural sand is the fine aggregate chiefly used in concrete mix. Sand may be obtained from sea, river, lake, etc, but when used in a concrete mix, it should be properly washed and tested to ascertain that it is free from clay, silt, and such organic matters. Fine aggregate used was river sand while crushed granite of maximum nominal particle size of 20 mm was used as coarse aggregate. The grading for the aggregates was done according to [11]. The uniformity coefficient (Cu) for the sand and granite were 5.4 and 5 respectively while their coefficients of curvature (Cc) were 1.36 and 1.0 respectively. Potable water was used in producing the concrete mixture.

— Mix Proportion

A mix ratio of 1:1:2 by weight (cement: fine aggregate: coarse aggregate) was adopted to achieve a concrete cube strength of 25N/mm^2 and cylindrical strength of 25N/mm^2. While the water – cement ratio of 0.5 was used. Waste Glass at 0%, 10% 20% and 30% replacement level were partially replaced coarse aggregate.

— Test Procedures

The mineral content of the digested sample were analyzed using Atomic Absorption Spectrophotometer (Buck Scientific 210 VGP), flame photometer (FP 902 PG) and their oxides were calculated using a conversion table. The production of concrete for this test was conducted at the Civil Engineering workshop at Federal University Oye-Ekiti according [12]. All of the materials were measured to scale as calculated using a weighing balance and then mixed thoroughly to avoid segregation. A mix ratio of 1:1:2 by weight (cement: fine aggregate: coarse aggregate) was adopted to achieve a concrete cube strength of 25N/mm^2, the water – cement ratio of 0.5 was used. Waste Glass at 0%, 10% 20% and 30% replacement level would replace coarse aggregate grading. Mixing of the concrete was carried out manually with a shovel.

The workability test was carried out using a metal mould in the shape of a conical frustum known as a slump cone which is opened at both ends and has an attached handle. The tool typically has an internal diameter of 100mm at the top and 200mm at the bottom with a height of 300mm, as shown in Figure 3.

Figure 3. Concrete workability test using slump cone

Figure 4: Concrete moulds for Compressive Strength and Tensile Strength tests

The cone was filled with fresh concrete in three stages. Each time, each layer was tamped 25 times with a 600 mm long bullet-nosed metal rod measuring 16mm in diameter At the end of the third stage, the concrete was struck off flush with the top of the cone. The cone was carefully lifted vertically upwards with twisting motion so as not to disturb the concrete cone.

The upturned slump cone was placed on the base to act as a reference, and the difference in level between its top and the top of the concrete was measured and recorded to the nearest 5 mm to give the slump of the concrete. When the cone was removed, the slump may take one of three forms. In a true slump the concrete simply subsides, keeping more or less to shape. In a shear slump the top portion of the concrete shears off and slips sideways.

The mixed concrete was transferred into the moulds of 150 mm x 150 mm x 150 mm for compressive test and 300 mm x 150 mm cylindrical pipes for tensile test (Figure 4)

RESULTS AND DISCUSSION

— Chemical Analysis

The result of the chemical analysis summarized from the procedures above are given in Table 1.

Table 1: Chemical composition of constituent elements

S/N	Chemical Composition	Portland Cement	Waste Glass	Granite	Sand
1	Na_2O	0.51	9.609	5.194	0.356
2	CaO	62.60	21	7.114	0.223
3	K_2O	0.29	2.176	8.208	1.091
4	MgO	1.74	0.719	0.609	2.271
5	$AlO2_3$	5.09	3.017	9.670	12.104
6	OnM_3	0.007	0.072	0.275	0.03
7	Fe_2O_3	3.20	0.746	4.817	0.497
8	SiO_2	20.34	94.23	75.830	81.484
9	SO_3	2.19	0.012	3.701	2.130
10	LOI	0	0.023	2.096	0.697

— Physical Properties

The value of bulk density of granite, sand and WGA aggregate were 1660 kg/m^3, 1786 kg/m^3 and 1364 kg/m^3 respectively. Bulk density shows how densely the aggregate is packed when filled in a standard manner.

The bulk density depends on the particle size distribution and shape of the particles. Table 2 shows the results of the specific gravity, moisture content and bulk density of the aggregate samples.

It should be noted that the higher the bulk density the lower the void content to be filled by sand and cement. Since sand aggregate had maximum bulk it alludes that it has minimum voids and it's the right aggregate sample for making economical mix. WGA had the lowest bulk density and the result shows that it had about less weight compared to both the fine and coarse aggregate making it a light weight aggregate.

Table 2: Physical Properties of aggregate

Properties	WGA	Granite	Sand
Specific gravity	2.70	2.75	2.64
Moisture content	0.60	0.01	1.14
Bulk density	1364	1660	1786

— Slump Test

The variation of result of the workability of the fresh concrete mix at 20mm and 25mm WGA partial replacement is shown in Figure 5.

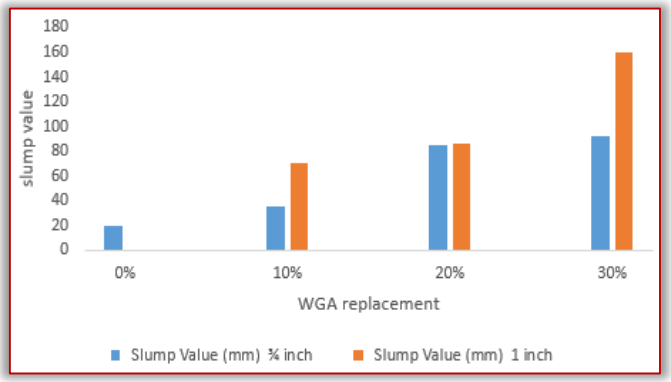

Figure 5. Workability of 20mm and 25mm WGA replacement

— Compressive Strength

The change in the compressive strength for concrete with different proportion of WGA at different percentages (0%, 10%, 20%, and 30%) for the 20mm granite replacement is shown in Figure 6, the compressive strength was found to decrease at 10% WGA glass replacement and then increased progressively as the percentage of the glass increases from 20% to 30%.

The maximum strength of the concrete cube was found at 30% replacement at 90 days which gave a compressive strength of 45.70 N/mm^2, while the lowest strength of the concrete cubes was found to be 27.98 N/mm^2 at 10% replacement of WGA at 14 days.

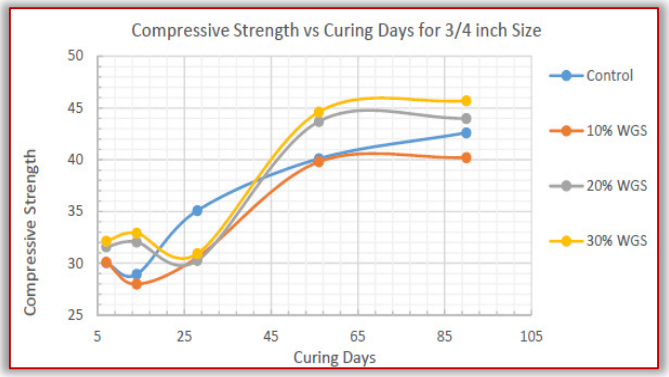

Figure 6. Compressive strength of concrete at 20mm WGA replacement at different proportion

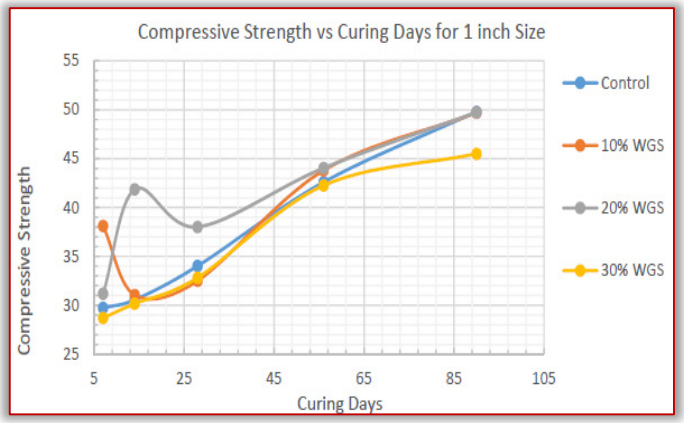

Figure 7. Compressive strength of concrete at 25mm WGA replacement at different proportion

The compressive strength for concrete with different proportion of WGA at different percentages (0%, 10%, 20%, 30%) for the 25mm granite replacement, the compressive strength was found to increase progressively at replacement from 0% to 20% and then continue to decrease at 30% replacement. For all ages except for 7days and 28 days which does not increase progressively from 0% to 20%, before it later decreased at 30 % like the other ages, as shown in Figure 7.

The maximum strength of the concrete cube was found at 0% replacement at 90 days which gave a compressive strength of 49.80 N/mm^2 while the lowest strength of the concrete cubes was found to be 28.71 N/mm^2 at 30% replacement of WGA at 7 days.

— Tensile Test

The tensile strength for all the ages reached it maximum at 10% and gradually began to fall as the percentages of the WGA increases except for the 90days result which strength decreases as the WGA increases from 0% to 30 %, as shown in Figure 8.

The maximum strength was 3.26 N/mm^2 at 10% WGA, 56 days curing age while the minimum tensile strength was 1.98 N/mm^2 at 30% WGA 90 days curing age.

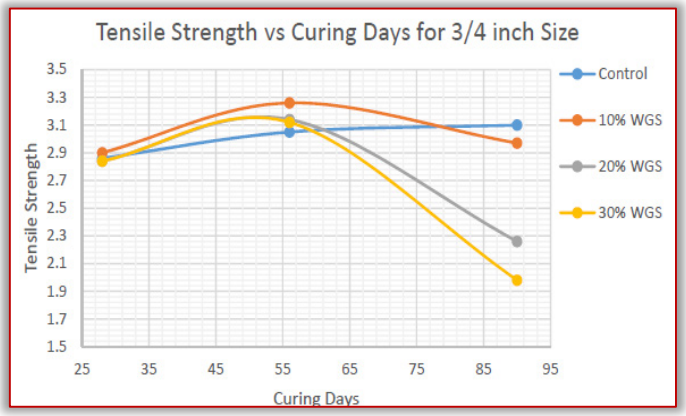

Figure 8. Tensile strength of concrete at 20mm WGA replacement at different proportion

The tensile strength for the 25mm WGA replacement for all the ages reached it maximum strength at 10% and gradually began to fall as the percentages of the WGA increases except for the 28 days result whose tensile strength decreases as the WGA increases in a nonlinear manner from 0% to 30%, as shown in Figure 9.

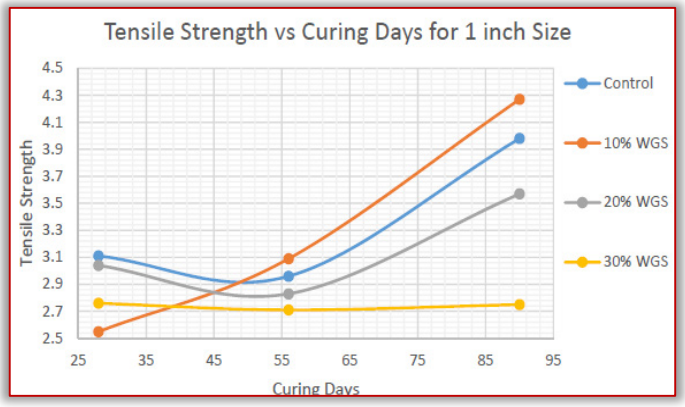

Figure 9: Tensile strength of concrete at 25mm WGA replacement at different proportion

At 10% WGA, 90 days curing age the 25mm WGA replacement was found to be 4.27N/mm^2 and the minimum tensile strength was found to be 2.55N/mm^2 also at 10% WGA, 28 days curing age.

CONCLUSIONS

Based on the findings of this study, the following conclusions were drawn;

- The physical and strength properties of the WGA are satisfactory, based on [13]. Physical properties such as specific gravity and bulk density values are found to be lower than corresponding values for the coarse aggregates, (granite). Waste glass aggregates WGA possess a low moisture content which affect the workability of the concrete at the mixing stage with subsequent effect on the hydration of the cement.
- The workability in the concrete mix with the 25mm WGA partial replacement was found to be greater than that of the 20mm WGA partial replacement because the 25mm WGA provides a greater void in the concrete mix, allowing for more air and water in the concrete mix which in turn resulted to the concrete mix of 25mm being more workable than the 20mm WGA.

Based on the physical properties of waste aggregate, WGA is a potential replacement for granite in regard with its different grading.

- The compressive strength of concrete with both 20mm and 25mm WGA increases as the curing age of the concrete increases progressively from 7 days up to 90 days.
- For the 20mm WGA replacement, the compressive strength at 10% was found to be lesser than that of the control mix (i.e. 0%) and the strength started increasing as the WGA increases progressively from 20% to30% increment and the maximum compressive strength was at 30% for the 20mm WGA.
- For the 25mm WGA replacement, the compressive strength of concrete at 10% was found to be lesser than that of the control mix, the maximum strength was at 20% of 25mm WGA replacement.
- Result showed that the tensile strength for all the ages reached it maximum strength at 10% and gradually began to fall as the percentages of the WGA increases for both 20mm and 25mm WGA replacement except for the 28 days and 90 days results whose tensile strength decreases as the WGA increases in a nonlinear manner from 0% to 30%.
- The densities of concrete with different proportion of WGA for the 20mm and 25mm coarse aggregate replacement ranges from densities of 2240 and 2400kg/m^3 and are classified as a Normal weight concrete and this helps in the optimization of concrete density to improve structural efficiency (the strength to density ratio), reduce transportation costs, and also enhance the hydration of high cementations concrete mixtures with low water-binder ratios.
- The M25 mix design used for this work was found suitable for the WGA partial replacement as the resulting compressive strengths for all the ages did not fall below 25N/mm^2 which was the minimum compressive strength of concrete of ratio 1:1:2.
- WGA is suitable in Civil Engineering construction with design mix M 25 up to 30% replacement without compromising the strength of the concrete

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ISSN: 2067-3809

Fascicule 4

[October – December]

t o m e XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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CHARACTERISTICS AND POSSIBLE ENTREPRENEURIAL PROFILES

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Abstract: Entrepreneurship implies the directing of resources in the area of their optimal use, while entrepreneur implies the person who acts, who gives concrete forms to jobs, who anticipates risk, create new forms of jobs, expands employment, and enables better and more efficient organization of enterprises capable of meeting all the challenges put in front of it. The role of entrepreneurship is universal. It includes almost all aspects of human life. Every society uses entrepreneurs' experience in management, support and success encouragement, resource activation, motivation and risk awarding, business efficiency, stability and growth, taking responsibility and business risk. Entrepreneurs see their chances where others see confusion and chaos. Key players enabling such changes are free entrepreneurs, young entrepreneurial managers, persistent innovators, and creators of a new business world.

Keywords: entrepreneurship, characteristics, profiles of entrepreneurs

INTRODUCTION

Many people search for activities that will make them financially independent. The reasons for creating one's own business are numerous. Such reasons depend on personalities. Not everyone is capable of running a business or grasps what is necessary to run a certain project. This suggests that there is a great number of those who may become entrepreneurs, who have entrepreneurial characteristics and who could express their potential in an effective way. Entrepreneurship has been in focus during the previous years, due to the significant benefits realized by small and medium-sized enterprises in the overall development of national economies of developed countries. Entrepreneurship is a multidimensional phenomenon which is involved in many disciplines. The entrepreneurship theories come from various schools, with different opinions, and many authors identify various different factors that lead to entrepreneurial ventures [7].

The key word that circulates around the economy development in numerous countries is education. The emphasis of entrepreneurship and entrepreneurial education is on starting a business and the growth of entrepreneurial activities, and especially on the occurrence of business problems. Enabling the young through the education, i.e. the introduction of entrepreneurship in the curricula within the present educational system-starting from the lowest educational level-creates more possibilities for a continuous increase in awareness and expands the horizons to future entrepreneurs.

Over recent decades, the change of economic structure on the global level has been characterized by a redistribution of those employed in the economic sector, where an overflow of labour force from the primary and secondary sector to the tertiary sector has occurred. The valorisation of real (hidden) potentials and productive employment have been greatly conditioned by the affirmation of entrepreneurial behaviour, starting from family, small and medium-sized enterprises and progressing to a higher (aggregate) level. A multitude of factors affect the processes of intensifying the development of entrepreneurship (including, among others, market, financial, urban, communal, legal, and human factors), which are the ambience in which the entrepreneurship is affirmed as an efficient way of running and developing a business, and also the improvement of quality of life and work in certain environments[10].

Small and medium-sized enterprises are one of the key sectors of the economy development in European countries. They are significant initiators of innovations, employment and social and local integration in Europe. In the European Union, there are about 23 million micro-, small- and medium-sized enterprises, comprising 99% of all registered business subjects. The enterprises employ close to 75-million people and constitute the basis of the economic growth strategy [8,9].

The business of small- and medium-sized enterprises, i.e. the entrepreneurs, is burdened by numerous problems, but vary based on the phase of life cycle of an enterprise. At the start of the business, entrepreneurs are often adequately not prepared to launch their business and do not perceive all problems they will encounter. On the other hand, there is an evident lack of readiness of banks to finance the "start-up" activities of future entrepreneurs. In the phase of growth and development, small enterprises are burdened with other additional problems. As the first, management is burdened by achieving efficiencies to overcome a lack of information about the possibilities of growth and development, as well the challenges of market recognition and evaluations of their business' chances and risks. As the second, the transition from the entrepreneurial to the management phase of an enterprise causes a crisis in the form of lack of management skills, which is manifested in the lack of, or inadequate, business plans, intuitive models of business decisions making, inadequate controlling methods, lack of education, or criteria and plans, in general. As the third, even successful small enterprises face a crisis due to the needs of further growth, and that requires greater technical and administrative knowledge related to export business, international marketing and financial operations, professional knowledge on modern production and quality systems. As the fourth, with the growth of an enterprise and the increase of the technical-technological level of the business, there occurs a lack of professional labour force, modern production equipment, adequate business premises/ objects and/or a suitable location. As the fifth, they must meet the

challenge of financing growth through self-financing, credits for working capital and long-term investments, often with unfavourable conditions from perspectives of interest rates and mortgages.

The process of quick technological changes, which characterizes the modern economy, is mostly the result of new entrepreneurial ideas [12]. Because of that, entrepreneurship becomes an opportunity for the countries in transition, because entrepreneurs can contribute to a greater degree of utilization of available resources and faster economic growth, by which it is possible to gain parity with developed countries [6]. As was shown by [5], young entrepreneurs are confrinted by limitations to a greater extent, above all as regards access to finances and the creditability of the young, and at the same time such limitations decrease the chances for the young people to build their own business by themselves.

The development of small- and medium-sized enterprises is not realized only through the entrepreneurial practice and economic policy measures, but through system efforts to achieve direct, structural changes in the sphere of education. On the basis of the research up to now [3], an increasing number of young people will link their professional development with the sector of small and medium-sized enterprises in the future. Many learned lessons and experiences [4], extracted from successful projects, confirm that entrepreneurs should have the following potentials and abilities: a sharp perspicacity for new market chances and consumers' needs; general and personal management skills, good communication with potential investors/financers, partners, employees; analytical dexterity, enthusiasm, self-confidence and innovativeness.

DEFINING ENTREPRENEURSHIP

In theory and practice, we often meet with the dilemma of making distinctions between the functions of an entrepreneur and a manager. The difference exists, certainly, but the distinctions depends on the amount of entrepreneurship actually used in particular enterprises, i.e. on the way that an enterprise is run. In every case, it is impossible to imagine the business of an enterprise outside the normal chain (ownership-market-entrepreneurship-management). So, it is impossible to imagine the function of a manager without entrepreneurship, and, at the same time, it is impossible to imagine an entrepreneur who does not use at least some of managerial methods.

The history of entrepreneurship dates back to the Middle Ages, and entrepreneurship came into full bloom with the development of capitalism, which unites the preferences for personal wealth and the wish for profit maximization.

Over time, entrepreneurship and entrepreneurial activities attained a professional and civilized character. The notions of entrepreneur and entrepreneurship were used for the first time by Richard Cantillon, an English economist at the end of the 17th and the beginning of the 18th century, and, until today, an entrepreneur is considered to be an initiator and organizer of jobs, an innovator, a vigorous business man who operates under conditions of, at least, moderate risk and under its own property liability. From this statement, it can be concluded what is the strength of the entrepreneurship spirit and why that spirit is what forms the heart of the spirit of a market and the economic system in general. Zombart thought that the spirit, form-order and substance were the three key formative elements of every economic system.

Entrepreneurship is often defined even more broadly [5], and it is related to the type of behaviour, and not only the running of a business, or self-employment. For example, the International Labour Organisation (ILO) defines entrepreneurship as the way of thinking and reasoning. That is much more than the bare running of a business. That is a process in which individuals become aware of the options for self-employment and career building, development of ideas, taking and management of risks, learning the process of taking initiative in the development and owning of a business [11].

The theorists in the area of entrepreneurship are obsessed with defining the word "entrepreneur." Their priorities are maybe backwards. The entrepreneurship theory, as stated by [1], can solve the problem with a definition, and it becomes irrelevant.

Thus, for example, a famous theorist [2] pointed out the nine primary factors of entrepreneurship. Due to the fact that all the notions (in English) start with "f", the concept has been known in literature as the 9F concept of successful entrepreneurship:

- Founders: significance of first-class founders, wise and respected;
- Focused: directing towards selected market segments (so called niches);
- Fast: fast decision making and fast application of the decisions;
- Flexible: fast adaptation to change;
- Forever-innovating: permanent quest for the new;
- Flat: permanent struggle to decrease all costs;
- Friendship: to be a friend with all stakeholders;
- Fun: it is fun to cooperate with an entrepreneurial enterprise.

It is clearly understandable that it is not easy to provide all the named factors simultaneously, as the assumptions of successful entrepreneurship, but it is undoubtedly necessary to strive to create a greater number of them, thus providing successful conditions for a good start of a business venture. Although it has been believed that a good start is what the entire entrepreneurial process depends on, a weak start will not disturb a true entrepreneur and make him/her quit. On the contrary, there is a not so small number of those, who draw additional inspiration and new energy, so that they persist and end up as winners. So, for a success, a synergy of the personal characteristics of the entrepreneur and business environmental conditions is necessary.

Although it is not disputable that, for the manifestation of entrepreneurial behaviour, besides the personal features of an entrepreneur, being an individual and the holder of personality, it is extremely important that there are adequate socioeconomic, legal and cultural ambients in which personal features of potential entrepreneurs can be realized and developed. At first, it is necessary to check if and to what extent there are participants who have psychological and other potentials to become entrepreneurs in the given environment. The characteristics of potential entrepreneurs are the following ones [8,9]:

1. Taking the risk. An entrepreneur is a person who takes risks, i.e. someone who deals with a new business run outside pre-existing organizations.

2. Independence. An entrepreneur is an independent person who does not like to work for others, but who rather works on his/her own.
3. Internal centre of control. Those who believe that they themselves have a great influence on what happens to them are denoted as people who have an internal centre of control.
4. Live though excitement. Although some people strive for a calm life, some other are oriented towards excitement and action. Entrepreneurs fit into the second category, because they like the excitement brought by the new and different.
5. Self-initiative. Entrepreneurs start things when they decide to do so, using their own ideas and energy as the rationale.
6. Self-confidence. Entrepreneurs have great self-confidence, i.e. significant belief that the new product, service, idea or approach they propose brings benefits. This self-confidence is necessary because others often do not support their new ideas.
7. Adaptability. Entrepreneurs are adaptable. Markets and systems change. Business must change together with them.
8. Pertinacity. Entrepreneurs are pertinacious. They are the people who do not quit in spite of obstacles.
9. Ambiguity. Entrepreneurs must tolerate the dilemma of choice placed in front of them. For some persons, some situations are difficult to be resolve, dangerous and psychologically problematic. That is not the case when an entrepreneur is in question, because the uncertainty affects them less, so they are even able to use it.
10. Identification patterns. Entrepreneurs are capable of solving disputes by using identification patterns. They are able to see how everything fits together, perceiving in one glance the entire "wood," while others choose to fight with "trees".
11. Little need for assistance. This is closely related to self-confidence. Entrepreneurs are more than self-confident. They feel little need for assistance from other people.
12. "The right thing". The phrase presumes a psychological perspective in entrepreneurship. It is necessary to possess certain features, i.e. the characteristics of someone who wants to be an entrepreneur.

Which of these characteristics-they can also be called the entrepreneurial values-will be accepted, rejected or ignored in the environment in which an entrepreneur operates, depends on numerous circumstances, and above all on accepted social norms, as well as on economic, political, and, increasingly, on international conditions. Politically and economically stable societies are more tolerant towards the stated values, because they are widely accepted and make up a part of the social and entrepreneurial climate, culture and moral.

Besides the analysed personality characteristics of an entrepreneur and the structure of knowledge he/she must possess, it is necessary to say something on the specific skills he/she needs to perform such a complex and multi-layered activity as entrepreneurship.

Above all, it is necessary to remember that his/her entire work is reduced to the realization of an idea to achieve a positive result and that is always together with other people, never alone. An entrepreneur needs skills so that he/she converts the ideas into reality. The conversion of ideas into reality requires two types of skills from an entrepreneur: management ability in the purpose of organizing physical and financial resources and human resources management skills because of the necessary support of others. Every entrepreneur, regardless of his/her abilities and education, has to rely on associates, and that is why teamwork skills and abilities are so essential for him/her. It is also very important that an entrepreneur possesses the following skills [8,9]:

- strategic ability, i.e. the ability to perceive a job as a whole, holistically, but also the ability to look ahead, prospectively;
- ability to plan as an initial step every action and ad a basis of perceiving the future, but also the ability to predict the future;
- marketing ability, by which the needs, demands and interests of clients as the key stakeholders are perceived, because of which, generally, an entrepreneurial venture has been initiated;
- financial abilities, because the management of money as working capital is the condition that ensures the continuity of a business and the flow of money, and the ability to evaluate the required investments and accompanying risks;
- ability for project management, which implies project organization and providing project resources at the right time and at the right place;
- ability for time management, since time is a resource that cannot be refunded, implying a strict hierarchy of priorities in performing the tasks.

Besides the named abilities and skills of an entrepreneur, it is useful to indicate the necessity of possessing the abilities which qualify him/her as a successful communicator within an enterprise's environment. Above all, in this regard, we think of [8,9]:

- management skills, needed to stimulate the people to work and perform the tasks important for the success of an entrepreneurial venture, their directing, support and assistance in realization of the tasks, organization of work processes, selection of staff and rational use of their abilities, administration and control of all work processes and achieved business results;
- motivation ability, by which the commitment to an entrepreneurial idea, jobs and tasks in its realization are achieved; it is also important that an entrepreneur equally motivates himself/herself, and also the people he administers in the business process;
- ability for the distribution or assignment of jobs and tasks, assuming knowledge about the abilities the people possess and the means of their engagement and of greater development of their abilities for a more efficient execution of jobs;
- communication abilities, i.e. the need for oral and spoken expression of ideas and informing of people about them with the aim to affect the actions of people by means of information and communication;
- negotiation abilities are not bargaining abilities, but the creation of a situation of general understanding and

recognition of possible outcome for all the sides in a negotiation process;
- operational ability, as a response to the changes in a dynamic organization system and as a condition for a successful and efficient business by taking adequate measures and actions;
- creativity, as the ability for logical thinking and inference, which produces the ideas and practical solution to problems by successful use of markets, technical aspects, staff, scientific details, other information and other potentials;
- ability for critical observation of statuses and relationships because nothing should be taken "for granted," but every bit of business information and phenomenon must be critically discussed, its positive and negative effects perceived, and only after that satisfactory decisions should be made:
- analytical ability enables a complex organizational system, composed of numerous elements and subsystems, to be perceived, arranged and functionally harmonised with numerous internal and external factors by entrepreneurs.

ENTREPRENEURIAL PROFILES

The current globalization process convinces use every day that the so-called global entrepreneurial revolution is in progress in which the main participants become the economies of China and India (not so significant until recently), and of many other Asian countries, as well as of Russia and Brazil.

The abundant talent for creation of almost incredible business ideas, a flood of the most diverse production and service programs and projects, unbeatable talent for innovation, and especially for imitation, great inner markets and aggressive orientation towards exports are all sufficient reason to reassess the up-to-now trajectories of entrepreneurship based on the Western paradigm of selfish individualism and quick enrichment. In the context of such global transition processes, the profile of an entrepreneur as a key agent of change, who confronts great challenges, should be redefined, i.e. redesigned.

At the beginning of the 1970s, the so called third technological (microelectronic) revolution started in the West, which really rocked the world of labour thoroughly, especially that of industrial production, and it contributed to sophistication and systematization of many spheres of human life. In the 1990s, completely new opportunities, the so-called e-business and net entrepreneurship, were launched along with revolutionary breakthroughs in trade, banking, the stock-exchange business etc. But, relatively quickly, the fast-growing business (dot.com) experienced a deadlock, and, at the turn to this century, even a collapse, with dramatic consequences. It is recovering at the moment and will probably gain new strength, but a logical question occurs on the real perspectives of new businesses, their reach, limits and likely prospects. In that light, new roles, tasks and, especially, the profile of modern and future entrepreneurs are being studied. Essentially, the roles and tasks of entrepreneurs will remain more-or-less the same, including the fact that the way to realization of the roles and tasks will experience many changes. It is apparent even now that the main change is reflected in the change of the entrepreneurs' focus from financial, material, and, especially, technical-technological resources, to human and intellectual resources as the key components of every entrepreneurial process. Some important characteristics of a modern entrepreneur then are [8,9]:

- A modern entrepreneur is not a rigid boss, slave driver who is awe-inspiring, but is also a leader and trainer who commands respect, because he/she knows how and wants to encourage, motivate and develop the creative energy of the members of his/her team in the realization of common goals.
- A modern entrepreneur is dominantly oriented towards the stimulation of creativity and innovativeness. He/she does not wait for changes to react, but generates or at least anticipates them, i.e. predicts and prepares himself/herself for upcoming changes. He/she is not afraid of change, because they are seen as a challenge and a chance for new success.
- A modern entrepreneur raises the morale and works on the improvement of business ethics in his/her environment. He/she is aware of the long-term importance of a business' reputation, and business ethics can contribute to that in many ways.
- Because of the strengthening of his/her own abilities, as well as the abilities of the associates, a modern entrepreneur becomes aware of the importance of constant renewal of knowledge and skills necessary for following, predicting and generating changes.
- The ability for effective communication becomes an imperative for success for modern entrepreneurs. This fact must be recognised in all educational curricula for entrepreneurship, and, above all, in business schools.
- A modern entrepreneur is greatly oriented towards the global business stage. Because of that, he/she must be familiar with international relations, relations among countries and people, various cultures and economies and must be capable of developing the goals and strategies of his/her enterprise in the wider context of international business and fiercer competition.
- Modern entrepreneurship becomes more and more based on high technology, especially information technology. Due to that, a modern entrepreneur has to know the key trends (megatrends) of production and control technologies and to take them into account as the key factors for gaining a competitive advantage.
- Modern entrepreneurship is based on legally regulation and the procedures that are internationally standardised and harmonised to a great extent. Because of that, a modern entrepreneur must know the logic of complexity in the field of legislation and respect the legality of competent local and international institutions and accepted conventions, treaties, agreements etc.

In brief, modern entrepreneurs are a personification of numerous human qualities and features, and because of that they can be classified into these three groups [8,9]:

- Entrepreneurs–technicians, when there is a wish to point out their emphasized technical orientation, which, above all, considers them as innovators in the creation of new products or processes. In that, they see the creation of organization as the instrument for realization of their defined goals, and not as the final goal.
- Entrepreneurs–creators of organisation, to whom the creation of organisation is the most important goal, as a opposed to entrepreneurs–technicians. The most important thing for them is to realize the development of organisation by means of the growth and development of business, which is measured by the increase of profit and the number of employees. They are aware that it is possible, through good cooperation with people, by organising them into teams within which they exert their influence and power.
- Entrepreneurs–job constructors, who are the "cause" of the processes of contracting, negotiating and making new arrangements, because they like initiating jobs. They do not tolerate a total dedication to one organisation over a long period of time and are always ready to start a new entrepreneurial venture because they enjoy the creation of a new business and always have a "backup option."

Although the territory of the Balkans is incorporated into the processes of European integration and global processes, there are still numerous specificities of doing business there, especially in so-called transitional countries. Such specificities are reflected, above all, in the long-term isolation and enslavement of some nations, in the major influence of tradition, in the mixture of cultures, religions (exchanges, of Eastern and Western Christianity and Islam), etc. They have a manifold origin and are not only resident, but are also formed in modern conditions that are marked by numerous crossed interests of a wide circle of (international) participants at the "geostrategic route" of Europe and which, in most cases, to not have legitimacy (justification) for their actions.

Having all that in mind, it is also possible to speak about a specific type of a so-called Balkan entrepreneur. However, in doing that, the significant differences between particular Balkan countries and societies must be taken into account, because some of them have always been capitalistic, while others are in the process of transition to capitalism, and some are formally integrated into European integrations, so that it gets more and more difficult to talk about a unique profile, although the differences in relation to the Western European profile are still very visible. It also have to be pointed out that there are many entrepreneurs who, in their features and behaviour, do not differ in any way from the best European entrepreneurs and managers. Unfortunately, they are still not a majority. In brief, we can state a few important flaws of Balkan entrepreneurs, which should be removed as soon as possible [8,9]:

1. The lack of vision and clear perspective on what to do in a turbulent business environment;
2. Wrong or completely neglected following of the flow of money in most enterprises;
3. Insufficient knowledge and understanding of the structure of costs;
4. Nonexistence of the practice of making business plans for an enterprise;
5. Underdevelopment of a marketing approach to entrepreneurship;
6. There are no traditions, skills and techniques for rapidly making important decisions;
7. There is very strong distrust towards all forms of business cooperation, especially with foreigners;
8. Ethical standards of entrepreneurship and personal fairness are not on such a high level;
9. The age structure of entrepreneurs is unfavourable, i.e. there are very few young entrepreneurs in the Balkans in ages up to 30; most of them are up to 50 or older;
10. Mental inertness and aversion to further education;
11. Persistent orientation to waiting for external help (there is a strong inclination by some Balkan entrepreneurs towards waiting for someone (i.e. the state or an international organization, e.g. the European Union funds, to determine finally "our development priorities", with every entrepreneur hoping that exactly his/her enterprise will be included in the priorities, which would solve all problems automatically);
12. The lack of understanding and slow acceptance of the ecological criteria of business.

CONCLUSION

The definition of entrepreneurship has evolved over time. The earlier understanding of entrepreneurship is not similar to the current one and will acquire yet other attributes in the future. Basically, there is a consensus in some aspects of definition, such as: creativity, innovativeness, independence, and affinity for risk.

Entrepreneurship does not come to the fore outside a market ambience. Entrepreneurship and its creative components are related for the idea of market verification, i.e. the commercialization of a result in the market. The main characteristic of entrepreneurship is the creation of something new in a production or service program, depending on influences from the environment.

The characteristics and profiles of entrepreneurs presented in the paper do not characterize, to the same degree, all those who consider themselves entrepreneurs. These characteristics comprise what could be called the typical entrepreneurial profile. Due to the fact that every person has her/his own special personal features, they make an entrepreneur unique. Of course, the number of features varies and is more expressed in some entrepreneurs then in some other.

If the entrepreneurial profile of a person is similar to the profile of entrepreneurs, in general, these persons can be expected to exhibit entrepreneurial behaviour and to be more strongly motived to start their own businesses. If certain conditions and events are favourable, the individuals with adequate entrepreneurial characteristics apply their resources and compensate for their weakness to exploit a sufficiently favourable situation. None of the discussed characteristics and profiles of entrepreneurs gives an

integral interpretation of the key factors for success of an entrepreneur, but they integrally enable the understanding and explanation of the reasons for success of entrepreneurial enterprises and, of course, entrepreneurs as owners of such enterprises. Success is the result of the personal characteristics of an entrepreneur and the ability to learn from experience and to adapt to influences from the environment. The personal characteristics of an entrepreneur are the most important in the start-up stage of a new business. The ability to learn from experience becomes more important after the running of an enterprise, and the growth and development of the enterprise depend on the gained experience, knowledge and ability to adapt to influences from the environment. Entrepreneurial intentions depend on the way in which an entrepreneur experiences the feasibility of the imagined idea and his/her affinity for action. The spark to action often depends on the availability of resources. Before starting a business, an entrepreneur usually has a form of a business plan. That is the entrepreneur's personal concept, vision and expectation about the way in which the business activity will develop. From that point of view, a business plan is desirable and relevant. An entrepreneur may plan only the project, i.e. to design a business plan, but he/she usually depends on some assistance in the form of training, advice or consulting. His/her decision to take action in a certain moment may depend on whether he/she feels relevant and efficient.

The future of entrepreneurship is promising. The support to entrepreneurship, i.e. to entrepreneurs, is growing. There is even a global process that unifies, to a certain degree, the relationship of the state to entrepreneurship and the development of small- and medium-sized enterprises pursuant to that. It is apparent even now that the main change is reflected in the change of the entrepreneurs' focus from financial, material, and, especially, technical–technological resources to human and intellectual resources as the key components of every entrepreneurial process.

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ISSN: 2067-3809

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FUNCTIONAL FLOW BLOCK DIAGRAM WITH UML FOR TEST VISUALIZATION

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Abstract: The use of UML models for testing context is gaining momentum in the existing model based testing scenario. Appending the model semantics and annotation are important mechanisms to represent functional and nonfunctional properties of design elements. This also leads to evolution of new models preserving the semantics of underlying models like UML as reference. In current research such models depend on complex mathematical and graphical notations for its realization. This makes model evolutions or transformations difficult to generate and tedious to use. However, if the development model is adopted for representing test conditions, it will bridge the semantic and operational gap between developer and tester. The structural composition and the interaction pattern during runtime are different aspects of visualization. The analysis of system requires both interpretations to conform for expected behavior. This will serve as an insight for test preference also. This paper focuses on developing semantics of UML applicable to visualize tests. This includes an abstract notation, Functional Flow Block Diagram (FFBD) that incorporates the flow semantics into component diagram to better visualize the execution context. This diagram is adopted from UML and is drawn with intent to visualize test requirements of the system. An important application for reliability analysis is the motivation to the work. The FFBDs are easily mapped into Reliability Block Diagram (RBD) that associated reliability constraints to the diagram. This facilitates visualization of quality which is the contribution of the paper.
Keywords: UML models, Functional Flow Block Diagram (FFBD), Functional Flow Block Diagram (FFBD)

INTRODUCTION

Testing is an activity that assures successful execution of functionality. It focuses on validating the requirements with possible input and achieving desired behavior. Systems generally fail due to incomplete or incorrect interactions which were not estimated during design phase. These interactions include sharing of data or functionalities within or beyond a system. This, however are not explored unless executed. Testing designs for early detection of flaws is a matter of discussion since years. The understanding of the structure of the system, data that flows through various components and the dynamic nature of software today need to be understood. Various diagrams in the UML have significantly accommodated structural and dynamic constraints of execution. When we evaluate the software architectures today, we find that the demand for quality (not only functionality) is the concern of engineers. The applications draw data from various sources, manipulate them with various algorithms for a wide range of applications. In the view of customer, the system needs to be reliable, secure and robust for giving the performance up to mark. The responsibility of the developer and the tester has escalated simultaneously. New methods for the evolving architectures and the testing strategies need to be devised to deliver quality with functionality.

The current scenarios in software development exploits reuse oriented design patterns that are deployed to fulfil the functional requirements of the system. They are more of coalition based systems which come from varied sources, technologically and vendor based. The concept of design is casually taken with a fact that they do not adapt to implementation requirements and do not scale or evolve with code. They even lack updated versions while the interaction of components is required from the various sources. Our paper is intended to handle these exceptional conditions of designs. The beauty of the design is however versatile to answer any such query. Software reuse makes existing components fit into the design. The quality of the components taken together form the metrics of quality of the system. A decision-making capability can be drawn during design stage to select components of high quality to achieve a better software. The functional attributes along with non-functional ones can be annotated to serve the purpose. The strategy will enable design to predict the capabilities of the system in terms of quality. The challenge is to define such annotations in the semantics of existing models to make them applicable in industry practices. The choice of UML models is the preference in our work. These models have grounded concepts through UML infrastructure and specifications formally defined and used as standards. The capability of the UML to extend gives a suitable dimension for framing our concept into modeling terminologies.

Several models have been used in the analysis of software. The models for testing applications are an interesting research in the subject area. Several researches have been made to employ one or another diagram out of UML for the testing signifying the area of Model Based Testing. The area is emerging with new technologies in development. The challenges also float with trends to mark thrust in the research in the state of art of model based testing. May it be service oriented systems or designing models or metamodels for them, the concern for quality is an upright choice. A general overview of the various issues pertaining to the model based testing is presented in the figure 1. The concept of component based testing is relevant to our paper and the domain in which it shall be applicable is shown in figure 2.

Testing is important for quality. A software requirement if marked with perspectives and so the testing must also conform to the same perspectives. Sufficiency is attainted when all the aspects of testing are fully covered and most of the code is verified. The test oracles with specific test criteria and proper planning for test process are important. With the concepts of object oriented and component based testing, major areas of research has evolved like aspect oriented, domain oriented or performance testing. This is reflected

from the new architectures to develop software. Thus a challenge for the existing design models is to cope up with the new architectures.

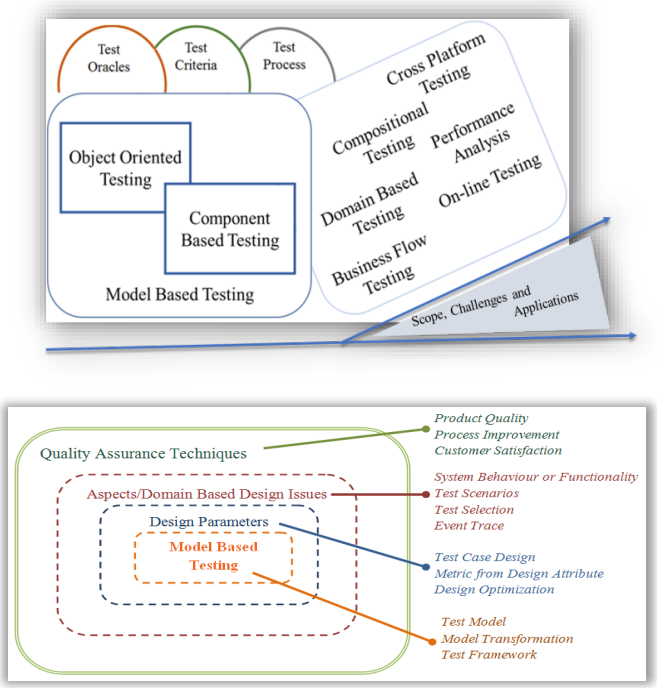

Figure 1: Scenario of model based testing and its application in current research

Another challenge while using models for testing is reading its specification to extract relevant test information [18,19]. The UML specifications effectively model systems with formalism in syntax and semantic rules. The syntax of the specification defines elements of the UML in abstract form as diagram and also as textual descriptions as annotations. The semantic are descriptions in the form of OCL and other constraints. The model properties are extracted and used in test automation methods. Several functional and non-functional characteristics are tested through such annotations and contribute to an essential characteristic of UML that is well-formedness. Description logics [22,23], multi-diagrams [24], are alternatives of knowledge representation and semantics of UML models. The next section details the research based on various models and acknowledges the valuable contributions.

The paper is organized as follows. Section 2 reviews and acknowledges past research in the domain. Section 3 proposes the methodology of deriving a new representation of system. Later in the same section are the algorithmic based specification derivation and its use in test case preparation. It also gives the interpretation of the FFBD for reliability assessment. Finally, in Section 4 the model is created and results are expressed. Section 5 is the conclusion that describes the essential gain from this technique and its scope to automate the process with the newly derived functional flow notation.

RELATED WORK

A critical part of development involves testing the code. Developments in life cycles for Agile Methodology with Test Driven Development, Test Design First Development, Behavior Driven Development, have made testing a decisive activity. Model Based Testing [13, 14] rules with prior system estimates before implementing it. Models in UML are classified structural and behavioral to represent the system with different aspects. Certain algebraic methods and formal / informal models exists that are based on mathematical analysis of model properties and their interconnects. These models are more analytical for research and so fail to be easily adopted for software development practice methods. But to highlight the contributions, it is the activity diagram that is most suitable to understand the flow and then can easily be modulated with graphs for assessment [1-3,11,12]. State diagrams [16,17] also contribute to test case generation based on coverage criteria. Class diagrams [20,21,10] are important to understand the structure of the system, its dependency with other parts or modules of the system, to estimate complexity in realizing the behavior through the collection of classes. These diagrams as stated earlier lead to large amount of tests that are derived from the transactions stated in requirements [5]. The code thereby developed also comes in several iterations with subsequent testing and corrections thereafter. The drawback is that the design does not get updated with it. So the testing stage has the code to test and the design faces neglection.

A combination of diagrams is sometimes adopted to generate tests. A mapped class and state chart [4,7] or an aggregate notation from sequence and collaboration [8] is seen in papers. Model based tests does not restrict to identifying defects only but has a broader value in terms of creating a system model, its analysis in terms of inputs and outputs, reporting flaws in design, formal report generation and generating test requirements for future phases [13]. This is an intelligence imbibed in design which even allows to choose appropriate from a marketplace to create new systems.

In order to generate the diagrams, the architectural constraints must be clearly stated. This depends on the type of software being developed. The quality is an umbrella feature for any software. UML defines QoS and concepts of fault tolerance as the extensions of UML profile and specifications. The attributes of quality can be within a QoS framework and defined appropriately. The same notation can even extend to define attributes like reliability in the same UML notation. The paper actually contributes to the test requirements and quality to represent in developer's conversant modeling format like UML. The practice for quality and its inclusion in early life cycle stages is important to achieve quality throughout the system phases. An example for which is CISQ. The Consortium of IT Software Quality (CISQ) defines certain quality characteristic measures for nonfunctional aspects such as reliability, performance efficiency, security and maintainability. There are recommendations for incorporating quality into development and includes certain best practices for achieving it. For instance reliability can be achieved by good coding practices like protecting state in multithreaded environments, safe use of inheritance and polymorphism, resource bound management and managing the allocated resources. The same can be stated in architectural practices like multilayer design compliance, managing data integrity and consistency, exception handling through transactions, class architecture compliance and so on. Similarly the QoS characteristics and constraints can be placed in UML metamodel to define modeling for quality. QoS characteristics are quantifiable attributes of system and logically constructor for non-functional

aspects of quality like latency, throughput, availability, reliability, safety, confidentiality, integrity, probability and accuracy.

The paper explores possibilities to embed these QoS characteristics in design properties for evaluating these parameters in the design stage itself. The next section is a formal definition of our proposed model. The semantics are of UML and scoped to future aspects like sustainable designs.

PROPOSED METHODOLOGY

Models are the artifacts generated and used in the stages of software development. As in conventional systems, all the diagrams that pertain to system representation are drawn. Other than these diagrams, a new diagram inspired from System Engineering Flow Diagram is to be drawn which is illustrated later in this section.

Functional Flow Block Diagram is the formal model that encompasses the components participating in execution context. The notation is actually adapted from the activity diagram, component diagram and system engineering flow diagram. It characterizes activity diagram with its events and the sequence in the flow from beginning of the transaction to its end. This is a most appropriate way to depict the dynamics in the system with available se of components in the design. It also borrows certain features of the class diagram to preserve its structural composition in place.

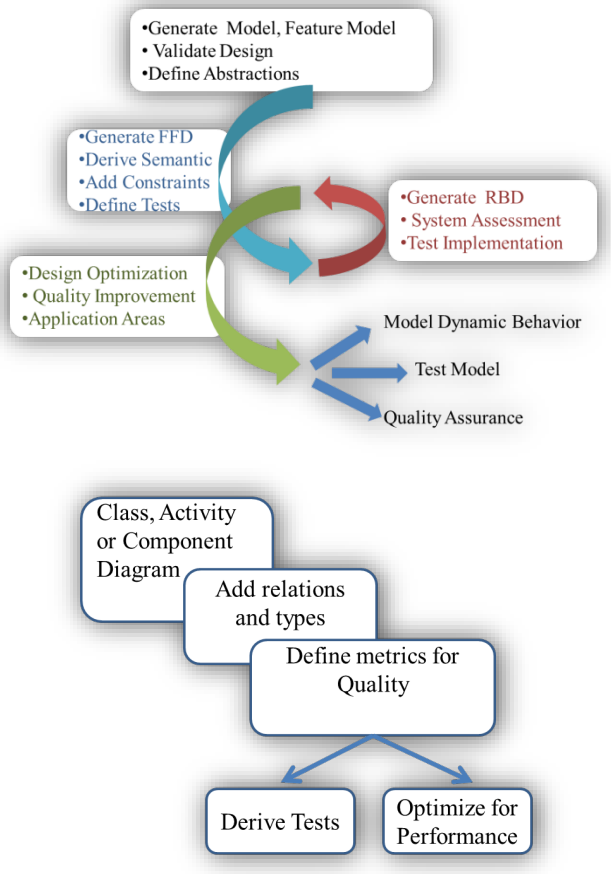

Figure 2: Proposed Methodology for Test Modeling

Our model aggregates the details from both the diagrams and creates explanatory diagram similar to a component diagram with greater details. The process of generating the right model streams from the requirements started in the early analysis phase. The usual practice is specifying the functional requirements in the use cases and realizing it in the activity diagram. We also annotate the non-functional requirements from the beginning so that it is also incorporated in the design. For the same we define our feature model along with use cases. Now the functionalities are drawn hierarchically in the feature model. We define the levels in our feature diagram to bring it in an n-tier architecture. The feature model will somehow represent the component that invokes a set of another classes or components while execution. The level of abstraction resolves to a fine-grained level each time such invocations occur.

The second stage evolves the Functional Flow Block Diagrams with the semantics as defined in SysML for blocks. The same can be easily transformed to reliability block Diagram to model reliability within the design. The assessment is done through this RBD.

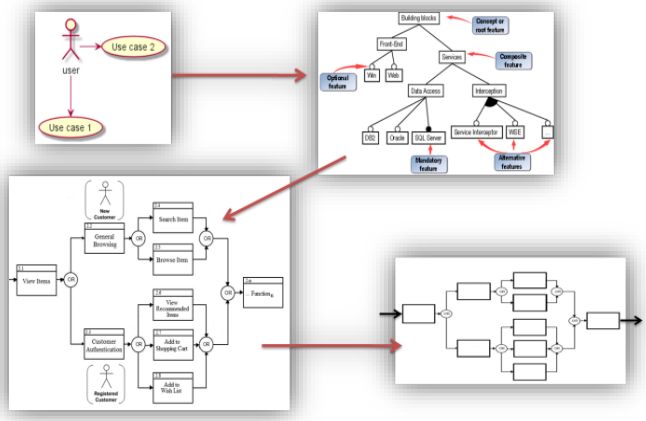

Figure 3: Stepwise Model Transformation

The abstract syntax for Block as specified in the SysML standards is SysML: Blocks: Block which is characterized with constraints, operations, parts, references, values and properties. A SysML block defines a system with its features. The Block contains compartments for each of its characteristics. For example constraints are written to specify any physical constraints in the system. The constraints are the places where we can define the exceptional conditions about the execution of the component. The blocks are further incorporated with internal blocks and their properties. The SysML notation [SysML] is shown as in figure

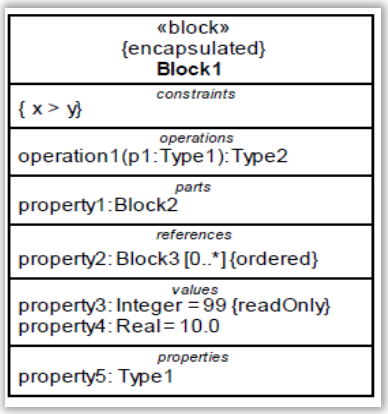

Figure 4: SysML Block

The whole process is a four-stage model transformation strategy which needs formal annotations. The UML semantics for quality has been well formulated as QoS Profiles and we annotate the design

elements with the syntax as mentioned with the profile. The parameters for quality are broadly defined and are referred as characteristics. This is described as QoS Characteristics with QoS values. For example, failure occurs when the behavior of system differs from the intended behavior. Fault in the same way is the adjudged or hypothesized cause of an error. The OCL notation for the same is defined for fault and failure as QoS characteristic with domain, perception and consequences.

The same semantics for reliability is stated as <<QoSDimension>>Reliability with the attributes as expected-number-service-failures: {direction(decreasing)} and <<QoSDimension>> operation semantic:string type. It is characterized with the value estimate of failures to define the ability of the system to keep operating correctly over time.

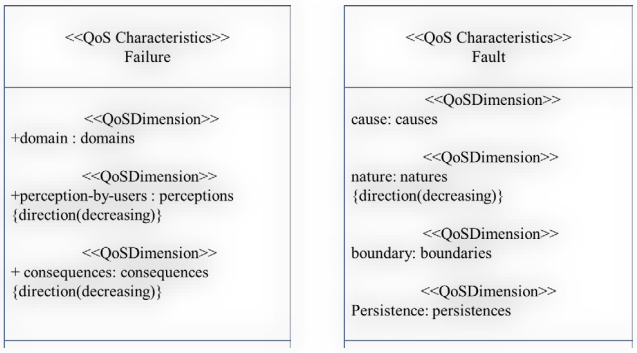

Figure 5: QoS Characteristics in UML Profile

Availability is syntactically annotated as:

<<QoSCharacteristic>>Availability
<<QoSDimension>>
time-to-repair:real
{direction(decreasing), statisticalQualifier(mean)}
<<QoSDimension>>
time-between-failures:real
{direction(increasing), statisticalQualifier(mean)}
In the context of availability ie context availability:: availability-post
result OK: result = time-between-failure / (time-between-failures + time-to-repair)
<<QoSDimension>>
availability-value()
{direction(increasing), statisticalQualifier(mean)}
Another characteristic is fault tolerance which is also defined as
<<QoSCharacteristic>>fault-tolerance
<<QoSDimension>>
max-number-of-faults:
{direction(increasing, statisticalQualifier(maximum)}
<<QoSDimension>>
+error-processing:error-processings
{direction(increasing)}
<<QoSDimension>>
Fault-treatment:fault-treatments
{direction(increasing)}

Once the profile for the component is ready the values pertaining to the attributes are evaluated for the design of system. The actual values attained are used for deciding the component for its inclusion in design. In case the component needs to be backed with error detection, error control and fault treatment properties, then the annotation is marked as model property. This reference to characteristics of QoS in design of system based on reusable components enables test prioritization [26] for such components so that reliability is ensured. Regression testing thus has a ranked set of components based on such properties to clearly state critical functions.

RESULTS

The test visualization is easily managed through the diagram FFBD and the assessment of non-functional requirements of quality is also performed. The structural and dynamic behavior of the system in line with system engineering conventions is applied for software systems here. The large-scale systems can easily be decomposed into hierarchical components and defined within abstractions.

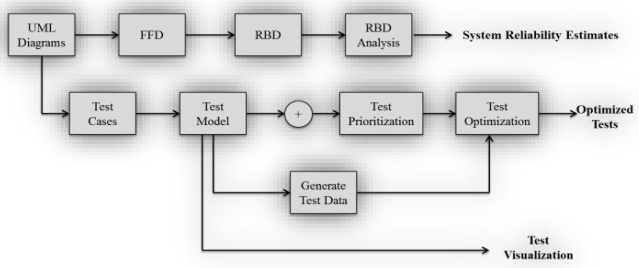

Figure 6: Assessment Model [24]

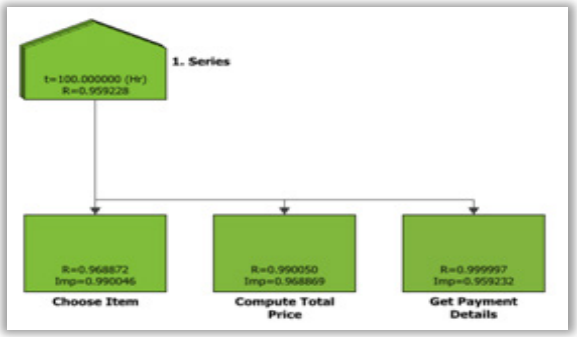

Figure 7: Reliability Importance for Blocks [24,25]

Thus, a complex system is fit into a single view of representation here. The reliability estimates for components are generated that can be annotated into the design. This leads to additional attribute which defines suitability of that component to fulfil quality requirements of the system. Rather than complex mathematical illustrations, the probabilistic modeling confines to a simpler method of assessment. The scope of the paper restricts the implementation related analysis, but the methodology is hereby suggested for the assessment and visualization. The reliability analysis leads to a parameter of Reliability Importance which prioritizes the blocks or components for testing purpose also [figure 7]. This is rephrased in the model properties as model characteristics and subsequently used.

CONCLUSION

This paper focuses on developing FFBDs in the semantics of UML to visualize tests. This includes defining Blocks in its abstract notation then incorporating the flow of control into the definition of components to visualize the execution. This FFBD has been referred from SysML and is drawn with intent to visualize test requirements of the system. An important application for reliability analysis is presented in this paper k. The FFBDs are easily mapped into

Reliability Block Diagram (RBD) for further analysis of reliability of the system. As this is a part of testing, therefore we recommend our methodology for the test based visualization in model based design and testing. This may further be applied with agile or test driven development strategies for evaluation.

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ISSN: 2067-3809

Fascicule 4

[October – December]

t o m e XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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USING SYSTEM MODELING AND SPECIFICATION METHODS

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Abstract: After presentation of MERISE method as a general-purpose modeling methodology for developing information systems, we propose a specification approach based on the OOPP method (Oriented Objective Project Planning) and Merise enabling a description of a system. In fact, a cooperative approach of two methods has been proposed and a case study of a cereal storage system has been presented. This cooperative approach has been presented in this work according to a methodology integrating the two methods OOPP and Merise that can complete them and that lead to the global resolution of a problem of management of activities of grain silos.
Keywords: Information System, MERISE, OOPP specification methods, grain silos

INTRODUCTION

Performances of a production structure as complex either it especially depends on the performance of its system of information. This is how the development of an information system of an enterprise and the efficiency of its exploitability is an important operation. It enables to adapt constraints of measure and collection of information to those of treatment and exploitation. The modeling of such information system enables us to dispose of a tool of analysis and help to the decision making.

Various methods and techniques have been exploited in a context of upgrading particularly the systemic OOPP method (Oriented Objective Project Planning), that has been spread and applied in various case (Project of upgrading of a grain silo, analysis of financial activities, analysis of the cereal grading system…) [1, 3]. This method has been used in order to contribute to the deployment and development of a system of information of various industrial enterprises. This activity requires using modern tools enabling to fear problems concerned by the enterprise.

We exploited the OOPP and SADT methods (Structured Analysis Design Technique) [4, 5] to express needs (not necessarily computer), to land the functional aspect of a load notebook, to communicate between a team's different members, and no as methods of functional analysis of software, because the gotten results depend more the analyst's expertise than of the rigor of the method.

The object of this paper is to present a specification approach based on the application of the method MERISE for the modeling of the information system in a context of cooperation with OOPP method.

DEVELOPMENT OF A MERISE MODEL

In order to manage a complex process as the cereal storage process, it is useful to model it taking in account of its behavior as well as rules of its conduct.

The achieved model will enables us to put in evidence dysfunctions of the system notably the aspects of the distribution of cereals in the one hand, and to make simulations of new scripts of optimization and organization, in the other hand.

If we consider the complexity of the system and the different aspects according to which we want to model, it is necessary to make a simplification of this last while defining for each of its constituent the degree of detail to not to pass.

MERISE [6, 7] has been applied in order to elaborate a model of representation of the process of cereal storage. This computer method is more complex than SADT [8, 9]. MERISE integrates the different levels of abstraction (Figure 1).

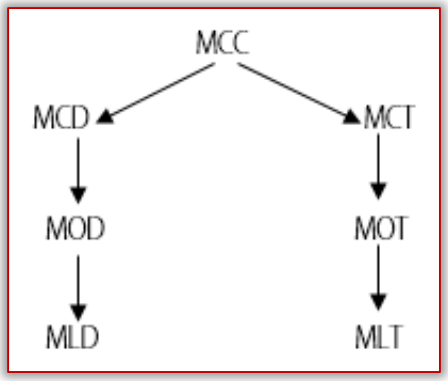

Figure 1. The abstraction cycle of MERISE

Conceptual Model of Communication (MCC) is the investigation of the current environment, which ultimately allows the realization of Conceptual Data Model (MCD) and the Conceptual Model of Treatments (MCT).

MCD is a model that represents the structure of the information, from the point of view of the data. This looks closely at the relationships between various key points like the relationship between clients, products, orders...

MCT is a model that represents the different treatments and responses to specific actions.

The Logical Model of Data (MLD) contains the contents of the MCD but specifies the structure and organization more clearly so it can be implemented.

Logical Model of Treatments (MLT) which specifies the parts and means to be implemented. It is in this part where each role is put into place.

The vocation of MERISE is double: on the one hand MERISE represents a method of conception of the information system of enterprises and on the other hand MERISE proposes a methodological gait of development of information system [10].

MOTIVATION OF COOPERATION APPROACH

Of the fact of its character structured and participative, we consider the OOPP method extensively evolutionary and adaptive (Figure 2). This is why our research team invested itself in view to develop some convivial and functional tools for the extended OOPP method, definite under the denomination MISDIP (Method Integrated of Specification, Development and Implantation of Project) [11, 12]. This new method, under development and normalization, present today a limit as for its environment of utilization.

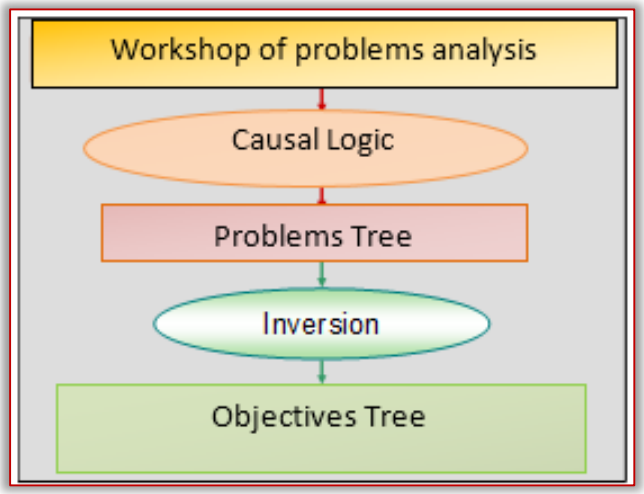

Figure 2. OOPP method

Hence, of our motivation to offer an environment of help to the development, we tempted to make cooperation between the OOPP [13, 14] and Merise that profit today of a more functional environment (tools, formalism, culture…).

The objective of this cooperation is to exploit the structuring and participative and specification aspect of the OOPP method on the one hand and the convivial tools of the environment MERISE, on the other hand [15].

MERISE is considered as being a standard, and an important tool for the survey and the development of a computer application. Its representation arranges numerous qualities as: a very good legibility thanks to the clarity of its diagrams; a hierarchical structure and no formalized; recognition of synchronizations as basis concept…

The methodology of this cooperation resides first to exploit OOPP in the phase of the structuring and the specification of the system to develop, to exploit an interfacing of cooperation between the two methods then and to exploit MERISE for the representation and the development (Figure 3).

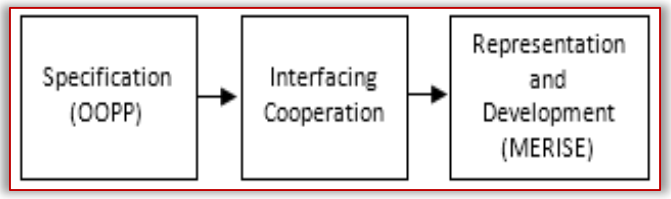

Figure 3. Methodology of cooperation

This is why the methodology of this cooperation is based on 3 phases: the first concerns the system with its various processes, the second relates to the process of cooperation and the third to the state of exit.

— 1st phase:

a. to delimit the process, object of the development, and to represent it by a simplified diagram block limited to the first levels of the analysis
b. to analyze by OOPP the system by a hierarchical manner
c. to identify the informational environment of every entity "Activity"
d. to establish the matrix of information that enables to determine ties between the entities "Activity". These information are regrouped them also by entity" Information"

— 2nd phase:

e. To consider these information as a data structured constituent so the dictionary of Merise
f. to define objects of MERISE according to a logical appreciation of entities as "Activity" that "Information"
g. to establish relations between objects while exploiting the entities "Activity" on the one hand and on the other hand the free ties of the "information" Matrix

— 3rd phase:

h. the whole of these elements (dictionary of data, objects, relations, events, operations, results) constitutes the specification of the system
i. to exploit the environment of representation, modeling and development of Merise to develop the project

CASE STUDY OF A GRAIN SILO

The analysis of the system of receipt, storage and expedition of cereals clears a part relating to data manipulated representing the information system and a part relating to the relative treatment process on the one hand to the system and to its management and its conduct on the other hand [16, 17].

Considering the fixed objectives and of results of simulation waited us we interest to rules of management of the system and its conduct. For it, one supposes that the system of handling is dimensioned in order to not to complicate the modeling, in the same way one won't retail the system of provision that is governed by the complex procedures [18, 19].

— Management process of activities of grain silos

In order to present a model simplified of the management process of the activities of grain storage system (Figure 4), we used a representation of block diagram and while retailing the two coins in particular process purchase and sale of cereals.

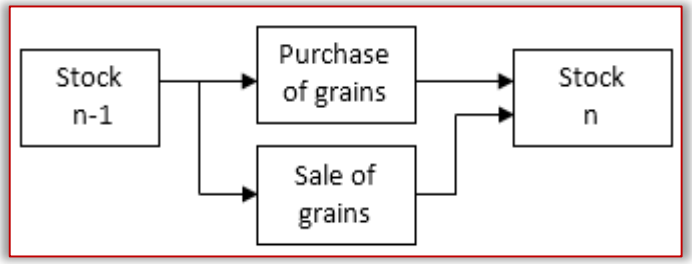

Figure 4 - Block diagram of the management process of activities of cereal storage system

— Specification of elements of the Merise formalism

In order to specify the various elements of the graphic formalism used on the one hand by MERISE, and the information associated to the management process and rules of conduct, we exploited the OOPP method (Table 1); besides we represent on this same matrix, in its last column, the correspondence of the entities "object" of the method MERISE.

Table 1- Results of the OOPP analysis

N°	Code	Designation
1	GO	Process of grain movement analysed
2	SO1	Extern information needed for the process of grain movement identified
3	R1.1	Extern information needed for the product identified
4	R1.2	Extern information needed for the purchase order identified
5	R1.3	Extern information needed for the provider identified
6	R1.4	Extern information needed for the client identified
7	R1.5	Extern information needed for the exit ticket identified
8	R1.6	Extern information needed for the stock identified
9	SO2	Process of purchase of grains analysed
10	R2.1	Product identified
11	A2.1.1	Estimate the number of grain purchase transactions
12	A2.1.2	Identify the code of grains
	A2.1.3	Identify the nature of grains
	A2.1.4	Identify the origin of grains
13	A2.1.5	Identify the quantity of grains
14	R2.2	Purchase order established
15	A2.2.1	Identify the order number of the purchase order
16	A2.2.2	Identify the date of establishment of the purchase order
17	A2.2.3	Identify the quantity of the ordered grains
18	A2.2.4	Identify the code of the ordered grains
19	A2.2.5	Identify the author of the purchase order
20	R2.3	Provider requested
21	A2.3.1	Identify the name of the grain provider
22	A2.3.2	Identify the code of the grain provider
23	A2.3.3	Identify the name of the grain applicant
24	A2.3.4	Identify the date of the solicitation

EXPLOITATION OF TOOLS OF MERISE

For the example of cereal storage presented, we considered the system of cereal storage as an information system, for which MERISE is well adapted. This is why we present the Conceptual model of Data (MCD) and the Conceptual Model of Treatments (MCT).

— Development of MCD

Considering the presented elements, we elaborated the MCD model. In order to facilitate the reading of the model, we specified by verbs the nature of relations.

From the list of properties and rules managing the system, we determined in a first time objects (correspondent often according to OOPP to Result) while specifying for each of them identifying him (correspondent for OOPP to information the more representative and most applicable). In the same way, we determined relations (correspondent for OOPP to the entity "Activity") and cardinality from the observation of the system and its working and the OOPP analysis done.

— Development of MCT

In the MISDIP model, the matrix of information, of by its constitution, can be considered like a support illustrating relations between information imported by an entity "Activity" and information produced by this last; these last information are considered then as the transformation of information imported by the entity "Activity". The relation between the produced information and the information imported by an entity "Activity" constitutes a treatment can give the MCT of Merise.

A treatment can be very elementary as the one of a registration of information considered like an event that triggers an operation to generate a result constituting another event triggering the following operation. Thus, the event whole - Operation - Result can constitute a basis entity of the representation of the MCT.

CONCLUSION

Techniques of specification, formal or semi-formal enable the description of a system; in view to model a grain silo while exploiting a cooperative approach of system analysis. This is why we presented a model of representation of based on two methods OOPP and MERISE. In this specification approach, we especially surrounded parameters of every method and we established correspondences between them in an objective to make complete them mutually.

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ISSN: 2067-3809

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EFFECTS OF DIFFERENT ENVIRONMENTS ON THE CORROSION PROPERTIES OF WELDED MILD STEEL PLATE

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Abstract: The study on the effects of different environment on the corrosion properties of welded mild steel was evaluated using the weight loss analysis method. Chemical analysis was done on the mild steel plate using ARX spectrometer. Three sets of samples were used; two samples were not subjected to any corrosive environment. Two other samples were immersed in 0.3 M NaCl and the last two samples were immersed in water. Results showed that the un-welded samples exhibited greater loss in weight compared to the welded samples; the rates of corrosion of welded samples were observed to be lower in comparison with their un-welded counterparts in their corresponding corrosive environment, and the maximum values of corrosion rates of the samples were obtained for un-welded steel sample immersed in 0.3 M NaCl (1.924344 mg/mm^2/yr.); welded steel sample immersed in 0.3 M NaCl (0.509108 mg/mm^2/yr.); un-welded steel sample immersed in water (0.001821018 mg/mm^2/yr.); and welded steel sample immersed in water (0.000780731 mg/mm^2/yr.).
Keywords: environments, corrosion, weight loss, welded and un-welded samples

INTRODUCTION

Mild steel is a type of steel alloy that contains a low amount of carbon as a major constituent. Its carbon content falls within the range 0.10 – 0.25% of low carbon steel. Mild steel is the most common form of steel and it is the major material used in construction industry due to its low cost. Mild steel have good strength, hard and can be bent, worked or can be welded into an endless variety of shapes for from vehicles to building materials. Its unique properties such as low cost, high strength, hardness and easy availability, made it to have wide range of applications in many areas such as vehicle parts, truck bed floors, automobile doors, domestic appliances, nut bolt, chains, hinges, knives, armour, pipes, magnets and military equipment (Kumar and Yadav, 2013; Talabi, *et al*., 2014).

The interaction of these materials with their immediate environment results in the deterioration of the mechanical properties (such as hardness, toughness, ductility and strength) and physical properties of the materials. In metals, there is actual material loss either by dissolution or by the formation of non-metallic scale or film (Callister, 2007). This material loss is as a result of corrosion. Corrosion can therefore be regarded as the gradual degradation, destruction or deterioration of a material, usually metals, by chemical reaction with its environment. This is done as a result of the electrochemical oxidation of metals in reaction with an oxidant such as oxygen. A common example of electrochemical corrosion is rusting, which is the formation of iron oxides. This type of oxides typically provides oxide(s) or salt(s) of the original metal. All environments are practically corrosive to some degree. Some examples are air and moisture; fresh, distilled, salt, and other gases such as chlorine and ammonia (Fontana, 2007).

Corrosion is a multifaceted phenomenon that adversely affects and deteriorates metals through oxidation. Corrosion degrades the useful properties of materials and structures including strength, appearance, and permeability to liquid and gases. Katundi *et al*., (2012) characterized the corrosion resistance in the steel sheets (Hot dip galvanizing of steel sheets) used in automotive industry. They carried out simulated corrosion tests, wet/humidity test and hot dust/dry cycle talk test in laboratory conditions. They tested dynamic behaviour of the corroded specimens dynamically to simulate under the crash test conditions. They exposed the samples to changing climatic conditions in terms of humidity. It was also observed that pitting corrosion damage and crack initiation sites were developed and propagated.

This research focuses on the evaluation of the effects of different environments on the corrosion properties of welded mild steel plate for automobile body service application using the weight loss analysis method.

MATERIALS AND METHOD

— Materials and equipment

The materials used for the experiment include: low carbon steel alloy of known chemical composition, emery paper of the following grades (60, 120, 180, 220, 320, 400, 600, 800, 1200 grits), tong, plastic containers, diamond paste, and zinc rod. The chemicals used for the experiment are sodium chloride (NaCl) and distilled water.

The following equipment were used for the research: universal polishing machine; metallurgical microscope; mass spectrophotometric analyzer; universal hardness tester; cutting machine; grinding machine; digital multi-meter; pH meter; welding machine (electric-arc and oxy-acetylene); calibrated cylinder; digital vernier caliper and digital weighing balance.

— Methods

≡ Sample preparation

The mild steel plate was sectioned into six samples each of equal sizes (20 mm length by 20 mm thickness). The first three samples were un-welded while the remaining three samples were further sectioned into two each and welded (using electric-arc welding). The six samples were then separated in pairs (each pair containing a welded sample and an un-welded sample) resulting into three

pairs. The three pairs are M_1 and M_2 as un-corroded samples, S_1 and S_2 as samples immersed in the chloride environment and lastly W_1 and W_2 as samples immersed in water. Samples M_1 and M_2 were purposely set aside just to examine the pre-corrosion microstructure of the steel sample. The sample description is presented in Table 1.

Table 1: Sample Description

Sample	Description
M_1	Control sample for pre-corrosion microstructural analysis for un-welded samples
M_2	Control sample for pre-corrosion microstructural analysis for welded samples
S_1	Un-welded steel sample immersed in 0.3 M NaCl
S_2	Welded steel sample immersed in 0.3 M NaCl
W_1	Un-welded steel sample immersed in water
W_2	Welded steel sample immersed in water

≡ Chemical analysis:

The chemical analysis was done on the mild steel plate using ARX spectrometer (Oyetunji, *et al.* 2013). Corrosion rate determination was done by weight loss method. In order to effectively calculate the corrosion rate of the samples, the initial weights of the samples were taken using the digital weighing balance. Two samples (M_1 and M_2) were not subjected to any corrosive environment for proper comparison. Two other samples (S_1 and S_2) were immersed in 0.3 M NaCl and the last two samples (W_1 and W_2) were immersed in sea water. The corrosion exercise lasted for 61 days and weighed at intervals of 4 days for the samples immersed in the chloride environment and samples immersed in sea water. The corrosion exercise was undertaken at room temperature, and the weight loss of each sample was obtained by calculating the difference between the initial weight and the obtained weight at each interval.

The corrosion rate of each sample is then calculated using equation 1 in accordance to (Fontana, 2007; Seifedine, 2008) and the results are presented in graphic form and depicted as Figures 1, 2, 3, and 4.

$$\text{Corrosion Rate; } R = \frac{KW}{\rho AT} \quad (1)$$

where:
K, a constant,
W, the weight loss of the metal in gram
T, time of exposure (hours)
A, the surface area of the metal exposed (cm^2),
P, the density of the metal (kg/m^3).

RESULTS AND DISCUSSION

— The chemical analysis result

The result of the chemical analysis of the as-received mild steel plate is as presented in Table 2.

Percentage of alloying elements = Mn 0.82 + Cr 0.080 + Ni 0.102 + Nb 0.0054 + W 0.0001 + Ti 0.0003 + V 0.0016 = 1.0094 %

From the above calculation, it can be deduced that the steel pipe is a plain carbon steel and definitely not an alloy steel because the percentage sum of all alloying elements is less than 2%. This implies that there is no inherent element to prevent or reduce the corrosion rate of the steel. The carbon content falls within the range 0.1 – 0.25%, therefore the steel is a low carbon steel (Degarmo, *et al*, 2003).

Table 2: Elemental Composition (wt %) of the As-received Mild Steel Plate

Elemental composition	Weight percent (wt%)
C	0.133
Si	0.307
Mn	0.820
P	0.0061
S	0.0081
Cr	0.080
Ni	0.102
Mo	0.038
Al	0.0036
Cu	0.178
Co	0.0085
Ti	0.0003
Nb	0.0054
V	0.0016
W	<0.0001
Pb	<0.0001
B	0.0007
Sn	0.0063
Zn	0.0042
As	0.0005
Bi	0.0010
Ca	0.0010
Ce	0.0023
Zr	0.0006
La	<0.0001
Fe	98.300

— Effects of distilled water and chloride environment on the cumulative weight loss of low carbon steel samples

Samples S_1 and S_2 were immersed in a chloride environment and Figure 1 show the cumulative weight loss of both samples. Generally, cumulative weight losses of these two samples were said to increase with increasing exposure time.

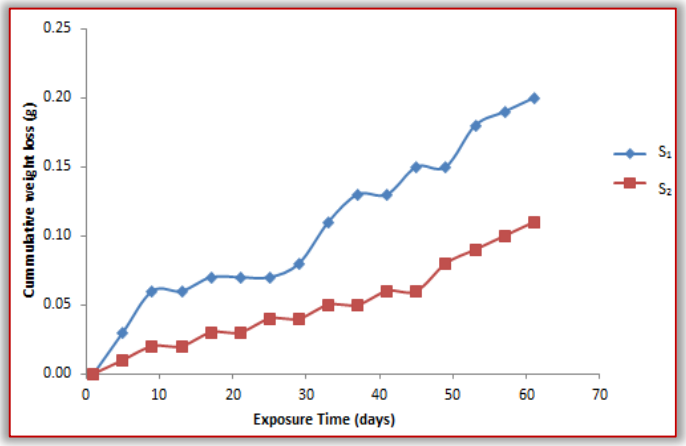

Figure 1: Variation of Cumulative Weight Loss with Exposure Time of Samples Immersed in 0.3 M NaCl

Sample S_1, being an un-welded sample, has a higher cumulative weight loss as the exposure time increases. This means that the weight lost by sample S_2 over the specified number of days were much lesser than the weight lost by sample S_1. It can be inferred

from the graph that the welded sample (S_2) exhibits a better resistance to weight loss compared to un-welded sample (S_1), because the graph shows that the rate at which sample S_2 loses weight is not as high as the weight loss rate of sample S_1, (Chinwko, *et al.*, 2014).

As shown in Figure 2, the cumulative weight loss of samples W_1 and W_2 with reference to the exposure time was analyzed with the two samples immersed in sea water. The cumulative weight losses of these two samples increased with increasing exposure time. Figure 2 shows that sample W_2 (welded) did not lose much weight as sample W_1 (un-welded). This implies that the overall cumulative weight loss of sample W_1 is lower than that of sample W_2 which is an indication that the un-welded sample shows a better resistance to the loss of weight when immersed in water. The reason for this can be traced to the action and effect of welding on the steel sample, which had positively, affected the microstructural arrangement of the atoms (Oladele, *et al.*, 2014).

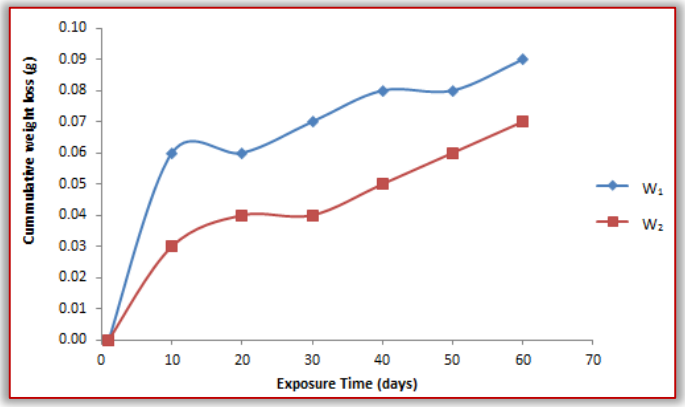

Figure 2: Variation of Cumulative Weight Loss with Exposure Time of Samples Immersed in Distilled Water

Figure 3 shows the comparison among the cumulative weight loss of all samples with distinctive difference between the cumulative weight loss of samples immersed in the chloride environment and samples immersed in distilled water, including welded and un-welded samples.

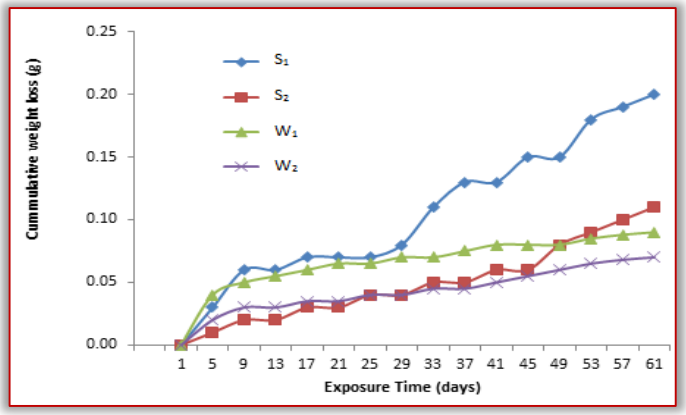

Figure 3: Variation of Cumulative Weight Loss of All Samples with the Exposure Time in Days

Generally, the welded samples (S_2 and W_2) lost lesser weight compared to their un-welded counterparts (S_1 and W_1). However, samples S_1 and S_2 which were immersed in the chloride environment lost much weight compared to samples W_1 and W_2 which were immersed in water. This is due to the fact that the chloride environment is aggressive and more corrosive than the natural water environment. The corrosive nature of the chloride was majorly due to the actions of the chloride ions on the steel sample, but the available oxygen in the water formed a corrosion cell until passive films were formed, and the rate almost became constant (Chinwko, *et al.*, 2014).

— Effects of chloride environment on corrosion rate of low carbon steel plate samples

Figure 4 shows the relationship between the corrosion rates of the samples immersed in chloride environment. It can be seen from the figure that both samples S_1 and S_2 exhibited a higher corrosion rate within the first 10 days compared to the remaining days. This is usually expected holding to the fact that the chloride environment, in which the samples were subjected, tends to decrease in potency over time. However, the corrosion rate of sample S_1 was far higher than that of sample S_2 because the weldment of sample S_2 undoubtedly acted against the corrosion reaction of the sample compared to the other sample S_1 which had no weldment. In addition, sample S_2 was observed to exhibit a more uniform corrosion than sample S_1 with increase in exposure time.

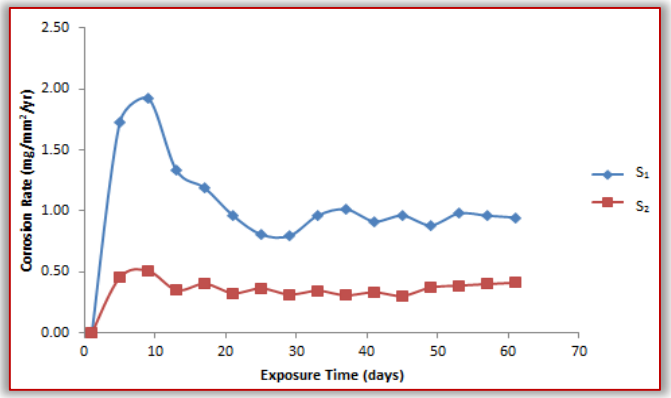

Figure 4: Variation of Corrosion Rate of Samples S_1 and S_2 with the Exposure Time in Days

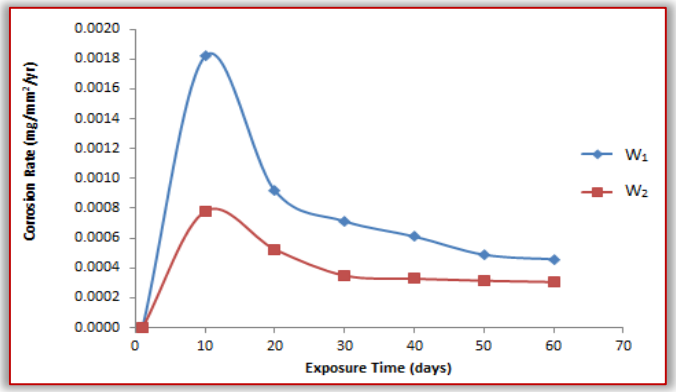

Figure 5: Variation of Corrosion Rate of Samples W_1 and W_2 with the Exposure Time in Days

The rate of corrosion of samples W_1 and W_2 in water can be seen on Figure 5. Sample W_1 (un-welded) exhibited a very low resistance to corrosion when compared to its counterpart (sample W_2 – welded). This is an indication of the fact that the welded sample exhibited a better corrosion resistance as a function of the action of the weldment with particular to the effect of the welding electrode. Although both samples shows a slightly noticeable uniform corrosion, however, their corrosion rate was very minimal and did

not exceed 0.0018 mg/mm²/yr. which implies that their rates of corrosion were within the passive extreme. To this end, the mechanical properties of the steels sample will only be slightly affected.

The corrosion rates of all samples were calculated and Figure 6 was plotted. Figure 6 therefore explains the corrosion relationship of all the samples immersed in different corrosive environments. Generally, the corrosion rates of the samples (S_1 and S_2) immersed in the chloride environment were distinctively higher than those (W_1 and W_2) immersed in water. This was mainly due to the actions of chloride ion on steel samples, which is more corrosive than water. These chloride ions react with the Fe^{2+} in the steel sample and hence, form passive corrosive films on the steel samples and these makes the corrosion of mild steel faster in the chloride environment than in water. Moreover, the welded samples were observed to possess a lower corrosion rate when directly compared with their un-welded counterpart immersed in the same corrosive environment (Seidu and Kutelu, 2013).

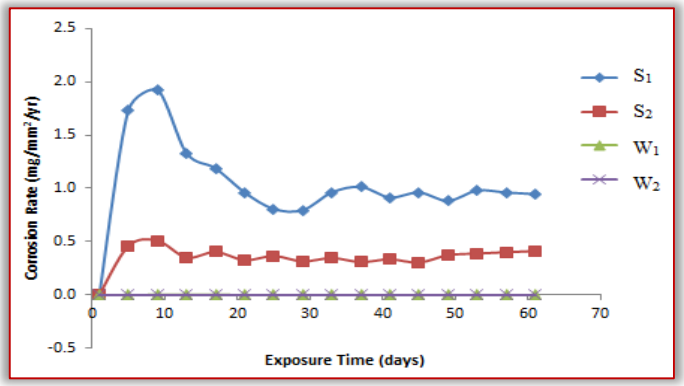

Figure 6: Variation of Corrosion Rate of all Samples with the Exposure Time in Days

CONCLUSIONS

The effects of different environments on the corrosion properties of welded and un-welded mild steel were investigated, and the following conclusions were drawn:

- The un-welded samples exhibited greater loss in weight compared to the welded samples. This is due to the fact that the weldment of the welded samples reduced the rate of weight loss in the steel samples.
- The rates of corrosion of welded samples were observed to be lower in comparison with their un-welded counterparts in their corresponding corrosive environment.
- The maximum values of corrosion rates of the samples are S_1 (1.924344 mg/mm²/yr.), S_2 (0.509108 mg/mm²/yr.), W_1 (0.001821018 mg/mm²/yr.), W_2 (0.000780731 mg/mm²/yr.). This implies that samples (S_1 and S_2) immersed in the chloride environment exhibited the higher corrosion rate than samples (W_1 and W_2) immersed in distilled water. The factor responsible for this can be traced to the actions of chloride ions which tends to form passive films on the on the steel samples (S_1 and S_2) unlike the other samples (W_1 and W_2) that corrode uniformly under the influence of water.
- The corrosion behaviour of all the steel samples were within the passive region even-though there was a noticeable discrepancy between the corrosion behavior of samples immersed in the chloride environment and the distilled water environment. This implies that because all the values of corrosion rate fell within 0.00030583 mg/mm²/yr. to 1.924344 mg/mm²/yr. (i.e. they did not exceed 5 mg/mm²/yr. because active corrosion is known to be within the range of 10 mg/mm²/yr. – 200 mg/mm²/yr. or greater), the overall corrosion behaviour of the steel samples in the given corrosive environment can be regarded as being *Passive*.

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ISSN: 2067-3809

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THE NEED FOR GOVERNMENTAL POLICIES AND STRATEGIES IN GREEN BUILDING CERTIFICATION IN GHANA

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Abstract: Green building has received increased attention over the years from both environmental economist and policy makers. The number of buildings put up every year produces a huge impact on the consumption of natural resources. However, only a small number of these buildings can be identified as green buildings. There are several policies implemented in various countries that aim at reducing the environmental impact of buildings on human health and the environment. Some of these policies are voluntary and mandatory programs that affect the entire lives of buildings. This paper aimed at examining the literature regarding current green building strategies and polices in Australia, United States, United Kingdom and South Africa to enable recommendations to be made for its uptake in Ghana. The key finding from the review revealed that governments in these countries play a pivotal role in the promotion and implementation of green building policies and strategies in their various countries. The survey further assisted in identifying the policies and strategies that can be adopted by the government of Ghana to promote green buildings. The government of Ghana is therefore being called upon to wake up and join the call by governments of various countries in building green to help save the environment.

Keywords: Green Building, Green Building Certification, Government Policies, Strategies, green building council

INTRODUCTION

The increasing preoccupation with natural resources availability and the way they are used by the society, particularly the construction industry, have prompted a reflection on both the causes and the solutions for this problem, and the need to introduce and apply sustainable concepts have been long advocated [1]. The number of buildings built every year produce a huge impact on the consumption of natural resources. However, only a small number of these buildings can be identified as 'green buildings' [2, 3]. The construction sector has been accused of its excessive consumption of material resources because of the use of non-sustainable materials, with high values of embodied energy [4, 5]. Therefore, since over 80% of people's time is spent inside buildings [6] it makes the construction sector the ideal vehicle to introduce sustainable guidelines of development, given that resource savings can be achieved [7]. Korkmaz et al. [8] reported that in the United States, buildings consume approximately 40% of all energy, 72% of all electricity and produce 39% of primary greenhouse gas emissions. China consumes 40% of the world's cement and steel every year on the total floor areas of new buildings due to its fast-economic development and urbanization [9]. Adegbile [10] asserts that due to increase in technological advancement and economic growth, building construction has greatly increased and has accounted for almost half of the greenhouse gas emissions and energy consumed due to the energy used in the production and transportation of materials. Brundtland [1] also attributed the excessive consumption of energy and water to the needs of people in terms of comfort and quality of life of modern society. Many recent buildings disregard the needs required by users, such as level of thermal comfort, acoustic comfort, ventilation and indoor air quality, leading to unbearable energy costs over the long term [4]. Therefore, there is the need to reverse this trend and promote practises that seek to maintain the remaining resources in order to sustain humanity.

GREEN BUILDING: BACKGROUND AND DEFINITIONS

The concept of green building was developed in the 1980's as a result of the alarming trends of climate change due to increase in the emissions of CO_2 and scarcity of resources [11]. Richardson and Lynes [12] defined green building as a building which is more resource and energy efficient, releases less pollution into the air, soil and water and is healthier for occupants than conventional buildings. The words 'green' and 'sustainability' are most of the times used interchangeably. Sustainable building means changing the process that cause pollution, non-renewable resource usage into renewable resource-efficient products and processes beneficial for environment and society during the phases of pre-building, building and post-building [13]. A certified green building is mostly used synonymously to "high-performance building", "environmentally friendly building", "sustainable building", and "energy efficient buildings". Landman [14] referred to sustainable buildings as "green" or "environmentally friendly buildings". Adegbile [10] argued that the basic aim of any green building certification system is to set criteria against which to rate a building and provide a score or descriptive rating for that building. Gundogan [13] identified another key element of green buildings as the certification systems or assessment systems or rating tools used to examine the performance of a building and to improve the green building process and strategies.

Several countries around the world have developed their own green building standards. These standards include Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the USA, GREEN STAR in Australia, and Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan. These certification systems offer a menu of building technologies and construction practices, including Water Efficiency, Material Efficiency and Energy Efficiency, Materials and Resources as well as other categories.

The assessment of a building is based on the framework of standards, criteria and requirements that a building project must meet in order to be recognized as "green" [15]. This presupposes that there is a direct link between green building and certification system. The green certification systems have been categorised into two, namely; Qualitative and Quantitative certification systems [16, 17]. The qualitative certification systems are often based on the auditing of buildings, followed by the rating of the assessed criteria, which then results in an overall score for the performance of a building [17]. Examples of the Qualitative certification systems are BREEAM, LEED and Green Star. The quantitative certification systems depend on the physical life cycle approach of the building which requires quantitative input and output data on flow of matters and energy [16] with ATHENA and Eco-Quantum as examples.

— BREEAM

BREEAM was developed in the United Kingdom in 1990 by Building Research Establishment Global Limited [18]. Since then more than 115,000 buildings have been certified in the United Kingdom with an additional 700,000 registered for eventual certification [19]. Say and Wood [20] identified the goal of the BREEAM as a medium to reduce environmental impact, ensure the best environmental practices in design, operation, and management and to increase awareness of the impacts of buildings on the environment. BREEAM has four assessment tools that can be used at different stages of a building's life cycle [21]. These assessment tools include the BREEAM Design and Procurement (D&P), BREEAM Post Construction Review (PCR), BREEAM Fit Out (FO) and BREEAM Management and Operation (M&O) [21]. The BREEAM Design and Procurement is used during the design stage of a building renovation, for a new building, or an extension project. The BREEAM Post Construction Review (PCR) is carried out after the construction is complete to verify the D&P assessment. The BREEAM Fit Out (FO) assessment is employed during major renovations of existing buildings and the BREEAM Management and Operation (M&O) assessment evaluates the performance of a building during its operation [21]. Credits are awarded according to 10 categories for meeting a series of performance criteria. The total number of credits in each category is multiplied by an environmental weighting factor, which considers the relative importance of that category. The scores obtained in each category are added to produce an overall score on a scale of Pass, Good, Very Good, Excellent and Outstanding. Since 2000, the government in UK has made BREEAM a mandatory mechanism for all government procurement in the UK [22].

— LEED

The Leadership in Energy and Environmental Design was introduced by the United States Green Building Council (USGBC) in 1998 and it has five rating systems. These rating systems address the unique needs of buildings and project types; Building Design and Construction, Interior Design and Construction, Building Operations and Maintenance, Neighbourhood Development and Homes. LEED green building rating system is a voluntary standard for sustainable buildings [23]. The USGBC is made up of construction industry stakeholders including owners, contractors, architects, engineers, product manufacturers and environmental groups. In order to promote and facilitate the LEED process, there are over 50,000 LEED Accredited Professionals. According to [24], the number of buildings applying to the USGBC for green building certification has been doubling each year since its implementation. LEED is mostly used in USA, Canada, Spain, South Korea, China, Australia, Guatemala, India, Japan, Mexico, Puerto Rico, and Sri Lanka. The categories under the LEED certification are sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and design process. Gundogan [13] is of the view that compliance in the US and Europe on green building certification is more widespread because the requirements came from top down.

— Green Star

Green Star is a voluntary rating system developed by Green Building Council of Australia (GBCA) that evaluates the environmental design and construction of all Australian buildings. The GBCA launched the Green Star in 2002 with the main objective to encourage the Australian building industry to embrace sustainable building by promoting green building programs, technologies, design practices and operations [25]. New Zealand and South Africa have adapted Green Star to rate and certify green buildings [26]. Ghana has consequently adapted Green Star South Africa to certify green buildings. In as much as the Green Star rating tool is available for self—assessment of a design or project or building, one cannot claim publicly or promote a Green Star rating or use its logo without prior validation of the project's achievement through a formal assessment [25]. A project is eligible based on eligibility criteria; space use, spatial differentiation, conditional requirements and timing of certification. According to GBCA, projects that are awarded one to three stars may not be certified but those awarded with four or more stars may be certified. The categories under the Green Star are Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land-use and ecology, pollution, among other things.

— Green Star Sa-Ghana

The Ghana Green Building Council (GhGBC) launched a building rating system used to certify buildings to be "green" in Ghana. As mentioned earlier, the rating system was adapted from South Africa Green Star [27, 28]. The tool is called Green Star Sa-Ghana because South Africa exhibits some form of control over the usage of the tool. This tool though adopted from South Africa, has enabled Ghana to certify its green buildings located in Accra. The One Airport project in Accra applied Green Star S-Office v1 tool to their project and attained a four-star certification level. Ghana is only eligible to own and manage its own tool and certification process if the local Ghanaian capacity is built over time [29]. The categories used in Green Star-Sa Ghana are sustainable sites, water efficiency, energy and atmosphere, materials and resources and indoor environmental quality.

EMPIRICAL EVIDENCE OF THE BENEFITS OF GREEN BUILDING CERTIFICATION

Several studies have found empirical evidence of financial benefits for building owners. South Africa Green Building Council [30] reports that green star certified buildings in the country benefits from energy savings of between 25% and 50% in comparison with

conventional buildings. In Singapore, green buildings save approximately 10% in operating cost and green commercial buildings increase in value by 2% [31]. Zhang et al. [32] found that developers of green buildings receive favourable land prices and improved access to financing and higher sales prices. According to [33], certified buildings in the United Kingdom rent longer contracts and at a 28% rental premium. Also, in Russia, Greendale building consumes 36.5 % less energy [34]. Furthermore, in Australia, a 4 Green Star certified building could expect to experience a 2%-5% saving on the up-front capital cost [26]. Green building makes economic sense on the life cycle basis. This is due to the use of sophisticated energy conserving lighting systems and air conditioning systems with exceptional response to building and outdoor conditions [24]. Green building offers intangible benefits to occupants through improved comfort, health, productivity, amongst others.

THE NEED TO CERTIFY BUILDINGS IN GHANA

Studies have shown that green buildings have longer lifecycles, lower maintenance and operational costs, reduced energy and water bills and they can attract higher rents, experience lower turnover and have higher rates of occupant satisfaction when compared to conventional buildings [35]. In a typical office building for instance, energy represents about 30% of operating expenses which directly affects tenants and building owners [36]. Thus, the onus lies on the design, construction and operation of buildings to play an important role in energy conservation.

However, Ghana has not been actively seen in constructing and advocating for more green buildings as compared to countries like USA, UK, Canada and Australia. Ghana can only boast of three green buildings since its introduction by the Ghana Green Building Council in 2009. UK records over 115,000 certified green buildings with additional 700,000 registered for eventual certification [19], Canada records over 480 certified green buildings [11], and Australia records over 148 certified buildings [19]. A major strength of countries recording high numbers of green buildings is that they enjoy high level of support from their government. Because governments in the countries actively support green buildings by practicing them in their own buildings and encouraging the populace in any way that they can, they record high number of green buildings [35].

However, the action of the government of Ghana in terms of green building commitment needs more attention and improvement. The green building certification system which directly promotes green buildings in the country today is a voluntary compliance with standards promulgated by a private organisation [37] which is the Ghana Green Building Council (GhGBC). Green Building Councils (GBCs) and green building certification systems serve as indicators of a country's green building status and proficiency. This is evident in countries with well-established GBCs and certification systems as they are the world's most advanced green building nations compared to countries which do not have a vibrant GBCs and active certification systems [35].

THE ROLE OF GOVERNMENT OF GHANA IN THE GREEN CERTIFICATION OF BUILDINGS

Koski and Lee [38] identified governments as the most visible members of the regulated community, although they are often scrutinized for their actions. Ghana's contribution to gross domestic product is about 8.2% per annum [39]. This makes the Ghanaian construction industry very important to the economy. Green building councils are beneficiary to countries because they act as coordinators of green building efforts, run training programs and conferences, and offer wealth of information on a variety of green building topics [35]. Although Ghana Green Building Council encourages the application of green technologies as stated, this voluntary based certification system does not provide enough incentives for developers to adopt innovative green technologies. According to Landman [14], the responsibility for learning, educating, demanding and implementing more sustainable or green practices depends on the government rather than the private sector. Also, the government's involvement gives legitimacy to the efforts of environmental advocacy groups like the Ghana Green Building Council. Even the private sector presumes and expects that governments should play some role, although perhaps only to encourage and support organisations or individuals that voluntarily choose green building certification [40]. According to United Nations Environment Programme [41], it seems universally true that in most countries the solution requires active involvement of the government to create a suitable framework for green buildings. It further affirms that leaving the private sector to promote green building without any external support is in most cases not feasible. Often the barrier to green buildings is that there is insufficient support and leadership by various levels of governments [35].

The absence of active government's coordination and consistency in its policies concerning green building certification frustrates the efforts of the GhGBC in promoting this agenda. For green building to be firmly rooted in Ghana, the government would have to have an undulating partnership with the GhGBC and other stakeholders to encourage the Ghanaian populace to adopt the practice of "greening" their buildings. Government is usually the single largest owner of buildings in a country and is an opportunity to be supportive of green buildings and encourage this type of development in any way that they can [35]. Implementing green practices in their own buildings is a great way for governments to demonstrate leadership and environmental responsibility. The active presence of government in promoting green building certification reduces uncertainty related with regulations [42]. It also acts as an informative tool for firms considering certifying their buildings to be green by providing insight into what techniques are successful in reaching similar goals. Furthermore, [43] posits that governments are the proving ground for green buildings because their short-terms and worries are displaced by long-term concerns related to sustainability and climate change. By so doing, governments that choose to certify their buildings employ and create specialists in green buildings such that availability and expertise of architects, construction firms and building materials suppliers increase [38].

LESSONS FROM OTHER COUNTRIES

— Australia

In Australia, the building sector contributes to 20% and 23% annual energy consumption and greenhouse gas emissions respectively [44, 45]. In so doing, there is a major initiative in Australia to promote green building which will reduce greenhouse emissions

through the reduction of energy consumption and resource conservation [46]. The government of Australia's commitment has led to the Green Star certification of 68 government-owned building projects around Australia [46]. The support of the government towards the green building certification system was in a form of financial incentives, such as tax and funding solution, and non-financial incentives, such as green door policies and provision of green skills training [46]. In order to demonstrate the government's commitment to green building in Australia, the government agreed to design and construct by Green Building Council Australia's rating standards a 'six star' world class building to accommodate their administrative staff [46]. The Szencorp building in Australia reported energy savings of over 70% after two years of operation [26].

— **United Kingdom**

In United Kingdom, the number of organisations supporting sustainable building is very high, notable amongst them are the Construction Industry Council (CIC), the Home Builders Federation, the Royal Institute of British Architects (RIBA), the Commission for Architecture and the Built Environment (CABE) and the Chartered Institute of Building (CIOB). It also has Energy Saving Trust (ESTR) which operate many incentive programs to help people increase their home energy efficiencies and to decrease their energy consumption [35]. The UK has a press called the UK Green Building Press that publishes green building information monthly on a website in many mediums to help people create healthy and ecological homes, offices and other buildings.

— **United States**

In the US, the growth of green buildings has been increased by the city and government initiatives and the low prices of sustainable materials through the efforts of the government [20]. The government in the U.S. involves itself in promoting green building. An example is the Seattle city government legislatively adopting a policy to make their own municipal buildings green in the year 2000 [35]. In the US, the government dominantly uses the economic instrument target as its tactics in promoting green buildings. Some cities in the US that have enacted mandatory standards apply them primarily to public projects and those that use public funds. Other cities also reduce the burden of land use regulation for developers or building owners who adopt green building techniques and certify their buildings subsequently by expediting the environmental permitting process or reducing reporting requirements [47].

— **South Africa**

In South Africa, the increase in awareness of energy efficiency and global climate change has significantly impacted the construction industry in recent years [48]. Since the establishment of the Green Building Council South Africa, there have been a total of 36 certified green buildings. This demonstrates that green building certification is gaining grounds in South Africa [30, 49]. The South African Government is dedicated to reducing greenhouse gas emissions through green buildings. The government has decided to reduce greenhouse gas emissions by 34% by 2020 and 42% by 2025 [50]. The South African government adopted a National Green Building Framework to assist with its green building commitment. A key strategy was to develop green building regulations and standards [51] by enacting the SANS 10400 and Part XA of the Building Regulations to guide the design and construction of green buildings in South Africa.

DISCUSSION AND THE WAY FORWARD: THE NEED FOR POLICIES AND STRATEGIES

The role of the government can be in the form of well-established legal principles which gives both the government and the GhGBC the substantial freedom to regulate the design and building industries to achieve green building objectives [52]. The behaviour of the building sector to a greater extent is influenced by a wide range of signals from government, clients and researchers. Government policies have a special role in that they can influence the construction industry itself and the behaviour of the clients, financiers, researchers and other stakeholders [41]. The public sector constitutes a major actor in the building sector as building owners, tenants, developers and financiers. Government can cease this opportunity to influence the building sector to adopt green certification systems not only as a regulator but as an actor putting up good examples for others to follow [53]. The government can make use of economic tools including wide range of different kinds like constraining ones (taxes, fees, price levies, rebates); enabling ones (tax breaks, rebates, preferential lending opportunities), amongst others. These economic signals can create market conditions that provide quantifiable economic advantages to green buildings [54]. It is important to ensure that these economic signals are sent to the correct actors or the investors who pay the cost of the buildings. In this case, the investor is likely to prefer that the building is built according to green standards. The experiences of many developed countries show the deliberate intervention of governments in implementing and advocating for green buildings. The Ghanaian construction industry can achieve the kind of progress that has been made by green building councils in other countries if the government of Ghana certifies some of its public buildings to be green just as has been done in the developed countries. Evidence from literature shows a well-regulated green building certification system in UK, US, Australia and South African construction industries.

Moreover, the GhGBC and the government will have to deal with the challenges that arise due to green building, as identified in the studies conducted by [55] and [56]. Also, there is the challenge of inadequate database on past green building projects. The green specification database on green products and related technical standards enhance the awareness of project teams to gain access to resources necessary for green buildings. Furthermore, there must be in place a commercial database of green building products which have been independently vetted against sustainability criteria just as with the United States EcoSpecifier. In the United States for example, their EcoSpecifier is a database where green building products can be easily located. The insurance industry in New Zealand is realising the benefits of green buildings and in 2008 they launched a new suite of sustainability insurance products for use in commercial buildings [26].

CONCLUSIONS

The government has at its disposal several instruments such as regulations, taxation and pollution permit which can be used to

promote green buildings. The government should help in promoting certified green buildings by administering incentives which include financial and non-financial incentives. Financial incentives in the form of tax incentives, direct grants and rebates, which are monetary in nature, to developers and owners who meet some green requirements or who have their buildings meeting a green building certification system's recognition. This will partially pay or compensate companies and owners for the additional costs and efforts involved in certifying their buildings to be green, thereby reducing the effects of high cost which is a major barrier [58, 59]. The governments in the countries play a pivotal role in the promotion and implementation of green building strategies in their countries [13]. Also, the government of Ghana needs a national green building agenda which would stimulate nationwide interest and provide indirect guidance and support. The government should collaborate with the green building council in Ghana to educate the building design, construction, and investment industries, as well as ordinary citizens, on the benefits of building green. If the government implement green practices and strategies in their own buildings, they demonstrate that they are willing to make a commitment to improve their buildings and reduce their environmental impacts and that green buildings are both feasible and cost-effective.

The purpose of this paper was to examine the literature regarding current green building strategies and polices in Australia, United States, United Kingdom and South Africa so that recommendations can be made to enable its uptake in Ghana. Through the literature survey, the paper identified various pivotal roles that governments play in promoting green buildings in their various countries. This has assisted in identifying the policies and strategies that can be adopted by the government of Ghana to promote green buildings.

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ISSN: 2067-3809

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AUTOMATIC GARBAGE MONITORING AND HANDLING SYSTEM

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Abstract: The greater parts of the urban areas are overflowed by the garbage receptacles which are causing an unhygienic domain. It will additionally prompts emerge of various kinds of anonymous ailments and will debase the way of life. To overcome these circumstances, a productive brilliant rubbish management strategy must be created. This paper proposes a method of checking the status garbage bins from the point of its level of garbage in the container. The Size of rubbish and garbage is constantly checked by ultrasonic sensor. Framework additionally utilizes the air quality component. Contingent on above parameter esteems pushing of garbage will occur. In light of the contributions from the sensors, microcontroller will choose which vehicles ought to go to pick the garbage. These processes are controlled via android application and web application. The proposed system ensures cleanliness and hygienic environment.
Keywords: IOT, Ultrasonic sensors, Air quality sensor, Waste compression mechanism, Node MCU, Android application

INTRODUCTION

Solid waste management is important in many aspects in our current life which mainly includes environmental cleanliness, health services and basic daily needs. In this paper, we propose the process of controlling of waste collection, testing quality of service, quick and authorized ways for solving disputes and problems. There is a system that can monitor the truck and bin in real time, the collection process can be improved. The enough data regarding the bin can allow the admin to reassign bin positions depending on their situation and level status of bin. The records may also be used to elevate truck schedules. Waste truck drivers need navigation system and reporting problem system.

The system included the bins equipped with level sensors enhanced the collection process, dynamic scheduling and routing policies. Operation cost, distance and time of collection of garbage is reduced by using sensors compared with static collection of garbage with fixed route. The real time data which is received by the server, good dynamic schedule and effective routing policy can be used easily to decrease the operating costs, shorten the collection of garbage and lower the labor hours. A decision algorithm is implemented based on level detection to distinguish the class of bin and waste grade or grade of the waste.

Citizens want to have facility, at negligible cost with easy manageable reports. The major advantage of this proposed system is that it will stop the trashcan spilling over around the localities as smart bins are used in real time.

In present situation of digital world everything in the environment has been outfitted with current innovation and web to facilitate work and increase the effectiveness. The significance of this work is a unified system model for intellectual waste collection.

RELATED WORK

The urban reusing and solid waste prevention are required at the nearby scale as opposed to intensely depending on the disposal and treatment at the regional scale. Separated gathering is fundamental however confuses the present plans of waste accumulation. To connect this hole and build a viable, efficient, and practical plan, existing framework built up a Smart and Green System (SGS) which embodies the inside and out combination of different technique and the data of feasible waste management [2].

IOT based a smart and novel cloud-based waste management system is managed in which the refuse can are fixed with sensors, that can advise the waste level status and the information identified with status is transferred to the cloud. [4]

The proposed system heuristic algorithm that links introduction and improvement stages explains the models with numerical efficiency to look for the earth amiable arrangements and most cost effective solution. A unified heuristic algorithm is proposed for tending to hub directing and moves on or moves off steering issues. Results demonstrate that separated accumulation builds chances to seek after the best steering techniques with manageable implications through affectability examination to the expense of higher gathering costs. The investigation closes with the viewpoints of a brilliant and green waste accumulation framework intended to make a sustainable waste management frameworks later on [5].

How IoT mix with information access systems, electronic designing, Geographic Information Systems (GIS), and combinatorial advancement can add to improve urban areas the executives frameworks. By utilizing an IoT model inserted with sensors based a waste gathering management arrangement dependent on giving knowledge to trashcans, which can peruse, gather, and transmit junk volume data or information to the Internet. This information put into a spatio-transient context and prepared by diagram hypothesis improvement algorithm can be utilized to efficiently and progressively oversee waste gathering methodologies [6].

A system utilizes an algorithm to calculate the most brief separation between two points in the zone (e.g., two trashcans), joined with GIS information of the roads in the city. The road system can be spoken to as a chart where road portions are edges and the joining focuses are vertexes. Subsequently, it is conceivable to compute a sensible most limited driving separation between focuses by applying Shortest Path Spanning Tree (SPST). The separations are vital as a contribution for the course improvement process. For useful reasons, it is advantageous to precompute the good ways from all-to-all trashcans to accelerate the road improvement process [7].

The Garbage containers or Dust canisters set at open or uncovered places in the urban areas are increasing rather flooding daily because of increment growth in the waste each day. It makes

unhygienic condition for the general population and awful smell around the surroundings this leads in spreading some destructive sicknesses and human ailment; to keep away from such a circumstance a Garbage Monitoring System utilizing IoT is intended. In the proposed framework there are various waste bin situated all through the campus or city, these waste bins are given minimal effort gadget which helps in following the level of refuse canisters and a special ID will be accommodated each waste bin so it is anything but hard to identify which waste bin is full. At the point when the level achieves edge constrain, the gadget will transmit the level alongside the one of a kind ID gave. These points of interest can be gotten to by the concern experts from their place with the assistance of Internet and a prompt activity can be made to clean the dustbins [11].

The framework proposes a propelled technique in which squander administration is mechanized. Radio recurrence ID (RFID) is a standout among the most encouraging and expected advances as of late. The framework makes utilization of radio recurrence (RF) labels and web bolster. This work displayed here surely gives a novel approach in dealing with and arranging off the everyday strong squanders in a proficient and simple way. The framework comprises of four primary subsystems which mainly includes Smart Trash System (STS), Local Base Station (LBS), Smart Controlling Hut (SMCH), Smart Monitoring and Smart Vehicle System (SVS) [14].

SYSTEM DESCRIPTION

The method of proposed framework is based on the waste collection system. The System architecture is shown in the Figure 1. System process is carried on waste level data from bins situated in different zones of the city associated with Internet remotely as shown in Figure 2.

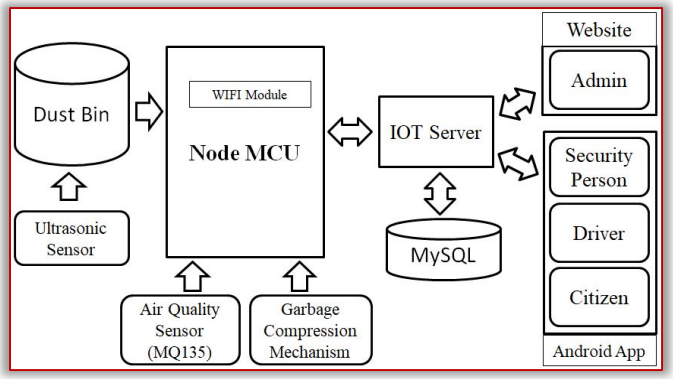

Figure 1: System Architecture

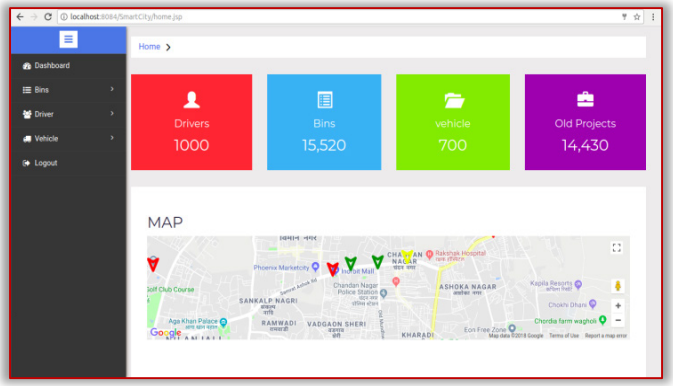

Figure 2: Home Page, Dashboard and Location of Dust bin

The data gathered by the sensors is sent through the net over a server where it has to be processed and stored. Data collected is then used for monitoring and improving the daily selection of bins to be collected, scheduling the routes accordingly. The smart waste bins end the data to focal online interface (administrator) utilizing WIFI module. In the event that the waste bin is topped off to its edge esteem, at that point the message is shown on web-based interface and the mindful expert make appropriate move and it will demonstrates the all data on to the Smart waste container android application on the clients cell phone. Waste truck drivers need route framework and announcing issue framework. Residents need to have better administration, lower cost and having simple available reports. The significant favorable position of this proposed framework is that it will stop the dustbin flooding around the street side and territories as savvy containers are utilized progressively.

To structure framework for waste gatherer this will demonstrate the data about level of waste in waste authority to client and on android application and furthermore demonstrate the all accessible waste authority in adjacent region and way to closest waste authority.

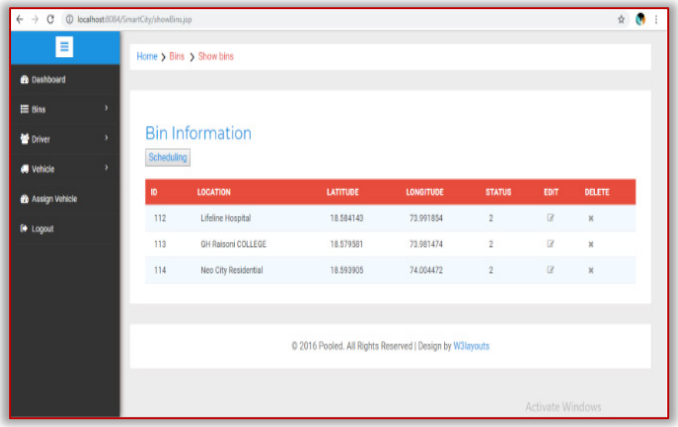

Figure 3: Dust Bin Information

The System contains Ultrasonic Sensor, Air Quality Sensor and Garbage Compression Mechanism. It also comprises Node MCU. Information will be gathered by cloud is from three places as shown in Figure 3. The ultrasonic sensor will be utilized for recognizing level of trash in container. The actuator will be utilized for squeezing waste descending way and it has following two conditions. On the prospect that the garbage is dry, it will squeeze trash or engine will be ON and in the event that the waste is wet, then engine will be OFF. On the other side, that garbage has awful scent, at this case the engine won't squeeze trash yet in the event that it has not be crossed the edge, then garbage will be squeezed further to make some space for new waste. Parameters estimated by sensors like ultrasonic sensor will be refreshed on cloud.

IMPLEMENTATION

— Hardware Architecture

The complete block diagram is as shown in Figure 1. The system includes hardware that consists of Node MCU, Ultrasonic Sensor, Air Quality Sensor, Relay, Actuator, Smart Society Module, Bins, and Laptop. The whole works on a 5V or 9V dc regulated power supply. Figure 6 shows the connection of hardware with desktop.

— Node MCU

An open source IoT development board called Node MCU is used.

In this system, one of its very special highlights is that it has worked in WIFI availability backing, and consequently makes IOT application improvement a lot simpler.

Microcontroller unit is open source programming software and equipment or hardware advancement platform that is worked around a reasonable System on-a-Chip (SoC) called as ESP8266.

The ESP8266, planned and fabricated by Espressif Systems, contains every single urgent component of the advanced PC: RAM, CPU, WIFI, Networking, SDK, and modern operating system.

— Sensors

In this paper, a sensor is a gadget which measures or recognizes an object, physical property, and shows, or generally reacts to it. Particular information could be motion, heat, movement, moisture, light, weight, or any of an extraordinary number of other natural marvels. The yield is commonly a sign that sensor area to be changed over to intelligible presentation or it has electronically transmitted through a system for further perusing or further handling. Various sensors used here are air quality sensor is a device that monitor and detect the quality of air in the surrounding area and ultrasonic sensor for measuring level of garbage.

— Actuator

An actuator is a device that is used for controlling and moving a system or mechanism. In simple terms, it is a "driving force". An actuator requires an energy source and a control signal. Its important energy source may be hydraulic fluid pressure, an electric current or pneumatic pressure. When a control signal is received by an actuator, an actuator converts the signal's energy and gives the resultant output as mechanical motion which is a conversion of signals energy.

MODULE

— Smart Bin Module

Level of Garbage bin is detected by using ultrasonic sensor level detector. Node MCU receives the output of level detector. Ultrasonic sensor receiver becomes dynamic low on highest level of waste bin.

— IOT Module

Output is given to Node MCU to send the message to the admin module via IOT module.

— Admin Module

Admin module is present where all the actions are managed like Scheduling, Routing, Update status, Send Notification as shown in Figure 2.

— Driver Module

Receive notification, clean bin, and send notification

MATHEMATICAL MODEL

Sm = {Ip, Pr, Op}

Sm = System
Ip = Input
Pr = Process
Op = Output

Ip = {Ip0, Ip1, Ip2}

Ip0 = Bin details
Ip1 = Admin details
Ip2 = Driver details

Pr = {Pr0, Pr1, Pr2, Pr3}

Pr0 = Receive message from bin to admin
Pr1 = Schedule and Route
Pr2 = Send message to the driver
Pr3 = Receive message from admin

Op = {Op1, Op1, Op2}

Op0 = Schedule which first bin clean
Op1 = Route to which bin is close to garbage collector truck
Op2 = Clean bin

ALGORITHM

Input: K- the number of clusters
D: A data set containing n objects
Output: A set of k clusters
Steps 1: Select k data objects randomly from dataset called D as initial cluster center.
Steps 2: Repeat.
Steps 3: Distance can be defined and calculated between each data object x (1 <= i <= n) , All k cluster center which can be defined as y (1 <= j <= k) and also data object assigned x to the nearest cluster.
Steps 4: For each cluster j (1 <= j <= k), recalculation of the cluster center is required.
Steps 5: Till center of cluster is changed

O (nkt) is the computational complexity of the algorithm.
where: n: the total number of objects, k: the number of clusters, t: the number of iterations

RESULTS

Figure 2 shows the screenshot of user home page, dust bin dashboard, and location of dust bin, i.e. dust bin location map.

Figure 3 shows the screenshot of dust bin information such as ID, Location, Latitude, Longitude, Status, Edit, and Delete. Figure 4 shows the screenshot of user login page such as user name or email address, password, and server IP address and port number.

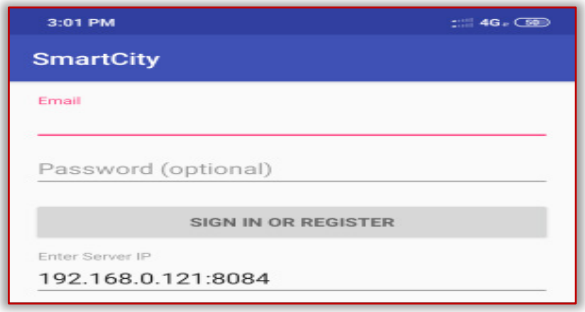

Figure 4: User Login Page

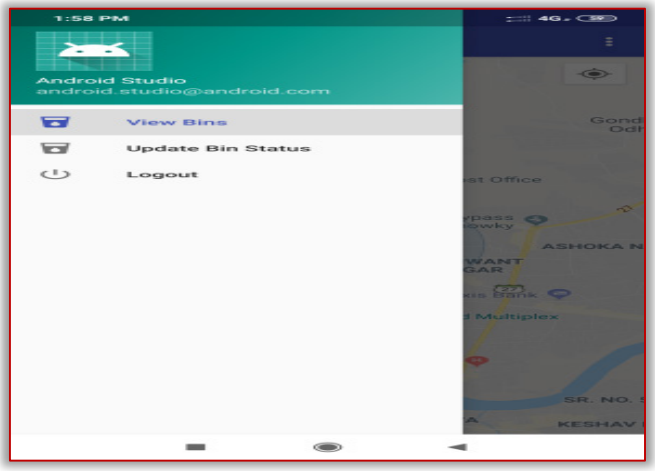

Figure 5: View Dust Bin Location

Figure 5 shows the screenshot of user home page, dust bin location i.e. map view. Figure 6 shows the project hardware i.e. Node MCU, Ultrasonic sensor, Air quality sensor.

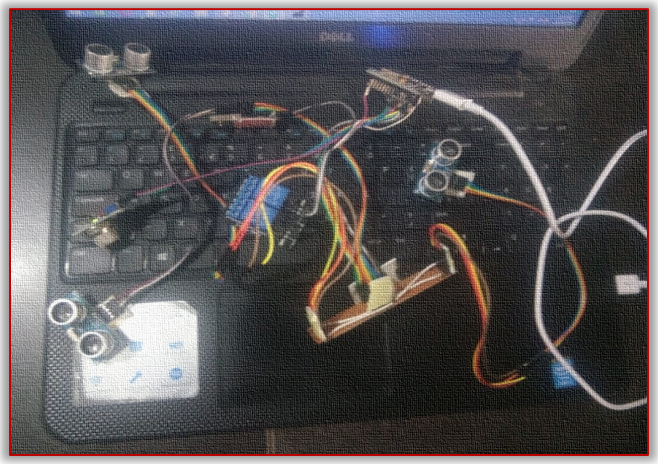

Figure 6: Hardware Setup

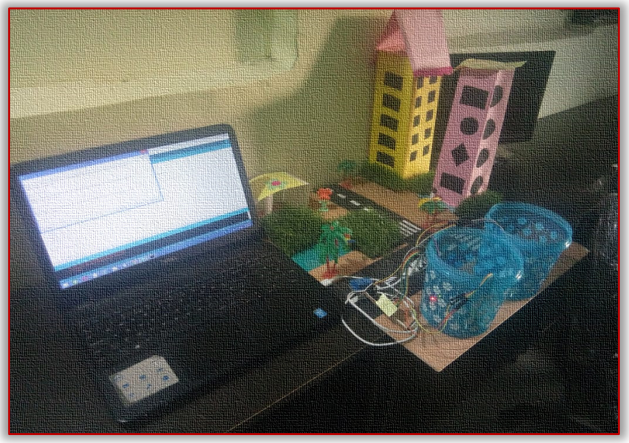

Figure 7: Hardware interface with Laptop and Module

Figure 7 shows the hardware interface with laptop and module.

CONCLUSION

This proposed methodology can be utilized to keep our city clean. We began from shrewd waste bin. By utilizing system condition, the ongoing exact information from the executed framework could be utilized for the effective strong waste administration framework. A waste management framework is a stage forward to make the manual recognition and gathering of garbage robotized in nature. The presently utilizing strategy wherein concerned metropolitan worker needs to search for the filled waste receptacles physically crosswise over various spots in a road/zone for checking routinely whether the waste container is filled or not. This approach is complex and time consuming. The proposed framework can gather exact information on continuous which can be utilized further as a contribution to an administration framework. This proposed automation approach of garbage or waste management will minimize and reduce the cost of the whole process significantly and also minimize the human effort.

FUTURE SCOPE

In future, rather than individual in the vehicle we can utilize a line follower robot which does not require a man power to move the vehicle. This way line follower robot can pursue line set apart on differentiating foundation generally dark line on a white surface or white line on a dark surface. So utilizing line follower robot innovation vehicle moves to the specific waste bin zone dependent on the data sent from the LoRa Gateway. So this makes the framework progressively dependable. In future, some extra highlights will add to this venture to squash and reusing plastics and different materials consequently.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

[1.]Oluwaseun Adedapo ADETAYO, [2.]Bamidele Ibukunoluwa DAHUNSI

INTEGRITY OF PHYSICAL AND STRENGTH PROPERTIES OF SOME SELECTED CONSTRUCTIONAL TIMBER SPECIES FROM SOUTHWESTERN NIGERIA AFTER CHARRING

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Abstract: Fire safety is the main precondition for the use of wood for constructional purposes and therefore an important criterion for the choice of material for buildings. The research investigated changes in post fire density and strength properties of Nigerian timber species used for construction. The selected species are: Terminalia superba (Afara), Milicia excels (Iroko), Nauclea diderrichii (Opepe), Khaya ivorensis (Mahogany), Mansonia altissima (Mansonia), Tectona grandis (Teak). Densities and strength properties of the species were determined at Moisture Contents (MC) of 9.0, 12.0, and 15.0%. Species were exposed to fire at various temperature ranges. The results revealed that at 9, 12 and 15%MC, Opepe had the highest density values of 630±28.85Kg/m^3, 686±22.64Kg/m^3 and 752±17.22Kg/m^3 respectively. At 9%MC, Mahogany had the lowest density (439±10.58Kg/m^3) while at 12 and 15%MC, Afara had the lowest density values of 444±4.18Kg/m^3 and 469±7.07Kg/m^3 respectively. Post fire exposure revealed that Afara had the highest percentage loss in density 29.2% and strength properties, while both Iroko and Mahogany exhibited the lowest percentage loss in both density and strength properties. Mahogany and Iroko species which had lowest overall post fire change in density and strengths values are useful and recommended to ensure the safety in case of fire outbreaks.

Keywords: Nigeria timbers, constructional purpose, wood density, strength properties, fire resistance

INTRODUCTION

Many buildings and civil engineering works are at high risk of fire. Therefore, accurate prediction of behaviour of the structures subjected to fire is of primary importance for the evacuation of persons, as well as for the safety of rescue teams. (Bednarek, 2008). Timber is one of man's oldest building materials. It is a renewable, naturally occurring organic polymer, unique in a world of synthetic and composite building materials. Today, timber is derived from sustainably managed forests and is one of our most environmentally friendly building materials. The wide distribution of timber, its ready availability, variety of uses and relative ease of handling and conversion, have all contributed to its wide acceptance in the building industry.

Timber is easy to form, saw, nail and fit; even with simple hand tools. Timber is natural and renewable. It has a high strength to weight ratio and is easy to work with, making it especially useful where only basic technology and procedures are available (Apu, 2003). The small tubular cells that are the fundamental structural elements of solid wood give timber its good properties for sound, electrical and heat insulation, for engineering requirements, and strong aesthetic appeal. Because of its wide range of properties, it is essential that for a particular application, the most suitable timber species is selected (Timber Manual Data file, 2004).

Timber as a building material has the disadvantage of being combustible. Consequently, timber structures are seen by many as creating an environment less safe than structures built of noncombustible materials such as steel and masonry. Until recently, the use of timber for major structures was viewed with suspicion, or at best accepted as a black art, practiced by a few privileged professionals. However during the past two decades, some very useful analytical tools have been developed, which enable the reliability of timber structures to be compared with the reliability of constructions with other structural materials such as steel and reinforced concrete. However, experience has shown that some timber structures have a fire resistance comparable, or greater than that of many noncombustible alternatives. Contrary to many people's expectations, timber used in construction performs well in fire. It will not flake, spall, melt, buckle or explode. Steel and concrete members (Bednarek, 1996) under fire have been extensively investigated in last decades. However, far fewer investigations have been carried out on timber structures (Bednarek, et al., 2002). Timber burns steadily at a predictable rate called charring. In the charring process charcoal is formed on the surface of the timber, which serves to insulate and protect the core. As a result, timber is now viewed as a respectable construction material.

Heavy wood members have long been recognized for their ability to maintain construction integrity while exposed to fire. Early mill construction from the 19th century utilized massive timbers to carry large loads and to resist structural failure from fire. Wood density is an important wood property for both solid wood and fibre products in both conifers and hardwoods (De Guth, 1980). Panshin and de Zeeuw (1980) reported that density is a general indicator of cell size and is a good predictor of strength, stiffness, ease of drying, machining, hardness and various paper making properties.

Brazier and Howell (1979) also expressed the opinion that density is one of the most important properties influencing the use of a timber. They emphasized that it affects the technical performance of wood and in particular the strength and processing behaviour of sawn wood and veneer, and the yields of wood fibre in pulp

production. Cown (1992) reported that the density of wood is recognised as the key factor influencing wood strength. Indeed according to Schniewind (1989) much of the variation in wood strength, both between and within species, can be attributed to differences in wood density. Research has shown that higher density species tend to have stronger timber than lower density species (Addis Tsehaye et al., 1995; Walker & Butterfield, 1996).

The mechanical properties of wood are dependent on the density, moisture content, the amount of extractives, among other factors (Chrsitoforo et al., 2012), strength of wood increases as the wood density increases. When evaluating the density of wood, the level of moisture in which its mass and volume were measured must always be known. Mechanical properties most commonly measured and represented as "Strength properties" for design include maximum stress in compression parallel to grain, compressive stress perpendicular to grain.

BURNING BEHAVIOUR OF TIMBER

Timber hardwood species are used in the field of construction due to the particular qualities they can offer. Presently it is no longer possible to envisage the development of construction materials and products without taking into consideration the problem of their fire behaviour, and more particularly of their fire resistance. There are two distinct phases to a fire, the developing phase and the fully developed phase and material performance has to be categorized in respect of those two conditions. The developing phase incorporates a number of separate phenomena, the combustibility of the material, the ease of ignition, the speed of the spread of fire/flame across its surface and the rate at which heat is released (Buchanan, 2001).

The fully developed phase represents the post flash conditions where all combustible materials become involved in fire. The desirable properties are the ability to continue to carry load to contain the fire within the zone of origin without the escape of flames or hot gases and without conducting excessive heat to the unexposed face that may lead indirectly to fire being transmitted to adjacent areas. The ability to resist the fully developed fire is known universally as the fire resistance. But in general terms this can only relate to an element of construction rather than to a material. In the case of timber elements, this characteristic is mainly influenced by the charring rate of the external layers of the element. On the other hand, this charring rate is influenced by the density of the material. The charring rate and charred layer thickness are the starting points for determination of the undamaged core at any fire time and for determination of temperature layout inside the core (Plate 1).

The charring characteristics are important problems while determining the fire resistance of timber components by analytical method. The charring rate is dependent on a number of factors such as: timber species, timber density, timber thickness, moisture content, and chemical composition. Different timbers char at varying rates, largely as a function of their density with the higher density timbers charring more slowly (Adetayo & Dahunsi, 2018). For structural timbers listed in the code of practice for the design of structural timber, EN 1995-1-2, this rate of depletion is taken as 20 mm in 30 minutes from each exposed face. Certain of the denser hardwoods (>650kg/m^3) used for structural purposes merit rates of 15 mm in 30 minutes, e.g., keruing, teak, greenheart, jarrah. Timbers of lower density will char more quickly e.g. Western red cedar is quoted as 25mm in 30 minutes. The rate of charring is little affected by the severity of the fire, so for an hour's exposure, the depletions are 40 mm for most structural timbers and 30 mm for the denser hardwoods. This enables the fire resistance of simple timber elements to be calculated.

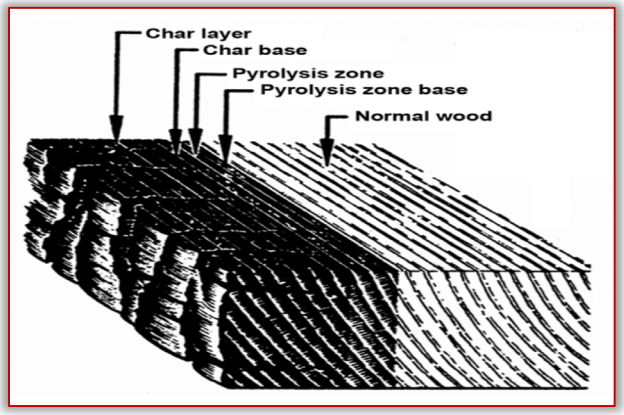

Plate 1. The changes in timber under influence of fire
Source: Charring rate of selected wood – transverse to grain (Schaffer, 1967)

Pyrolysis is essentially the thermal decomposition of organic matter under inert atmospheric conditions or in a limited supply of air, leading to the release of volatiles and formation of char (Plate 1). Pyrolysis in wood is typically initiated at 200°C and lasts till 450 - 500°C, depending on the species of wood. Pyrolysis has an important role in the combustion of wood since the products of this stage, namely, volatiles and char, subsequently undergo flaming and glowing combustion respectively to release thermal energy.

Timber is not readily ignited and there are very few recorded cases where timber will have been the first material to be ignited. Timber will require surface temperatures well in excess of 400°C if the material is to ignite in the medium to a short term without the pressure of a pilot flame. Even when a pilot flame is present, the surface temperature will have to be in excess of 300°C for a significant time before ignition occurs. The comparative fire resistance of wood and metal was never more graphically shown than the pictures taken after many hours of burning in the 1953 fire at a casein plant in Frankfort, New York (Plate 2).

Plate 2. Wood beam survives fire in casein plant Frankfort, NY.
Courtesy; Handbook of Wood Chemistry and Wood Composites Second Edition, 2013

The steel girders softened and failed at high temperature and fell across the 300mm by 400mm wood beams that were charred but still strong enough to hold the steel girders (Adetayo & Dahunsi, 2017). This charring protecting property of structural wood has found many applications, such as railroad wooden bridges (Handbook of Wood Chemistry and Wood Composites Second Edition, 2013).

MATERIALS AND METHODS

Preliminary studies were carried out to identify timber species used in the construction of structural members in Southwestern Nigeria. Six structural timber species were taken out of the ten mostly available species. All timber samples used in this research were taken from the heartwood region of the individual tree. And they were specially ordered from the lumber market.

The six species were:

- Afara (Terminalia superba)
- Iroko (Milicia excelsa)
- Mahogany (Khaya ivorensis)
- Mansonia (Mansonia altissima)
- Opepe (Nauclea diderrichii)
- Teak (Tectona grandis)

— Determination of Density and Moisture content

The specimens were cut into dimensions of 60mm x 20mm x 20mm for density and moisture content determination. Five samples were taken for each species and tested. The average results were then determined. Densities were determined by dividing the mass of the specimen by the volume as per equation 1.

$$\text{Density } \rho = \frac{m}{v} \quad (1)$$

where m = the mass in gram, obtained from weighing directly using digital weighing balance,

v = the specimen volume, determined by multiplying (60 x 20 x 20) mm^3.

Corresponding value of density for each specimen was converted to kilogram cubic meter (kg/m^3). Density is moisture dependent, because moisture adds to the mass and may cause volume to swell. Moisture content is defined as the ratio of the mass of removable water (m_{water}) to the dry mass of wood (m_{dry}). The dry mass is obtained by oven drying at 103 ± 2 °C for 24hours as per ASTM D143-94. Moisture content can be expressed as a fraction or in percentage terms (Equation 2)

$$\text{Moisture Content (MC)} = \frac{m_{wet} - m_{dry}}{m_{dry}} (100\%) \quad (2)$$

— Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

Test samples of 300 x 20 x 20mm were obtained from each sampling level. Thirty samples, five samples from each species were used for static bending test for MOE and MOR. The machine used for the measurements is the Hounsfield Tensiometer available in forest product development and utilization department at Forestry research Institute of Nigeria, Ibadan. The sample was prepared so that the growth rings are parallel to one edge and the sample was tested with the growth rings parallel to direction of loading i.e. it was loaded on the radial face: load of 1 ton (10,160N or 10.16KN) was applied at a speed of 0.1mm/s. The bending strength of these wood samples were presented as a modulus of rupture (MOR) which is the equivalent stress in the extreme fibres of the sample at the point of failure assuming that the simple theory of bending applies. The MOR is calculated in three points bending from the equation 3 below.

$$\text{MOR} = \frac{3PL}{2bh^2} \quad (3)$$

where, MOR is in N/mm^2; P = load in Newton (N); L = span in mm; b = width in mm; h = height in mm

Also the bending strength was also presented as modulus of elasticity (MOE) which provides values of works to maximum load and total work, as well as a measure of toughness. The MOE is calculated as:

$$\text{MOE} = \frac{PL}{4bh^2\Delta} \quad (4)$$

where, MOE is in N/mm^2; P = load in Newton (N); L = span in mm; b = width in mm; h = height in mm; Δ = angle of inclination derived from the graph.

The replicates of five samples from each species were used to obtain the mean values according with BS EN1957.

— Shear parallel to the grain

Shear is the ability to resist internal slipping of one part upon another along the grain. The samples sizes are 20mm x 20mm x 20mm and a load of 1tonne (approximately 10000N or 10KN) was applied to the piston of the cage at a rate of 0.01mm/s. The corresponding shear stress is calculated thus,

$$\text{Shear} = \frac{P}{\text{Area}} \quad (5)$$

P = maximum shear force (load) in Newton (N); Area = L x b; L= length in mm; b= thickness in mm

— Compression parallel and perpendicular to the grain

This test deals with obtaining the maximum crushing strength of the wood sample. The samples sizes is 60mm x 20mm x 20mm and a load of 1tonne (approximately 10000N or 10KN) was applied to the piston of the cage at a rate of 0.01mm/s. One of the precautions necessary in evaluating this property is the need to ensure that the samples do not buckle during loading, thereby subjecting it to a bending rather than a compressive stress. A special cage which ensures a uniform distribution of load over the cross-section was used.

The compressive strength in (N/mm2) was obtained by:

$$\text{Compression} = \frac{P}{\text{Area}} \quad (6)$$

P = load in Newton (N); Area = L x b; L = Length in mm; b= thickness in mm

— Fire Exposure Method

At time of test, the following data were recorded for the specimen properties:

- Species
- Ring orientation
- Specimen dimensions
- Specimen weight
- Specific gravity (dry)
- Moisture content (percent)

The specimen, were installed in the furnace, and the electric furnace was powered, the furnace temperature switched on was 20°C. At time of burner ignition, the following functions were done as simultaneously as possible.

- Automatic temperature recorder was started
- Stop watches started
- Furnace temperature controller started.

Specimens were exposed to fire in three batches; first batch went for time (0- 30) minutes, second batch for (0 -30) minutes and the last batch was for full (0- 60) minutes.

The first test for exposure period 0 – 30 minutes was stopped at the time when the stop watch reached 30 minutes, temperature ranging from 20°C to 230°C. Samples exposed during the second period were subjected to higher temperature 230°C to 600°C for 30 minutes (30 – 60 minutes). The third test, for exposure period 0 – 60 minutes was terminated when the furnace temperature reached 20°C to 300°C.

When testing completed, the charred wood was scrapped away from the samples and char depth measured millimetres. Charring rates were determined by dividing char depth with the corresponding fire exposure time (Adetayo & Dahunsi, 2018).

— Post Fire Strength Properties of Wood samples

The density and compressive strength of the wood samples that had charred were tested to determine their post fire strength after 0 – 60 minutes fire exposure and temperature ranging between 20°C to 300°C inside electric furnace, the char layers were easily scrapped off. The charred portion has no residual load capacity. The wood beneath the char layer has residual load capacity, but this residual capacity is less than the load capacity prior to fire.

RESULTS AND DISCUSSION

— Density and Moisture Content

Figure 1 illustrated the column chart of the values of density of each species at their corresponding Moisture Contents (MC) 9, 12 and 15%. The results showed that as timber species moisture content increases, the density increases. At 9% MC, Mahogany had the lowest density value of 439 ± 10.58 Kg/m^3. At 12 and 15% MC, Afara had the lowest density values of 444 ± 4.18 Kg/m^3 and 469 ± 7.07 Kg/m^3 respectively. At 9, 12 and 15% MC, Opepe had the highest density values of 630 ± 28.85 Kg/m^3, 686 ± 22.64 Kg/m^3 and 752 ± 17.22 Kg/m^3 respectively.

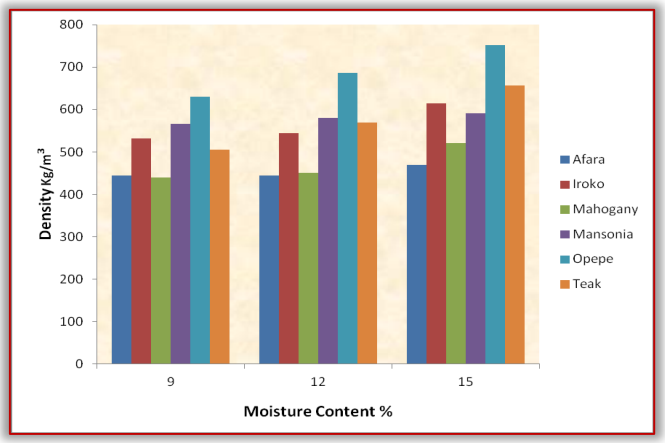

Figure 1: Density of selected Species at their corresponding Moisture Content

— Modulus of Elasticity

MOE is a useful property required in designing trusses for roofing structures, dry wood is often preferred in the design of wood structures to minimize shrinkage associated with in situ drying in service.

Figure 2 illustrated the column chart for the Modulus of Elasticity values of each species at their corresponding MC 9, 12, and 15%. It shows that MOE values increases as moisture content of wood sample reduces. At 15% MC, Teak had the lowest MOE value of 10269.20 ± 2049 N/mm2 while Mahogany had the highest value of 15368.20 ± 904.71 N/mm^2. Afara had the lowest MOE values of 12056.00 ± 2307.71 N/mm^2 at both 9 and 12% MC. Opepe had the highest MOE value of 15557.80 ± 4718.64 N/mm^2 at 12% MC and Iroko had the highest value of 19884.80 ± 7768.79 N/mm^2 at 9% MC.

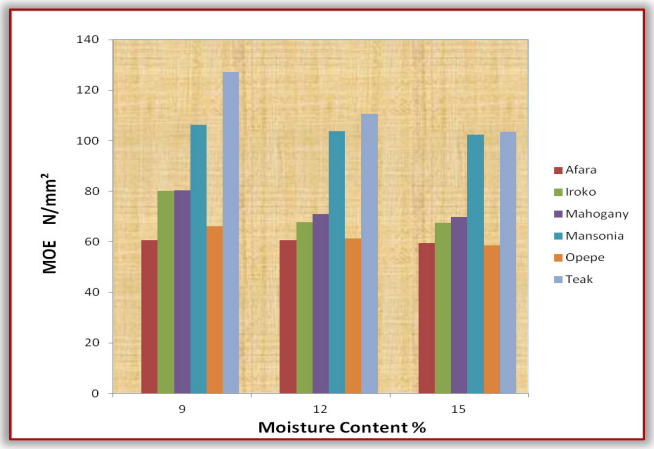

Figure 2: MOE of selected Species at their corresponding Moisture Content

— Modulus of Rupture

MOR is also one of the key mechanical properties of wood measured and presented as strength property for design. It is a reflection of the maximum load carrying capacity of a member in bending and is proportional to the maximum moment borne by the specimen.

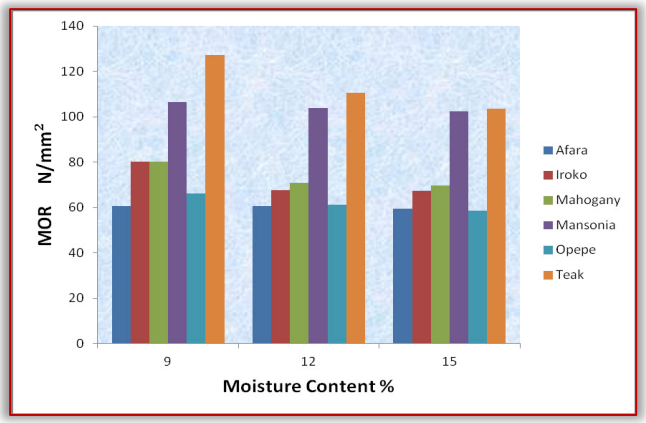

Figure 3: MOR of selected Species at their corresponding Moisture Content

Figure 3 illustrated the column chart for the Modulus of Rupture values of each species at their corresponding 9, 12, and 15% MC moisture content. It shows that MOR values increases as moisture content of wood sample reduces. At 15% MC Opepe had the lowest

MOR value of 58.50 ± 8.53 N/mm^2. At 9 and 12% MC, Afara had the lowest MOR values of 60.64 ± 2.10 N/mm^2. At 9, 12 and 15% MC, Teak had the highest MOR values of 127.14 ± 14.62 N/mm^2, 110.70 ± 12.67 N/mm^2 and 103.47 ± 10.17 N/mm^2 respectively.

— Compression Results

The mean values of compression strength parallel to the grain at 9, 12, and 15% MC for each species are given in Figure 4. Compression strength parallel to the grain is higher than perpendicular to the grain and the results are similar to previous results obtained from Odom et al., (1994) promotion of valuable hardwood plantations in the tropics and Excerpts from the rules for materials.

From the results, it showed that as timber species moisture content increases, the compressive strength parallel to the grain decreases. Afara of 9, 12 and 15% MC had the lowest Compression strength parallel to the grain values of 9.59 ± 1.08 N/mm^2, 9.59 ± 1.08 N/mm^2 and 8.13 ± 1.01 N/mm2 respectively, while Mahogany had the highest Compression strength parallel to the grain values of 16.57 ± 0.50 N/mm^2, 15.17 ± 0.49 N/mm^2 and 12.12 ± 0.42 N/mm^2 at the three MC levels.

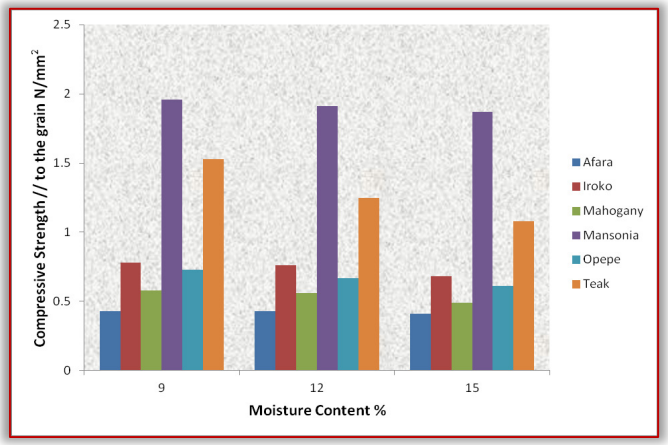

Figure 4: Compressive Strength parallel to the grain of selected Species at their corresponding MC

— Shear Results

The minimum, maximum and mean values of shear strength results parallel to the grain of the selected species at their corresponding MC 9, 12 1nd 15% are given in Figure 5.

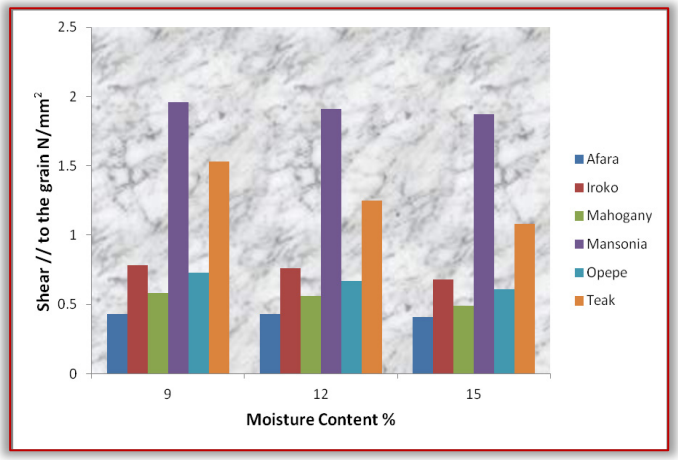

Figure 5: Shear parallel to the grain of selected Species at their corresponding Moisture Content

Afara had the lowest Shear strength parallel to the grain values of 12.05 ± 2.60 N/mm2 at both 9 and 12% MC, while Iroko had the lowest Shear strength parallel to the grain value of 10.43 ± 0.46 N/mm2 at 15% MC. At 9, 12 and 15%, Opepe had the highest Compression strength parallel to the grain values of 24.81 ± 1.56 N/mm2, 22.05 ± 1.23 N/mm2 and 19.11 ± 1.12 N/mm2 respectively.

— Post Fire Density of Samples

Table 1, showed the post fire densities values of samples. At fire exposure time of 0 - 60 minutes, 9, 12 and 15% MC, Afara had the highest percentage change in density values of 29.2, 29.1 and 28.6% respectively. At 9% MC, Iroko had the lowest percentage change in density values of 27.3%, while at 12 and 15% MC, Mahogany had the lowest percentage change in density values of 26.8 and 25.9% respectively.

Table 1: Post Fire Density of Samples and their corresponding Moisture Content (MC)

Species	MC (%)	Mean Density Before Charring test (Kg/m^3)	Mean Density After Charring test (Kg/m^3)	Percentage Loss
Afara	9	444.00	314.35	29.2%
	12	444.00	314.80	29.1%
	15	469.00	334.87	28.6%
Iroko	9	532.00	386.76	27.3%
	12	544.00	397.66	26.9%
	15	614.00	453.13	26.2%
Mahogany	9	439.00	318.71	27.4%
	12	451.00	330.13	26.8%
	15	521.00	386.06	25.9%
Mansonia	9	566.00	402.43	28.9%
	12	580.00	415.86	28.3%
	15	591.00	427.29	27.7%
Opepe	9	630.00	454.86	27.8%
	12	686.00	498.72	27.3%
	15	752.00	551.97	26.6%
Teak	9	505.00	366.13	27.5%
	12	569.20	414.94	27.1%
	15	657.00	483.55	26.4%

— Post Fire Modulus of Elasticity

Tables 2, showed the post fire MOE values of samples. At fire exposure time of 0 - 60 minutes, 9 and 15% MC, Afara had the highest percentage change in MOE values of 22.6 and 19.7% respectively while at 12% MC, both Afara and Mansonia had the same percentage change in MOE value of 21.3%.

At 9% MC, Iroko had the lowest percentage change in MOE value of 20.1%, while at 12% MC, Opepe had the lowest percentage change in MOE value of 19.4% and at 15% MC, both Mahogany and Teak had the lowest percentage change in MOE value of 18.6%.

— Post Fire Modulus of Rupture

Table 3, showed the post fire MOR values of samples. At fire exposure time of 0 - 60 minutes, 9, 12 and 15% MC, Afara had the highest percentage change in MOR values of 35.3, 34.8 and 34.3% respectively.

At 9% MC, Iroko had the lowest percentage change in MOR value of 30.6%, while at 12 and 15% MC; Opepe had the lowest percentage change in MOR values of 29.7 and 29.2% respectively.

Table 2: Post Fire MOE and their corresponding Moisture Content (MC)

Species	MC (%)	Mean MOE (N/mm^2) Before Charring test	Mean MOE (N/mm^2) After Charring test	Percentage Loss
Afara	9	12056.00	9331.34	22.6%
	12	12056.00	9488.07	21.3%
	15	11392.80	9148.42	19.7%
Iroko	9	19884.80	15887.96	20.1%
	12	15011.60	12009.28	20.0%
	15	13951.80	11287.01	19.1%
Mahogany	9	17883.00	14234.87	20.4%
	12	15284.40	12303.94	19.5%
	15	15368.20	12509.72	18.6%
Mansonia	9	14716.00	11478.48	22.0%
	12	14234.60	11202.63	21.3%
	15	13872.40	11084.04	20.1%
Opepe	9	17565.60	13964.65	20.5%
	12	15557.80	12539.59	19.4%
	15	14833.20	11940.73	19.5%
Teak	9	16015.80	12764.59	20.3%
	12	13429.40	10783.80	19.7%
	15	10269.20	8359.13	18.6%

Table 3: Post Fire MOR and their corresponding Moisture Content (MC)

Species	MC (%)	Mean MOR (N/mm^2) Before Charring test	Mean MOR (N/mm^2) After Charring test	Percentage Loss
Afara	9	60.64	39.23	35.3%
	12	60.64	39.54	34.8%
	15	59.62	39.17	34.3%
Iroko	9	80.11	55.60	30.6%
	12	67.69	47.32	30.1%
	15	67.50	47.52	29.6%
Mahogany	9	80.33	55.28	31.2%
	12	70.92	49.01	30.9%
	15	69.75	48.76	30.1%
Mansonia	9	106.39	69.79	34.4%
	12	103.78	68.70	33.8%
	15	102.38	68.70	32.9%
Opepe	9	66.13	45.70	30.9%
	12	61.34	43.12	29.7%
	15	58.50	41.42	29.2%
Teak	9	127.14	97.47	31.2%
	12	110.70	77.71	29.8%
	15	103.47	73.46	29.0%

— Post Fire Compression Results

Table 4, showed the post fire Compression parallel to grain values of samples. At fire exposure time of 0 - 60 minutes, 9, 12 and 15% MC, Afara had the highest percentage change in compression parallel to grain values of 83.6 and 82 and 82.1% respectively. At 9, 12 and 15% MC, Iroko had the lowest compression parallel to grain value of 81.8, 81.1 and 80.4% respectively.

— Post fire Shear Results

From Table 5, at fire exposure time of 0 - 60 minutes, 9 and 12% MC, Mansonia had the highest percentage change in shear parallel to grain values of 77.1 and 75.9% respectively, while at 15% MC, both Afara and Mansonia had the same percentage change in shear parallel to grain value of 75.2%. At 9, 12 and 15% MC, Iroko had the lowest percentage change in shear parallel to grain values of 73.8, 73.1 and 72.4% respectively.

Table 4: Post Fire Compression results parallel to grain and their corresponding Moisture Content (MC)

Species	MC (%)	Mean Compression (N/mm^2) Before Charring test	Mean Compression (N/mm^2) After Charring test	Percentage Loss
Afara	9	9.59	1.57	83.6%
	12	9.59	1.65	82.8%
	15	8.13	1.45	82.1%
Iroko	9	14.35	2.61	81.8%
	12	13.05	2.47	81.1%
	15	10.56	2.07	80.4%
Mahogany	9	16.57	2.87	82.7%
	12	15.17	2.73	82.0%
	15	12.12	2.27	81.3%
Mansonia	9	13.50	2.28	83.1%
	12	12.08	2.11	82.5%
	15	10.86	1.98	81.8%
Opepe	9	16.03	2.85	82.2%
	12	13.80	2.52	81.7%
	15	11.59	2.21	80.9%
Teak	9	14.69	2.57	82.5%
	12	12.15	2.21	81.8%
	15	9.52	1.80	81.1%

Table 5: Post Fire Shear results parallel to grain and their corresponding Moisture Content (MC)

Species	MC (%)	Mean Shear (N/mm^2) Before Charring test	Mean Shear (N/mm^2) After Charring test	Percentage Loss
Afara	9	12.05	2.82	76.6%
	12	12.05	2.92	75.8%
	15	11.40	2.83	75.2%
Iroko	9	14.19	3.72	73.8%
	12	12.90	3.47	73.1%
	15	10.43	2.88	72.4%
Mahogany	9	20.42	4.96	75.7%
	12	18.90	4.82	74.5%
	15	15.36	4.02	73.8%
Mansonia	9	16.01	3.67	77.1%
	12	14.65	3.53	75.9%
	15	13.38	3.32	75.2%
Opepe	9	24.81	6.40	74.2%
	12	22.05	5.82	73.6%
	15	19.11	5.20	72.8%
Teak	9	18.30	4.67	74.5%
	12	15.35	4.03	73.7%
	15	12.29	3.31	73.1%

CONCLUSIONS

In the study of the literature and laboratory tests results on material properties and external factors that influence the integrity of the timber members, the following properties and factors were found to have the largest influence:

— Moisture content: Moisture influences in wood charring process include a greater requirement of energy to burn the wood, increasing the thermal conductivity of the wood, and delaying the rise in temperature of the wood sample's core until the moisture is evaporated. The resulting lower temperatures and slower heating rates favor the formation of char that protects the inner core of the wood to maintain its initial strength.

- Density: Density is greatly influenced by the amount of moisture contained in timber at the time of measurement. The test results confirmed that density of wood influences significantly the charring rate, the charring rate increases with lower density, and higher density species have lower charring rate. At 9% moisture content, the highest percentage loss of density for all the selected species at 0 – 60 minutes fire exposure time (20 – 230°C) was 29% of the density before charring test. With over 70% density of the material still retained after fire exposure, the integrity of the material to continue structural functioning still intact before replacement.
- Species of timber: The properties of timber (e.g. density, composition, permeability) vary greatly and different species will exhibit different combustion behaviour when exposed to fire. From the results Afara had the lowest density 444 kg/m3 before charring and exhibited highest percentage loss in density 29.2% after charring as compared to Opepe with highest density of 752 kg/m3 and exhibited lower percentage loss in density 26.6% after charring.
- Grain orientation: Wood is an anisotropic material with most of its properties substantially different when considered along the grain or across the grain. Since the majority of the fire test calculations performed to evaluate the fire resistance of linear members are related to the transversal directions, little information regarding the longitudinal thermal properties of wood is available. However, it has been established that permeability for flow along the grains is 104 times that across the grains. Similarly thermal conductivity of wood along (parallel) the grain has been reported to be in the range 1.5 to 2.8 times the conductivity across the grain, with the average value being around 2. Charring rate of wood along the grain is higher than across the grain with ratio between them ranging from 1.3 to 2.0.
- Formation of char layer: Char layer and its fissures are important in wood charring; the layer being charred is thinner than the original thickness of the wood that has charred as a result of surface recession. The thinner insulative char layer is important in modeling of wood charring. The surface recession was due to the mechanical degradation or chemical oxidation at the surface or contraction of the char.
- Thickness: Wood thickness influences the rate at which heat is absorbed into the surface as well as the residual section of the unburnt timber. The charring rate of timber exhibited two peaks during fire tests, during the initial exposure before char layer is developed, and towards the end of the char interface approaches the unexposed surface. Thinner specimens exhibited higher level of charring rate.
- Thermal exposure: The low thermal conductivity of timber reduces the rate at which heat is transmitted to the interior, fire test showed that the thermal conductivity of timber is inversely proportional to the moisture content in the wood. Hence increasing moisture content (i.e. reducing thermal conductivity) will increase the rate of degradation of the wood. The charring rate increases with higher heat flux, better ventilation and more oxygen in the air.

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ISSN: 2067-3809

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ENERGY EFFICIENCY IN HVAC SYSTEM USING AIR COOLING BY DIRECT EVAPORATION

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Abstract: In developed countries, buildings represent between 30 and 40% of the total energy consumed and office buildings are one of the largest energy consumers. Specialty literature presents studies that showing air conditioning systems represent between 10 and 60% of total energy consumption in office buildings. This indicates that the heating / cooling system of a building has great potential for energy savings. The article presents classical cooling systems and describe the HVAC system used to cooling experimental room, located in a building from Timisoara. In order to determine the energy efficiency of the above-mentioned HVAC system, four control scenarios were made by varying the chilled water temperature at the evaporator exit and cooling mode of the chiller condenser. The indoor air temperature was set to the comfort value of 25°C, and the measurements were made within 8 hours for each scenario during July. Based on the analysis of the four proposed HVAC scenarios, it was concluded that the performance of a chiller may vary significantly depending on the system's partial loads and the evaporator and condenser operating temperatures, and For air-cooled chillers, the performance coefficient increases as the outside air temperature (te) decreases and the temperature of the cooled water (twr) increases at the evaporator outlet.
Keywords: Energy efficiency, HVAC system, air cooling, performance, comfort

INTRODUCTION

In present, the European energy efficiency target for 2020 adopted in 2007 is 20 as compared to 2005. For Romania, this indicative target is expressed as the level of savings of primary energy of 43 meters and 30.3 meters of final energy consumption respectively. The Commission's 2017 evaluation report shows that, despite Romania's situation in the group of 15 Member States that have achieved energy savings over the annual level needed to reach the target, the situation has deteriorated in the residential and transport sectors, which is the mitigation of the gap energy consumption compared to Western European countries.

For 2030, the European Energy Efficiency Target, commonly established for all Member States in 2014 was 27%. This percentage was raised to 32.5% in 2018, by the consensus between the European Commission, the European Parliament and the EU Council with a further upward revision clause until 2023. Such growth requires significant investment, supported by public policies and stimulated by favorable regulations [1-2].

Considering the current worldwide energy consumption requirements, the energy efficiency of heating and air-conditioning systems has an increasing share. So far, in most European countries, the energy required to heat the premises is higher than the energy used to cool the premises. In the future, the energy consumption for space cooling will increase due to increasing internal heat gains and the use of glazed facades. Low energy buildings are characterized by good thermal insulation and low heat losses between the interior and exterior, and high-quality glazed surfaces have U-value coefficients below 1.5 W/m^2K.

In developed countries, buildings represent between 30 and 40% of the total energy consumed. Office buildings are one of the largest energy consumers [3-4]. Generally, most of the energy is used to maintain an acceptable level of comfort inside buildings. Lighting and heating/cooling systems are the biggest consumers. Studies show that air conditioning systems represent between 10 and 60% of total energy consumption in office buildings [5]. This indicates that the heating / cooling system of a building has great potential for energy savings.

CONVENTIONAL AIR CONDITIONING SYSTEMS

Conventional air conditioning systems depend on the vapor compression cycle to ensure cooling. Types of conventional vapor compression systems are autonomous, factory-assembled compact units, separate compressor units and condensing units and internal air-flow units (CTAs) and cold systems. Cold systems use refrigerants to cool the water that is then distributed to CTA batteries. With each of these systems, cooled air is delivered via terminal devices to the space to be cooled.

— Experimental Parameters

When the liquid water evaporates and turns into water vapor, the heat entering the evaporation process is removed from the air, thus cooling the air temperature. Evaporative air conditioners are effective in medium to low-humidity climates and consume much less energy than other types of air conditioning systems. Air conditioners may have direct or indirect evaporation. In direct evaporation cooling, the water evaporates directly into the supply air stream, thereby lowering the temperature of the dry air thermometer when the humidity increases. Latent air heat is used to evaporate the air. Evaporation cools the air while increasing the moisture content or relative humidity. Do not add or remove heat from the air, so it is an adiabatic process.

Figure 1 shows a psychometric analysis of this direct evaporation cooling process. The air temperature entering the dry thermometer (T_{DB}) is 43.3°C, relative humidity, φ is 15%, and the thermodynamic temperature of the wet thermometer (T_{WB}) is 22.2°C. The cooling threshold of 21.1°C can be reached from 43.3°C to 22.2°C by adding only water to the supply air. In this case, the feed air stream was

cooled down to 3.3°C of the thermodynamic limit of the wet thermometer, so it was 84% more efficient than the theoretically possible 17.8°C. Obtaining 90% to 95% of the wet thermometer temperature is often the target of direct cooling performance.

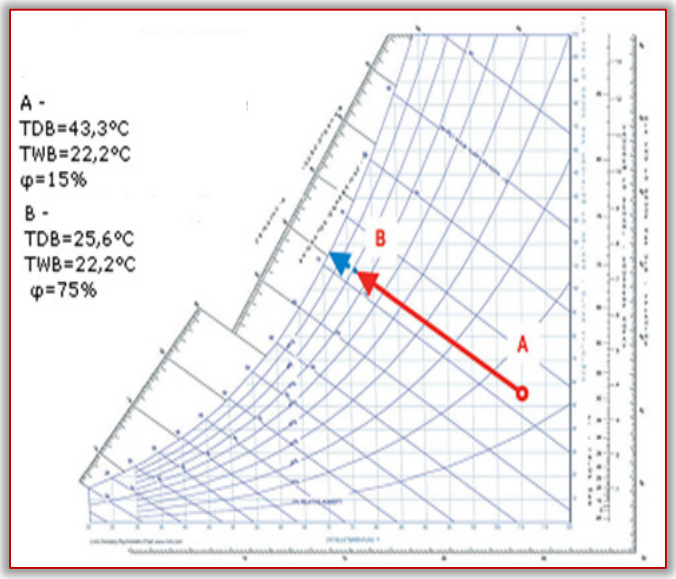

Figure 1. Direct evaporation cooling process presented psychometrically

A psychometric graph can show why direct evaporation cooling works well in dry climates and not very well in wet conditions. Using Figure 2, if we start with T_{DB} = 35°C (A) with 70% relative humidity, that air can only be cooled directly by 5°C before reaching saturation to T_{WB} = 30°C. Going further and to the left of the short red line to A, the final air temperature can be read by following the vertical lines to the temperature of the dry thermometer. Starting with T_{DB} = 35°C air (B) at relative humidity of 10%, that air can be cooled to 18.3°C before condensation, for 19.4°C when cooling. This is a significant increase in the amount of cooling that can be assured against wet air at the same temperature.

The cooling effect of direct evaporation air conditioners is the result of the amount of moisture added to the air. In very dry climates, direct cooling is quite efficient for cooling dry dry air. Additionally, moisture added to the air can be a bonus.

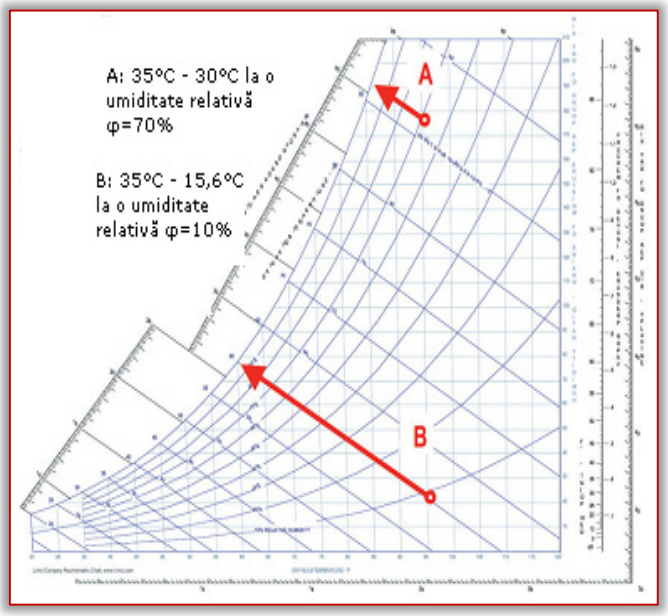

Figure 2. Comparison with direct evaporation cooling when starting with T_{DB} = 35°C at φ = 70% versus φ = 10%

PRESENTATION OF THE EXPERIMENTAL ROOM

The experimental room located in Timisoara (Figure 3) is bounded by an east-facing exterior wall, two adjacent interior walls of an office and an inner wall adjacent to a corridor, a floor separating the thermal area studied by a meeting room of a common floor with a top-level office.

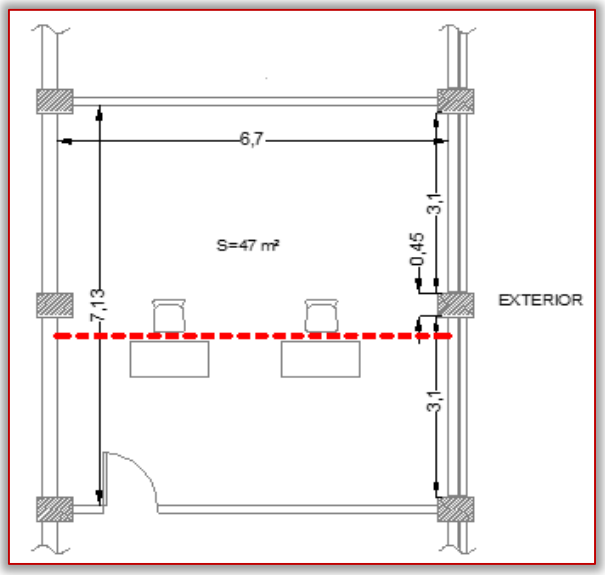

Figure 3. Plan of the experimental room

The calculations were made for Timişoara, with average daily air temperature in July, t_{em}=24.7°C, absolute air humidity, x_e=10.5 g/kg and the degree of system security ventilation/air conditioning of 90%.

The following basic data is also known:

- the height of the room is 3.70 m;
- total area of the room S = 47m^2, and the surface of the inner doors Su = 2.10 m^2;
- the glazed surface is 17 m^2 of thermopan glass, representing 64% of the exterior wall surface;
- the floor consists of parquet (0.02 m), screed (0.05 m), reinforced concrete slab (0.125 m), lime plaster (0.02 m);
- the floor consists of tiles (0.015 m), screed (0.05 m), reinforced concrete slab (0.125 m), lime plaster (0.02 m);
- the outer wall consists of lime plaster (0.02 m), autoclaved cellular concrete (0.25 m), cement mortar (0.03 m) and open brick (0.05 m);
- interior walls are made of lime plaster (0.004 m), gypsum board (0.02 m) and mineral wool (0,10 m);
- the occupants of the room are 2, each with a computer;
- electrical lighting has a thermal failure of 5 W/m^2;
- the tilt angle of the outer wall s = 90°C;
- azimuthal angle of the outer wall = -90°.

DESCRIPTION OF THE HVAC SYSTEM USED FOR AIR CONDITIONING

In order to achieve the comfort parameters in the experimental room, the following equipment was used:

- an air-cooled, air-cooled Daikin chiller (CH) (CH) with a refrigerant vapor compression (R410a) with a cooling capacity of 7.1 kW;
- a GEA air handling unit (CTA) with a maximum air flow rate of 2700 m^3/h, consisting of a mixing chamber, a fine F5 class filter, a flat-bottomed heating battery with fins and a collector- hot water dispenser, cooling fan and centrifugal fan with frequency converter and maximum pressure loss of 250 Pa;
- two wall-mounted ventilators (VCV), one Climaveneta type and one Rhoss type, with a total cooling output of 3.2 kW.

The thermal agent used in the ventilation / air conditioning systems analyzed is chilled water, using the chiller air-cooled. It has a cooling capacity of 7.1 kW under the condition that the outside air temperature is 35°C and the cooled water produced has a temperature of 7°C and the flow temperature difference between flow and return is Δt = 5°C.

The chiller was chosen taking into account the variation in EER energy efficiency with outdoor air temperature.

Heat pumps operating in heating mode are characterized by the COP defined by the relationship (1) [6-7]:

$$COP = \frac{Q_c}{P_e} \quad (1)$$

in which:

Q_c is the heating power in kW;

P_e - electric power to drive the heat pump, in kW.

The performance coefficient of a chiller or heat pump in cooling mode is obtained with relationship (2) [6-7]:

$$COP = \frac{EER}{3,413} \quad (2)$$

in which 3.413 is the transformation factor of Watt in Btu / h.

It has to be taken into account that the performance of such a refrigeration system can vary significantly [6-7]. Performance depends on partial system loads and evaporator and condenser operating temperatures.

In Europe, the energy efficiency rating for cooling for chiller operation at partial loads is called the EER_{sez}, defined by the relationship (3) [6-7]:

$$EER_{sez} = \frac{1 \cdot EER_{100\%} + 42 \cdot EER_{75\%} + 45 \cdot EER_{50\%} + 12 \cdot EER_{25\%}}{100} \quad (3)$$

where: $EER_{100\%}$, $EER_{75\%}$, $EER_{50\%}$, and $EER_{25\%}$ are yields of the cold water generator operating at various partial loads (respectively 100%, 75%, 50% and 25%) calculated for the outdoor air temperatures listed in Table 1 for the evaporator water outlet temperature of 6°C or 7°C and for the 5°C cold water temperature range.

Table 1. External air temperatures for different partial cooling loads

Cooling load	100%	75%	50%	25%
Outdoor air temperature	35°C	30°C	25°C	20°C

Applying relations (1) and (2) EER values were calculated at maximum load and using the relation (3) the values of the EER seasonal energy efficiency ratio were determined depending on the chiller's efficiency operating at different partial loads. The values obtained for EER and EERsez are summarized in Table 2. It is noted that the chiller selected for unfavorable conditions (te = 35°C, twr = 7°C and Δt = 5°C) has a seasonal energy efficiency ratio EERsez = 10.57.

Table 2. Chiller energy efficiency

t_{wr} [°C]	t_e [°C] 20	25	30	35	EER
	EER				
7	12.72	11.02	9.53	8.21	
11	13.76	11.90	10.25	8.70	
13	14.26	12.33	10.63	9.12	
16	15.01	12.97	11.20	9.86	
20	16.04	13.85	11.94	10.91	

Operation of the chiller is done by means of a Daikin ARC448A2 wall control, which, depending on the set DHW temperature, gives the compressor control. The chilled water temperature can be set between 5°C and 22°C. When the chilled water temperature has reached the set value, the compressor stops running, leaving only the circulating pump and the cooling fans of the condenser in the chiller.

The condenser cooling system on the chiller can be changed by placing a water spray equipment in the condenser area. The outdoor air temperature decreases to the wet bulb temperature, a process performed at constant enthalpy.

Condensers cooled only with air or water only make the condensation heat from the refrigerant only by the sensitive heat of the coolant causing significant air or water flows [8]. At the same time, heating this cooling agent leads to a higher condensing temperature.

Improvements to these two inconveniences can be achieved by using mixed cooled condensers with water and air. The water takes over the condensing heat from the refrigerant and vaporizes partially. Through this vaporization and heat exchange between water and air, the water flowing over the surface of the condenser maintains virtually the constant temperature and can be recirculated and used again in the cooling process [9].

In this way, a low condensing temperature is maintained, only 2-3°C higher than the water temperature, and lower water and air flow rates are required.

As the cooling system is based on water evaporation and the takeover of these vapors by the air, the hygrometric state of the air is of great importance to the operation of the condenser. This will be more effective when the air will have a lower relative humidity.

RESULTS OF EXPERIMENTAL RESEARCH

In order to determine the energy efficiency of the above-mentioned HVAC system, four control scenarios were made by varying the chilled water temperature at the evaporator exit and cooling mode of the chiller condenser shown in Table 3.

Table 3. Scenarios systems

Scenario	Type of cooling the condenser	Chilled water temperature twr [°C]
1	air	5
2	air-water	5
3	air	8
4	air-water	8

The indoor air temperature was set to the comfort value of 25°C, and the measurements were made within 8 hours for each scenario during July.

In scenarios 2 and 4, a mixed (air-water) cooling of the chiller condenser was carried out by spraying the water by means of three jets mounted at a distance of 0.2 m from the chiller housing (Fig.4). This results in a fog curtain that lowers the outside air temperature in the area to the humidity of the thermometer by cooling it iztalpically [10].

Figure 4. Water spray system for condenser cooling

To determine the distance of the dowel locations, the temperature and humidity of the outdoor air were measured before and after water spraying through the three wells.

The values recorded before spraying were 28°C for air temperature and 60% for relative humidity. After spraying, the values listed in Table 4 were recorded, corresponding to the different spacing of the nozzle. As the strongest cooling of the outside air, up to 22.2°C, was obtained at a distance of 0.2 m, the dowels were mounted at this distance from the chiller housing.

Table 4. Distance between the nozzles

Distance between the nozzle [m]	Relative humidity of outdoor air after water spraying [%]
0.40	83
0.35	87
0.30	91
0.20	98

In all scenarios shown above, the electrical energy consumption of each equipment of the system analyzed, indoor and outdoor air temperatures and the intensity of global solar radiation were measured.

Table 5 shows the measured power consumption values for the HVAC system and each considered control scenario.

Table 5. E_{el} power consumption values, in kWh, for the HVAC system in the four scenarios

Scenario	Chiller	CTA	VCV	Total
1	7.58	8.67	0.37	16.62
2	5.78	8.67	0.62	15.07
3	7.74	8.67	0.66	17.07
4	5.66	8.67	0.71	15.04

The fresh air from the treatment plant has a temperature equal to that set for indoor air, 25°C.

Analyzing the four scenarios for the HVAC system, the most efficient energy scenario is scenario 4 where the electricity consumed is 15.04 kWh. The share of electricity consumed by the chiller is only 37.6% due to the high electrical consumption registered at CTA (Figure 5). VCV electricity consumption is less than 5% of the total power consumption of the system.

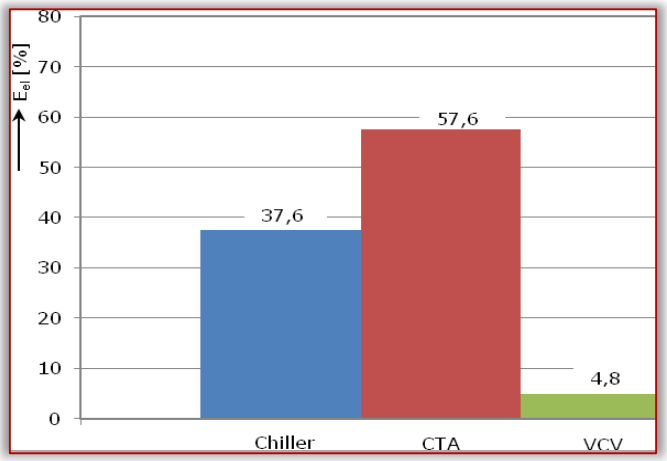

Figure 5. The share of electricity consumption of HVAC system equipment

Considering the share of electrical power consumption on equipment to reduce the power consumption of the system, it is necessary to act simultaneously to improve the energy efficiency of the chiller and to reduce the specific power of the CTA fans.

To determine the influence of chiller cooling mode on electricity consumption, scenarios 1 to 2 and 3 to 4 were compared for HVAC. Table 6 shows the E_{el} power consumption for two scenarios of the HVAC system, resulting in the corresponding ΔE_{el} energy savings.

Table 6 The influence of chiller cooling mode on electricity consumption

System		Scenario			
		1	2	3	4
HVAC	Eel [kWh]	16.62	15.07	17.07	15.04
	ΔEel [%]	9.32		11.89	

It is noted that the HVAC system records a ΔE_{el} electricity saving when using the air-water chiller (scenarios 2 and 4).

Spraying water causes the average outside air temperature to drop so that refrigerant condensation occurs much faster.

Table 7. Changing outdoor air temperature following water spraying

Te[°C]	
before	after
22.36	21.08
23.48	21.2
24.17	21.66
25.08	21.96
28.31	24.21
28.35	24.17
31.12	24.81
33.22	26.22

For the HVAC system, the highest energy saving of 11.89% is obtained when the chilled water temperature is 8°C.

Therefore, it is recommended to use the HVAC system with an air-cooled chiller and a chilled water temperature of 8°C. The energy efficiency of this system was determined by measuring the E_{rac} cooling energy and total E_{el} consumed energy, depending on the outside air temperature, and is shown in Table 8.

Table 8. Energy efficiency of the HVAC system

Nr. crt.	te [°C]	Erac [kWh]	Eel [kWh]	COPsist	EERsist
1	26.76	1.13	0.89	1.27	4.34
2	28.25	1.07	0.88	1.21	4.13
3	30.34	1.34	0.98	1.37	4.68
4	31.91	1.18	0.95	1.24	4.24
5	33.09	1.00	0.87	1.14	3.90

It is noted that at an increase of about 7°C of outdoor air temperature from 26.76°C to 33.09°C, EER_{sist} is reduced by 10.13% from 4.34 to 3.90.

CONCLUSIONS

Depending on the solution adopted, ventilation / air conditioning systems are made up of different components, such as chiller (CH), air conditioning (CTA), cooling tower, fan coil (VCV).

The performance of a chiller may vary significantly depending on the system's partial loads and the evaporator and condenser operating temperatures. Chillers with staggered partial loads operate at maximum load only a few days per year / season, taking into account the seasonal or annual performance coefficient (COP_{sez} (an))

For air-cooled chillers, the performance coefficient increases as the outside air temperature (te) decreases and the temperature of the cooled water (twr) increases at the evaporator outlet.

The seasonal energy efficiency of the chilled water chiller equal to 19.9 is 28% higher than that of the air cooled chiller with a piston compressor equal to 14.3 and 35% Air cooled chiller efficiency with screw compressor equal to 12.9.

Cooling chillers only with air or only with water make the condensation heat transfer from the refrigerant only through the sensible heat of the coolant, leading to significant air or water flows. One solution to alleviate this inconvenience is the mixed air / air cooling of the capacitors.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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MODIFICATION OF CEMENT STABILIZED STRUCTURAL LATERITIC PULVERIZED SNAIL SHELL

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Abstract: This study investigated the suitability of pulverized snail shell (PSS) as partial replacement of cement stabilized soil in foundation constructions. Preliminary and engineering tests were carried out on the soil samples. The optimum cement content fixed at 11% in correlation to Unified Soil Classification System, the PSS was introduced at varying percentages of 2%, 4%, 6%, 8% and 10%. Results revealed that, addition of PSS and 11% cement to lateritic soil caused a reduction in both liquid limits and plasticity index and an increased in plastic limits for all samples. Engineering tests showed the maximum dry density at optimum cement increased from 1493.34 kg/m^3 to 1632 kg/m^3 for sample A; 1476.77 kg/m^3 to 1668 kg/m^3 for sample B; 1460.77 kg/m^3 to 1651kg/m^3 for sample C. The CBR recorded highest value at 4%PSS optimum cement for all samples. The addition of pulverized snail shell increased the strength of cement stabilized lateritic soil for structural foundation construction.

Keywords: pulverized snail shell, cement stabilization, lateritic soil, structural foundation works

INTRODUCTION

The problems with foundation on soils have included cracking, heaving and break up of pavements, building foundation, slab members, etc. as a result of these problems associated with poor soils, various methods are being developed worldwide to treat these soils is known as soil stabilization. Weak soils usually are attributed to excess ingression of groundwater, high shrinkage and swelling potential, high liquid limit and plasticity index and lack of strength. All these defects are usually associated to deformable properties of the soil. [1], observed that, treatment of weak soils can be done by preventing ingress of ground water flow or removing it from the site in question, or improving soil strength through a mechanical medium or chemical medium on the other hands. [2], similarly states that, if such soil cannot be removed, then its engineering behavior properties can be enhanced by suitable method of ground treatment. [3], states that soils with low strength are highly deformable, lack of strength leads to soil failure if overloaded. However, this has been frequent in occurrence in civil engineering construction work due to some act of negligence being put up by some engineer when such problems are being encountered.

The various methods used to alter or improve soil properties such as their strength, settlement and bearing capacity are generally called soil stabilization techniques, which objectives are to improve on the volume stability, strength and stress-strain properties, permeability and durability. The concept of soil improvement or modification through stabilization with the use of additives has been around for several thousands of years.

Although this process of improving the engineering properties of soils has been practiced for centuries, soil stabilization did not gain significance until after World War II [4]. As far back as 5000 years ago, soils were already been stabilized with lime and other relevant available pozzolans. It has been proven that the benefits of using pozzolans materials in soil stabilization are both economic and technical. Several studies have been made on soil stabilization using different stabilizing agents. [5], showed the effectiveness of addition of calcium chloride to soil treatment. [6], used calcium oxide as a stabilization technique clay soils in order to inhibit its expansion contraction properties. [7], used coal combustion by-products in roller compacted concrete, roadway and parking lots. [8] and [9], investigated the effect of fly ash and pozzolanic material on soil improvement. The use of pulverized snail shell as a soil stabilizer is not a common practice worldwide but research findings have shown the immense benefit and potential of using snail shell powder as pozzolans in soil.

However much research have not been done on the performance of pulverized snail shell on cement stabilized soil. Snail shell gotten from the consumption of fleshy edible part of snail is a waste product that can lead to land population if not effectively managed. The shell comes in form of V-shaped spiral shell found in many coastal regions, especially here in Nigeria. The shells are a strong, hard and brittle material. The shells constitute waste and its disposal is posing problems in areas where they have no use for it [10]. It is in this light that this experimental study seeks to investigate into the suitability of pulverized snail shell as a complement for cement in soil stabilization by way of considering the effects of pulverized snail shell on cement-stabilized lateritic soil.

LATERITIC SOILS

Lateritic soils, one of the least fertile soil types, are found in wetter and hotter climates [11]. Lateritic soils may contain clay minerals but they tend to be silica-poor, for silica is leached out by waters passing through the soil.

Typical laterite is porous and claylike. It contains the iron oxide minerals goethite $HFeO_2$, lepidocrocite FeO(OH), and hematite, Fe_2O_3. It also contains titanium oxides and hydrated oxides of aluminum, the most common and abundant of which is gibbsite, $Al_2O_3 \cdot 3H_2O$. The aluminum-rich representative of laterite is bauxite. Laterite is frequently pisolitic (pealike). Exposed surfaces are blackish-brown to reddish and commonly have a slaggy, or scoriaceous, lavalike appearance. Commonly lighter in colour (red,

yellow, and brown) where freshly broken, it is generally soft when freshly quarried but hardens on exposure.

Laterite is not uniquely identified with any particular parent rock, geologic age, single method of formation, climate per se, or geographic location. It is a rock product that is a response to a set of physiochemical conditions, which include an iron-containing parent rock, a well-drained terrain, and abundant moisture for hydrolysis during weathering, relatively high oxidation potential, and persistence of these conditions over thousands of years. Laterite is a very widespread soil group. Lateritic soils occurs in all wet tropical regions, e.g. East, West and Central Africa, Indonesia, Thailand, Brazil and various island such as Hawaii and Cuba Lateritic soils are residual soils formed in hot, wet tropical regions with an annual rainfall between 750mm and 3000mm or more. The main soil forming process consists of intensive weathering with leaching of bases and silica resulting in a relative accumulation of iron and aluminium oxides and formation of kaolinitic clays. Intensive weathering producing deep Laterite profile occurs on flat slopes in the terrain where runoff is limited.

Laterite mainly occurs as:

- Surface deposits of unhardened, clayey soils
- Massive rock- like hardpans
- Gravel consisting of concretionary nodules in a soil matrix.

SOIL IMPROVEMENT

In foundation engineering practice the soils at a given site are often less than ideal for the intended purpose. They may be weak, highly compressible, or have a higher permeability than desirable from an engineering or economic point of view. It would seem reasonable in such instances to simply relocate the structure or facility. However, considerations other than geotechnical often govern the location of a structure, and the engineer is forced to design for the site at hand.

One possibility is to adapt the foundation to the geotechnical conditions at hand or otherwise to try to stabilize or improve the engineering properties of the soils at the site. Depending on the circumstances, this second approach may be the most economical solution to the problem. Stabilization is the process of blending and mixing materials with a soil to improve the pertinent properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, change certain properties, or act as a binder for cementation of the soil. Stabilization is usually mechanical or chemical, thermal and electrical stabilization have occasionally been used or considered.

Mechanical stabilization or densification is also called compaction. Chemical stabilization includes the mixing or injecting of chemical substances into the soil. Portland cement, lime, asphalt, calcium chloride, sodium chloride and paper mill waste are common chemical stabilization agents.

Other methods of stabilizing unsuitable foundation soils includes dewatering which is the removal or reduction of unwanted excess ground water pressure, and preloading, in which the foundation soil are surcharged with a temporary overload so as increase the strength and decrease anticipated settlement [12].

POZZOLANIC REACTION

Pozzolans are siliceous or siliceous and aluminous materials which in themselves do not possess any cementitious value but in finely divided form and in the presence of moisture will chemically react with calcium hydroxide (CH) to form a compound with cementitious value according to this general equation:

$$Ca(OH)_2 + H_4SiO_4 \longrightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\,H_2O \longrightarrow CaH_2SiO_4 \cdot 2H_2O \quad [1]$$

Which can be summarized in abbreviated notation of cement chemists;

$$\text{Pozzolans} + CH \longrightarrow C\text{-}S\text{-}H \quad [2]$$

Calcium silicate hydrates (C-S-H) is the strength-forming products of cement hydration. Pozzolans can be classified as artificial if firing (or calcination) is required to induce pozzo-lanicity and natural if no calcination is required. The product of general formula ($CaH_2SiO_4 \cdot 2H_2O$) formed is a calcium silicate hydrate, also abbreviated as CSH in cement chemist notation. The ratio Ca/Si, or C/S, and the number of water molecules can vary and the above mentioned stoichiometry may differ.

As the density of CSH is lower than that of portlandite and pure silica, a consequence of this reaction is a swelling of the reaction products. This reaction may also occur with time in concrete between alkaline cement pore water and poorly-crystalline silica aggregates. This delayed process is also known as alkali silica reaction, or alkali-aggregate reaction, and may seriously damage concrete structures because the resulting volumetric expansion is also responsible for spalling and decrease of the concrete strength. The pozzolanic reaction may be slower than the rest of the reactions that occur during cement hydration, and thus the short-term strength of concrete made with pozzolans may not be as high as concrete made with purely cementitious materials; conversely, highly reactive pozzolans, such as silica fume and high reactivity metakaolin can produce "high early strength" concrete that increase the rate at which concrete gains strength.

MATERIALS AND METHODS

The materials used include lateritic soil samples, Ordinary Portland cement, pulverized snail shell and water. The lateritic soil samples were collected from burrow pits within Obafemi Awolowo University along Road 7, Ile-Ife in Osun State Nigeria. These were designated as samples A, B, and C. The soil samples pre-treatment was ensured before the commencement of the study.

For easy identification of the soil samples, tags were placed on them to describe their dates of excavation, depths of excavation from the source and locations. The soil samples were spread on sacks in the laboratory to air-dry them for a minimum of two weeks, preventing water contamination and direct sunlight contact and local drying was prevented by frequently turning of the sacks of soil samples. This was later sieved with sieve No. 4 (4.76 mm opening) to obtain the final soil sample.

The required quantity of Ordinary Portland cement manufactured by West African Portland Cement Plc (WAPCO) Ota, Ogun State was obtained locally, and kept in a safe platform to prevent any contact with moisture and any other external affection of its property.

Portable water was obtained from treated water available in the laboratory.

The pulverized snail shell were obtained from snail shells (Figure 1) collected from different locations in Ibadan area. The fleshy parts were removed from the shell, the shells were thoroughly washed, air-dried for one week and calcined in an electric muffle furnace at 850° C. It was then grounded into fine powder particles form with the aid of grinding machine. The ash obtained was later sieved through 75µm and kept in a sack bag to prevent it from moisture and any other external influences that can affect its property to meet the requirements of [13] and [14].

Preliminary tests such as the natural moisture content, specific gravity, particle size analysis and Atterberg's limits were carried out on three unstabilized soil samples to determine their index properties. The major stabilizing material, cement was thoroughly mixed with the soil samples at a fixed percentage of 11% with respect to the soil classification and varying percentages of (2, 4, 6, 8 & 10%) of the pulverized snail shell by weight of the soil samples. This was done in conjunction with the liquid limit and the determined plasticity index (PI) from Atterberg's limit test. The point of lowest PI gives the optimum amount of cement required. Hence, engineering properties of cement stabilized soil was determined. These engineering properties are used as the control against which the engineering properties of cement stabilized lateritic soil modified with pulverized snail shell are compared. The main objective of the study is to determine the change in the engineering properties of the stabilized soil sample modified with pulverized snail shell.

Engineering tests such as compaction, California bearing ratio (CBR) and undrained traixial were also performed on soil samples at their natural states, when stabilized with optimum cement and when pulverized snail shell (PSS) was introduced as pozollan to the samples. The various tests were carried out with standard procedures stipulated in [15].

Figure 1: Snail Shells

RESULTS AND DISCUSSION

The results from the preliminary tests (grain size analysis, natural moisture contents, specific gravity, and Atterberg's limits test) as well as the engineering test (compaction test, California Bearing Ratio test and triaxial test) are presented and discussed below:

PRELIMINARY TEST

The summary of the preliminary test results for soil samples A, B, C are shown in Table 1. The natural moisture content of the selected soil samples A, B and C are 7.06%, 7.87% and 7.68% respectively. The result showed that sample B has the highest natural moisture content and sample A the lowest. [16] stated that the moisture content of a soil depends largely on void ratio, thus the results could be attributed largely to the void and the specific gravity. Sample A probably has a largest void ratio compared to the others. These also show that the soil samples still contain some appreciable amount of moisture, which is largely affected by the climatic condition.

The specific gravity of samples A, B and C are 2.684, 2.500 and 2.273 respectively. These values ranges within what [3] stated, that for most clay minerals, there specific gravity fall within a general range (1.6-3.2), a Halloysite (1.60-2.55) and Biotite (2.8-3.2) which indicated that the soils are Halloysites. AASHTO soil classification system was used

in the classification of the soil samples, the particle size analysis showed values of 67.4%, 51.2% and 61.2% passing the No. 200 sieves for Samples A, B and C respectively. [17], classified soil into seven major groups A-1 to A-7, soil classified under groups A-I, A-2, A-3 are granular materials while soil classified under groups A-4, A-5, A-6 and A-7 is mostly silt and clay-type materials. Soil samples A, B and C classified as A-5 to A-7 according to the AASHTO table for classification [18], and the subgrade rating is rated as fair to poor and therefore will require stabilization as established by [19].

Table 1: Summary of preliminary test for soil samples

Sample	Natural Moisture Content (%)	Specific Gravity	Percent retained (%)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plastic Index (PI) (%)
A	7.06	2.68	67.40	73.88	27.27	46.61
B	7.87	2.50	51.20	65.95	33.72	32.23
C	7.68	2.27	61.20	60.40	30.83	29.57

CEMENT STABILIZATION

The liquid limits, plastic and plasticity index are 73.88, 27.27 and 46.61% respectively for sample A, 65.95, 33.72 and 32.23% for sample B and 60.40, 30.83 and 29.57% for sample C without any additive. [20] stated that liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate or medium plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity. On this note, the three samples have high plasticity.

There were overall improvement in the plasticity of the samples as the variation in results of the Atterberg's limits tests for the soil samples on addition of the optimum cement dosage of 11% based on the Unified Soil Classification System showed significant reduction in both liquid limits and plasticity index and increase in plastic limits for all the soil samples as shown in Figures 1 to 3.

As shown in Figures 1 to 3, for samples A, B and C respectively, further improvement were observed in both samples as there were further reduction in both the plastic limit and plasticity index on addition of 11% cement and 6% pulverized snail shell (PSS).

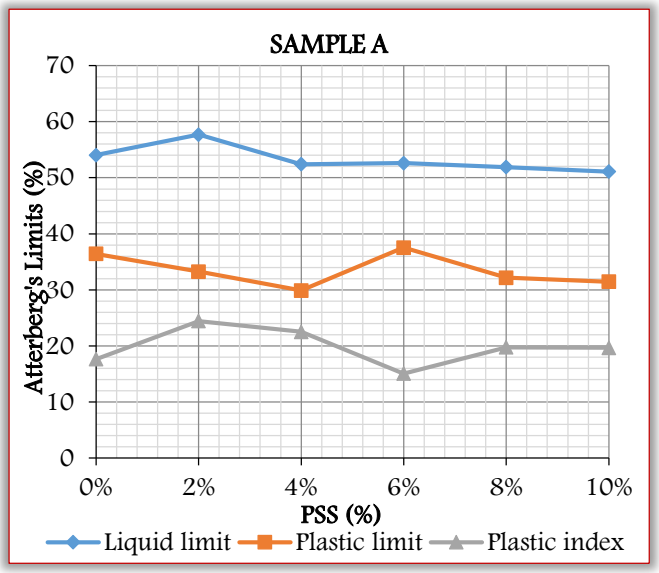

Figure 1. Variation of Atterberg limits with varying SSP at fixed 11% cement for Sample A

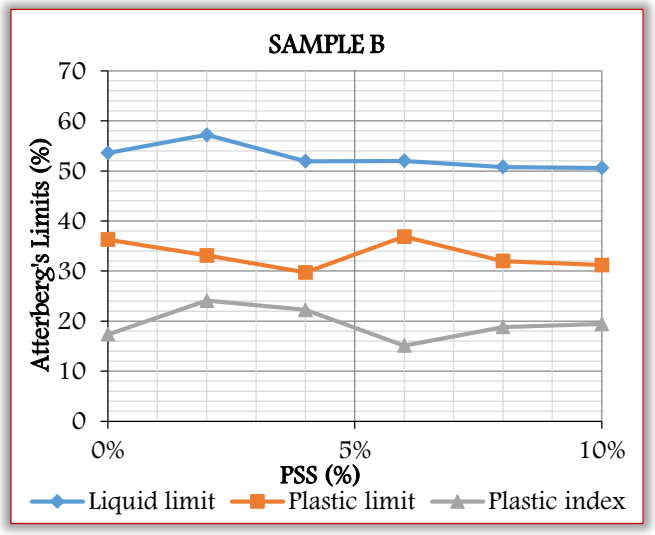

Figure 2. Variation of Atterberg limits with varying SSP at fixed 11% cement for Sample B

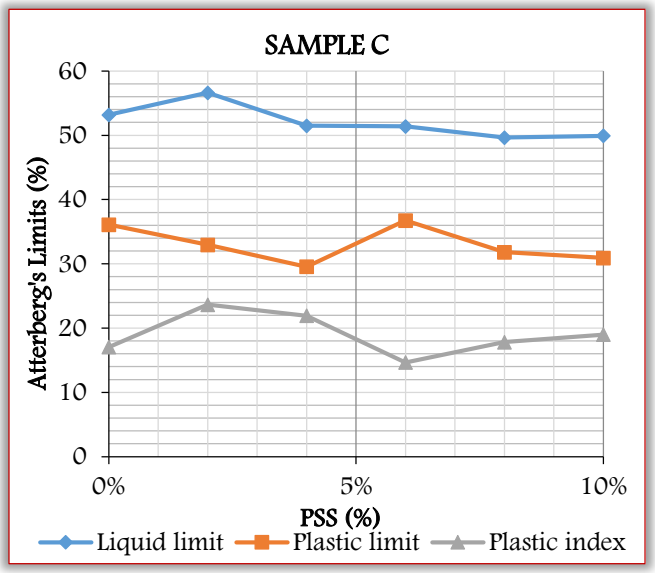

Figure 3. Variation of Atterberg limits with varying SSP at fixed 11% cement for Sample C

The reduction in plasticity index exhibited by all the three samples show the effect of addition of 11% cement and 6% PSS for all the soil samples. [21] explained that cement can be used to stabilize sandy and clayey soils. As in the case of lime, cement helps decrease the liquid limit and increase the plasticity index and workability of clayey soils. Which is effective for clayey soils when the liquid limit is less than 45 to 50 and the index is less than about 25.

ENGINEERING STRENGTH TESTS

The compaction test was carried out to determine the optimum moisture content (OMC) and the maximum dry density (MDD) of the three soil sample at the natural state, when stabilized with optimum cement dosages and the addition of the pulverized snail shell (PSS).

The natural soil samples have OMC of 24.07, 24.5, 25.67% and MDD of 1493.34, 1476.77, 1460.77kg/m^3 for sample A, B and C respectively. Stabilization with 11% cement reduced the OMC to 22.33% and increased the MDD to 1632kg/m^3 for sample A, reduced the OMC to 22.5% and increased the MDD to 1668kg/m^3 for sample B, reduced the OMC to 21.27% and increased the MDD to 1651kg/m^3 for sample C. The increase in the MDD can be attributed to the replacement of the soil by the cement particles which have lower specific gravity compared to that of the soil. It may also be attributed to coating of the soil by the powdery cement which result to large particles with larger voids and hence less density [22]. [16] stated that, for good soil, the lower the OMC, the better its workability and an increase in dry density is an indicator of soil improvement. The decrease in OMC with addition of cement can be attributed to increasing demand for water by various cations and the clay mineral particles to undergo hydration reaction.

Table 2: Summary of Compaction test on cement stabilized samples and varying pulverized snail shell (PSS)

Samples	Percentage Stabilization	Optimum Moisture Content (%)	Maximum Dry Density (kg/m^3)
A	0% PSS	22.33	1632
	2% PSS	25.04	1621
	4% PSS	26.70	1627
	6% PSS	25.04	1650
	8% PSS	25.75	1611
	10% PSS	30.52	1541
B	0% PSS	22.50	1668
	2% PSS	25.01	1655
	4% PSS	25.68	1612
	6% PSS	25.03	1634
	8% PSS	24.52	1638
	10% PSS	31.49	1525
C	0% PSS	21.27	1651
	2% PSS	26.99	1642
	4% PSS	25.66	1595
	6% PSS	26.01	1611
	8% PSS	23.51	1621
	10% PSS	32.50	1510

The addition of PSS at (2, 4, 6, 8, and 10%) and 11% optimum cement to the soil samples caused a decrease in the MDD and an increase in OMC of all the soil samples. The increase in the OMC confirmed the pozzolanic behavior of PSS with an increasing demand for water to react and form aggregate molecules in the soil.

Table 2 showed the result of MDD and OMC of the variation in mix percentage of PSS at optimum cement dosage.

The unsoaked CBR values for the natural and cement-stabilized soil samples are shown in Figure 4. The CBR test were conducted at OMC of the soil, soil-cement or soil cement-PSS as determined from the compaction test. The CBR tests were performed immediately after compaction. The unsoaked CBR values for the natural soil were found to be 3% for samples A and C and 2% for sample B. Stabilization with 11% cement increased the CBR value of sample A to 12%, sample B to 13% and 11% for sample C. Results of the unsoaked CBR fluctuated with the addition of PSS at (2, 4, 6, 8 and 10%) and when 11% optimum cement were introduced to the three soil samples where 4% PSS and 11% cement showed the highest CBR value for all the samples.

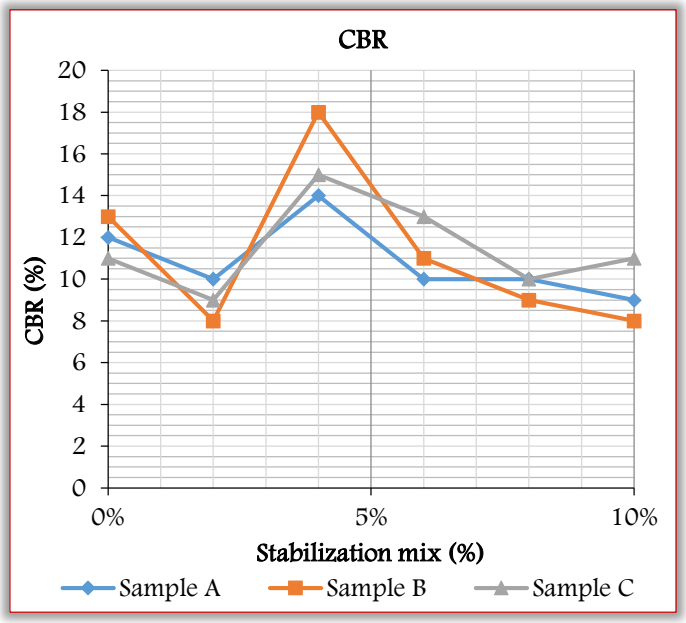

Figure 4. Variation of California bearing ratio with increasing PSS at 11% cement

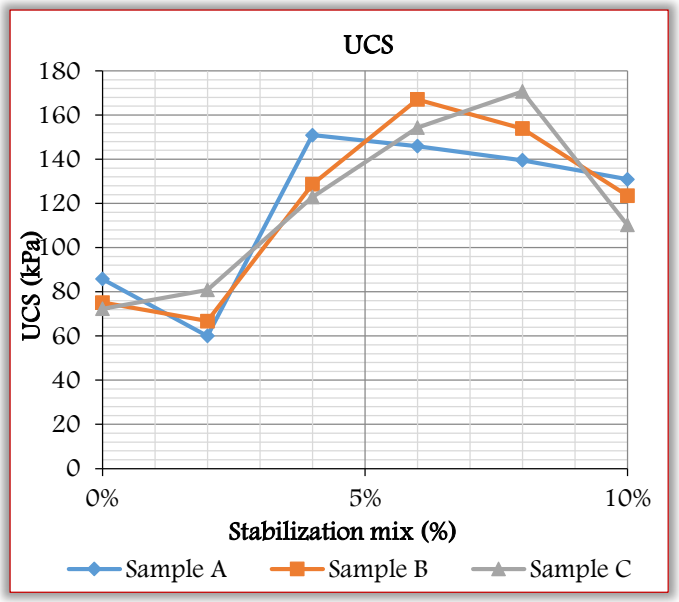

Figure 5. Variation of unconfined compressive strength with increasing PSS at 11% cement

Figure 5 shows the variation of the shear strength with increasing PSS contents. The shear strength values are 56.48kPa, 51.45kPa and 48.05kPa, at natural state and 85.81kPa, 75.17kPa and 72.31kPa when stabilized at optimum cement of 11% for samples A, B, and C respectively. The addition of 2% PSS decreased the shear strength to 59.98kPa for sample A, 66.72kPa for sample B and increase to 80.89kPa for sample C. For sample A, the addition of 4% PSS, increased the shear strength but later decreased on addition of 6, 8 and 10% PSS. For sample B, the addition of PSS at 4% and 6% PSS increased the shear strength but decreased on addition of 8 and 10% PSS. For sample C, the addition of PSS at 4, 6 and 8% increased the shear strength values but later decreased on the addition of 10%.

CONCLUSION

The cement stabilized with pulverized snail shell to subsoil showed significant improvement in the properties of the soil generally. The addition of 11% optimum cement reduced the liquid limit of soil samples A, B and C and a further reductions were noticed when PSS at 4%, 6%, 8% and 10% were added for all samples. Stabilization with 11% cement reduced the optimum moisture content and increased the maximum dry density of soil samples, for most soils, the lower the OMC, the better its workability and an increase in dry density is an indicator of soil improvement.

The unsoaked CBR values for the cement stabilized soil samples increased with the addition of optimum percentage of 11%. The CBR values for the cement-stabilized soil samples A and B further increased with addition 4% PSS, for sample C, the increase was at both 4% and 6% PSS. There were substantial increase in shear strengths for the cement stabilized soil samples and addition of PSS on the cement stabilized soil samples at all percentages, the highest shear strengths being observed at 4%, 6% and 8% PSS for all soil samples. The optimum stabilization value ranges between 4% to 8% pulverized snail shells for cement stabilized samples. In summary, this study has shown through literature review and experimental work that pulverized snail shell is a good complement for cement stabilization in lateritic soils.

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ISSN: 2067-3809

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SUSTAINABLE RESOURCE OF RAW MATERIALS: FROM TECHNICAL TEXTILES TO TEXTILE-REINFORCED COMPOSITES

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Abstract: Increasing market demand for end products made of lightweight composites ranging from automotive parts, aircraft structures, pressure vessels, wind turbine blades and sport products, leads to a fast-growing composite materials market. Technical textiles are fabrics and textiles designed / designed and made primarily for their technical and performance properties, rather than for aesthetic and decorative features. Textiles or composites based on technical textiles are intended to replace many of the current metal or plastic materials used in the leading or consumer industries. Therefore, the latest trends in composites expect the advanced and innovative industries to use new reinforced composites to replace parts currently made with other materials or other types of composites.
Keywords: composite materials, trends, composite textiles, new reinforcement materials

INTRODUCTORY NOTES

Composite materials are made from two or more constituents with diverse physical and chemical properties, which when clubbed together produces a material with characteristics different from their individual materials. Basically, composite materials are engineered to create a new structured material that is chemically and physically different from its individual components, which are mixed together to enhance the properties of composite and to make them suitable for the various applications in the end user industries.

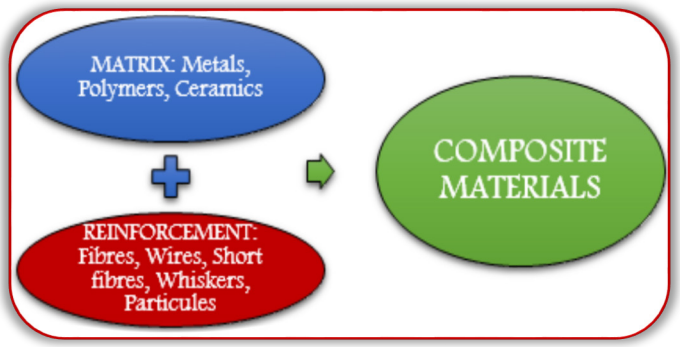

Figure 1. The composite materials

The composite materials keep their separate identity (at least at the macroscopic level), however, their combination generates different properties and characteristics from those of the component materials.

One of the materials is called matrix and it is defined as forming the continuous phase. The other main element is called reinforcing material (reinforcement) and it is added to the matrix in order to improve or modify its properties. The reinforcement is the discontinuous phase, evenly distributed throughout the matrix volume, and is the elements that give the assembly the characteristics of resistance to stress.

The matrix ensures that the fibers break before the matrix breaks down. As a liquid state, the matrix must have the ability to wet the fibers to ensure a good adhesion. If the choice of the matrix is largely guided by the working temperature, then the choice of the stinging fiber is made for other considerations. Reinforcement fibers have to bear without degrading all the stages of composite manufacturing. The surface of the fibers is also degraded by chemical reactions with the matrix. In polymeric and metallic matrices, the synergy of properties results from the proper bond between the reinforcement and the matrix. However, it should be emphasized that composite material is a unitary assembly, in which the two phases act together.

Unlike metals and polymers, which are normally treated as isotropic materials, composites generally exhibit anisotropic properties, which are determined by the type and format of the used reinforcement. Also, the matrix material and the processing method are further variables which can be tailored to provide the desired properties. Because composites can be tailored in so many ways to the various requirements of a particular engineering component, the key to optimizing cost and performance is a fully integrated design process capable of balancing all of the relevant design and manufacturing variables (matrix and reinforcement's properties, manufacturing processes, analysis of the properties and behaviour of the resulting structure).

THE MAIN TRENDS

Composites have growth opportunities in the forecast years. In the future, the composites industry will continue growing into more applications and markets. Environmentally friendly composites will incorporate recycled plastic and bio-based polymers to feed the growing demand for stronger, lighter, and more environmentally friendly materials.

The rises of composites have already transformed most of the world's industries and will continue to grow in the years to come. The researches in this area of composite materials will focus on:

- making advanced composites less expensive and energy-intensive to manufacture.
- making composites easier to recycle, and
- develop new fibers and resins to open up even more applications for composite materials.

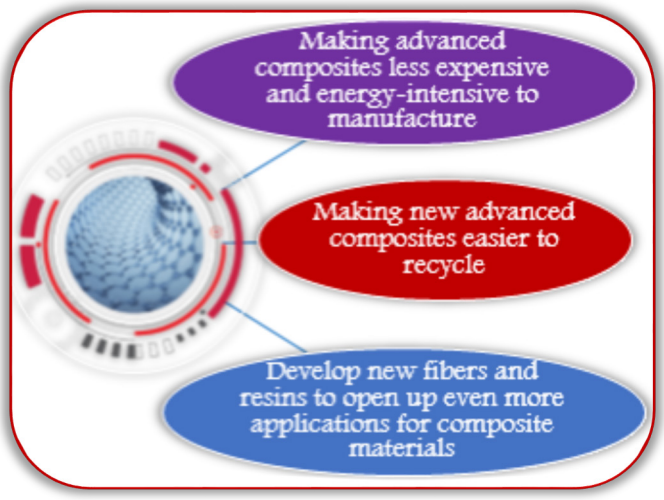

Figure 2. Main researches in area of composite materials

Increasing market demand for end products made of lightweight composites ranging from automotive parts, aircraft structures, pressure vessels, wind turbine blades and sport products, leads to a fast-growing composite materials market, where the main trends are:

- Trends in product and process innovations. Over the past few years there have been a significant developments and innovations in the composites industry across various industries, the composites playing a crucial role in all innovative industries.
- Trends in new fibers and new reinforcements. Companies are continuously investing in innovating and developing high strength natural fibers to improve both mechanical and chemical requirements. Additionally, the recent trends are on developing green materials and natural fibers.
- Trends in resins and matrix components. Companies are launching new resin types that focus on shorter cure time for mass volume applications, in an ecological way.
- Trends in new applications of advanced composites. Companies are launching new hybrid structures, penetrating continuously the areas of automotive, aerospace, construction, energy and various other advanced industries.

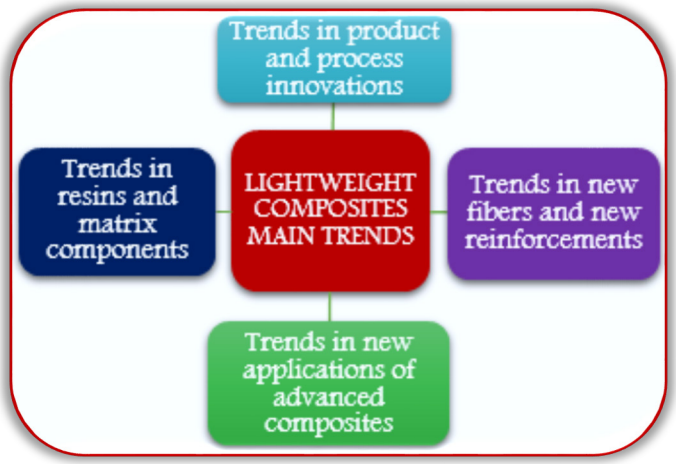

Figure 3. Main trends in area of composite materials

Therefore, the latest trends in composites expect the advanced and innovative industries to use new reinforced composites to replace parts currently made with other materials or other types of composites. The transport industry has for some time been engaged in the application of new lightweight materials for structural design, with advanced lightweight composites replacing traditional metal materials more and more in both structural and non-structural parts. The rail industry could also benefit from the use of structural new materials. It is a fact that the increased focus on green technology will result in advanced composites made to increase penetration in manufacturing. Resins, together with natural fibers, can create lightweight components for interior/exterior structural components in many sectors. Moreover, in the future, green technology's inspired materials may replace even the traditional composites and come to dominate the industry.

Having in view the previous presented trends, and trying to summarizing, the top business objectives, common to all composites manufacturers, are:

- exploring new materials and new composite solutions (new reinforcements and new matrix components),
- exploring new manufacturing processes (new technologies, new methods, innovated manufacturing, including the automating manufacturing processes),
- improving process and quality control, exploring the lightweight characteristics and cost reduction factor of composites
- reduce material expiration and waste, and
- increase the ecological sustainability and increase focus on green technology.

Figure 4. Top business objectives

In response to the growing market demand, and in search of a competitive advantage, leading composite manufacturing companies significantly invest in new technology, research of new materials and innovative manufacturing processes to increase throughput and profitability while improving process and quality

control. Such key business objectives indicate that companies dealing with composites invest in the areas of new materials research, process innovation and increased focus on green technology. Also, they look for ways to increase the composite production throughput while investing in improvement of process and quality control.

Having the background of the need for a sustainable resource of raw materials as well as environmental problems caused by plastics and metallic materials, which are hardly degradable, the leading industries are always looking for new materials, especially those with low impact on the environment, which after end–of–life cycle are easy to recycle.

The applicability of technical textiles in engineering has experienced an exponential growth over the last decades, although in the technical fields requiring mechanical stress is still limited. However, textile materials have particular advantages in terms of formability and dynamic impact properties, and thus composite materials with textile reinforcement are one of the main areas of application of technical textiles.

Figure 5. Technical textiles in engineering

Technical textiles are fabrics and textiles designed / designed and made primarily for their technical and performance properties, rather than for aesthetic and decorative features. Textiles or composites based on technical textiles are intended to replace many of the current metal or plastic materials used in the leading or consumer industries.

TEXTILE EMBEDDING METHODS

Many high performance composites exist, yet most notable are variations of fiber-reinforced polymers, carbon-fiber-reinforced polymers and glass-reinforced polymers are leaders in the ever advancing materials engineering sectors. Basically, fiber-reinforced polymers are made from a polymer base such as epoxy or polyester infused with a fiber matrix of glass, carbon, aramids or other fibers.

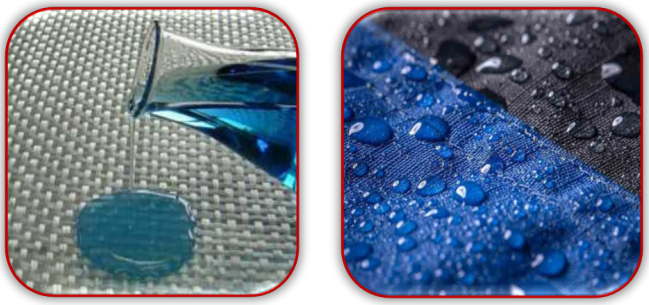

Figure 6. Fiber-reinforced polymers – the principle

Natural fiber reinforced polymers have been identified as a potential low impact alternative to glass-, carbon- or aramids-reinforced polymers. Although the replacement of glass, carbon or aramids fibers with natural fibers for reinforcement in polymer composites appears to be a modern phenomenon, natural fiber reinforced polymers are not strictly modern by invention.

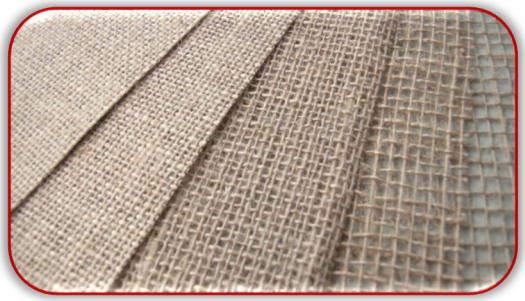

Figure 7. Natural fiber fabrics for reinforcements

The major advantage of composites is the ability to modulate properties and thus obtaining a wide range of materials, the usage of which can be extended to almost all areas of technical activity. Composite materials are the first materials whose internal structural design is conceived by man, not only in their molecular chaining, but by giving them favorable resistances in preferential directions.

The initial purpose of composites was to increase the competitiveness of classical materials, whose strength and stiffness properties could no longer be improved by other means. From this point of view, it is understood that the maximum efficiency of the reinforcement of a certain material is obtained by introducing, in its structure, fiber reinforcing elements.

Within the field of composite materials, we find a wide range of processing techniques based on the use of reinforcing materials mainly focused on textile structures and matrices of polymeric materials. The most common processes are hand layup, oven and autoclave curing, resin transfer moulding, vacuum infusion, compression molding and pre-pregging.

Composite textiles with reinforcement materials comprise a wide range of reinforcement material in the form of textile preforms which may be constituted by non–woven, woven or knitted materials. In order to select the optimal technology for preparing textile preforms, it is necessary to consider both the strengths and weaknesses of each technology. Different methods are used to obtain composite structures:

- embedding reinforcement material (woven or knitted material) into a matrix, which may be either a macromolecular substance or a colloidal solution or suspension with coagulation properties;
- consolidation of the base material by means of curing layers, resulting in a laminate.

The textiles are prepared separately and are incorporated into the matrix by one of the following methods:

- simple lay-up process. It is the case of synthetic resin matrices applied in alternating layers of textile layers. The method is used on an industrial scale for the manufacture of fiber composites.
- infiltration of the resin between the layers. The fibers are aligned in a shape corresponding to the part and infiltrate (under vacuum or under inert gas pressure) the matrix material in liquid state.

The very diverse manufacturing technologies of these materials involve specific processes for:

— obtaining the polymer matrix,
— preparing the reinforcement components,
— impregnating or treating the fibers,
— making the reinforcement (in the form of knit, fabric, and braiding),
— making the composite itself and so on.

Imposing these composite materials in the cutting–edge areas of the technique is also due to their technological features: easy machinability, with the possibility of obtaining finite pieces in a single operation or by not very difficult operations, operations in many cases possible mechanized and automated, which determines the location of costs at relatively low, competitive levels. These advantages are an important economic parameter that reduces the direct cost of making parts, structural elements, or building elements.

On the other part, large textile type material lost in landfilling or incinerations are unavoidable in the currently wasteful, linear system which creates negative impacts on the environment. It is important to find innovative solutions to valorize this waste to ensure that it does not add to the already significant environmental impact created by textiles. Therefore, in the field of textile waste, we can mention, according to technical, economic, social, ecological criteria, the following directions of action:

— establishing modalities for waste disposal at the end of life–cycle losing production cycles, using and recycling waste;
— designing and launching new products by improving the quality of materials to extend the life of products made from these materials;
— identification of the various internal and external organizations necessary for practice recovery

CONCLUSIONS

By processing on classic traditional and nonconventional technologies, the potential uses of recovered technical fibers and/or fabrics can be:

— phono– and thermo–insulating materials / building materials (which are used in the textile branch by the production of non–woven textiles, upholstery wadding for furniture and cars, insulating materials, geotextiles, and representing about 60% of the recovered waste: yarn waste knitted fabrics, knitted fabrics, knitted fabrics, knitted fabrics and strips);
— textile composites (which are used in the automotive, naval, construction, military technique, and so on) industries;

The use of composites will play an increasingly vital role through the manufacture of structures which enable the harnessing of sustainable energy sources. Factors such as the reduced weight compared to metallic structures, lower transportation and erection costs, and most importantly, lower maintenance costs are already positioning composites as a de facto material enabling economical solutions to large scale projects.

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ISSN: 2067-3809

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CORROSION BEHAVIOUR OF Ti-V-Cr-Rh ALLOY ELECTRODE IN 6M KOH

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Abstract: Corrosion behaviour of $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x= 0, 0.5, 1 at %) alloy electrode in 6M KOH was investigated. The V-rich alloy was produced under argon atmosphere in an open hearth crucible furnace. The microstructure of the arc-melted alloy was examined by scanning electron microscopy, and the phases were identified by X-ray diffraction. The as-cast alloys contained a primary (V) body centered cubic phase and an intergranular αTi phase. Rhodium (Rh) decreased the E_{corr} from -767 mV to -793 mV for 0.05 Rh and -825 mV for 0.10 Rh. The corrosion current also decreased from 1 μA/cm^2 in Rh-free alloy to 0.77 μA/cm^2 with addition of 0.05 at % Rh and 0.37 μA/cm^2 with addition of 0.10 at.% Rh. Addition of 0.05 at. % Rh decreased the corrosion rate from 0.0110 to 0.0009 mm/y and to 0.001 mm/y with addition of 0.10 at.% Rh. Hardness of the alloy electrode decreased with addition of rhodium.
Keywords: Corrosion Behaviour, V-rich Alloy, 6M KOH, αTi Phase, Body Centre Cubic Phase

INTRODUCTION

Palladium Group Metals, PGM are known for inhibiting corrosion. Schutz (1996) found that corrosion challenges of titanium (Ti)-based alloys in aggressive environments can be practically and cost effectively overcome by minor additions of platinum group metals such as palladium (Pd) and ruthenium (Ru) at < 0.25 at.%. Also, the corrosion rate of titanium metal surfaces exposed to strong acid media was highly inhibited by coating the surface with rodium (Rh) (Lal *et al*., 1982); addition of 0.04 - 0.08 wt% Pd to Ti-3Al-2.5V, Ti-6Al-4V, Ti-3Al-5V-6Cr-4Zr-4Mo alloys greatly improved the corrosion resistance in dilute sulphuric acid (Schutz, 1996)). Ruthenium additions to Ti-3Al-2.5V, Ti-6Al-4V, Ti-3Al-5V-6Cr-4Zr-4Mo alloys effectively inhibited titanium crevice corrosion in hot halite and sulphate environments (Schtz & Speller, 2003). Corrosion rate of CP-Ti was considerably lowered in 6, 9 and 11.5M HNO_3, and boiling 15.65M HNO_3 when alloyed with Ni, Pd, Ru and Cr (Ningshen et al., 2015). Binary alloys formed by addition of 10 wt% Ag, Au, Pd, or Pt to Ti has higher corrosion current density (Hwang, *et al*., 2015). Yamamoto and Kanda (1997) investigated the corrosion behaviour of AB_5 type hydrogen storage alloy in alkaline solution and found that, the effect of heat treatment on corrosion resistance is not significant. This study intends to investigate the corrosion behaviour of rhodium on Ti-V-Cr alloy in 6M KOH solution.

MATERIALS AND METHODS

Melting and casting of the alloy was done in a water-cooled, copper-crucible arc melting furnace under argon atmosphere. In order to ensure homogeneity, the ingot was turned over and remelted three times. The as-cast specimens were cut, mounted, ground and polished to a finish of 0.15 μm using colloidal silica.

Phase identification was done using optical microscopy and scanning electron microscopy (SEM) with energy dispersive X-ray Spectroscopy (EDX) using an Oxford system. Phases of the alloy were determined by XRD analysis, using the Xpert High Score® phase identification software on a Bruker D2_Phaser® X-ray diffraction machine. Analysis was done with Cu-Kα radiation from $2\theta = 10°$ to 90°. Further analysis of the alloy was done using a FEI Nova NanoSEM 200® scanning electron microscope (SEM) fitted with EDAX® advanced microanalysis solution. The approximate amount of the phases was determined by image analysis using ImageJ freeware.

Vickers microhardness tests with a 2 kg load were done on a FutureTech FT FM700® machine. The hardness values were measured five times and the average value was recorded.

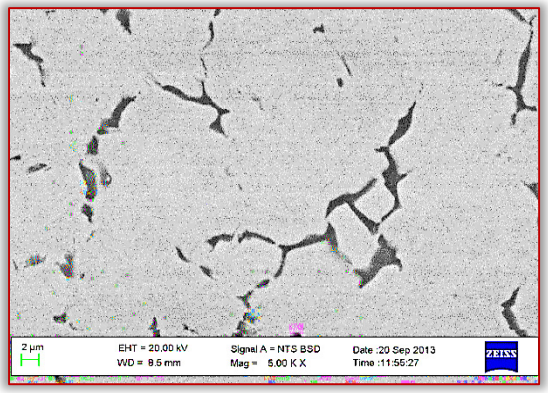
A Pottentiodynamic corrosion test was performed using an AutoLab® corrosion test apparatus and an electrochemical cell consisting of a tri-electrode: the platinum reference electrode, an Ag/AgCl counter electrode, and the test alloy as the working electrode in 6 M KOH aqueous solution as the electrolyte. The corrosion experiment was performed at 25°C, and a Tafel curve was recorded from -1.4V to -0.2V with a scanning rate of 1 mV/sec.

RESULTS AND DISCUSSION

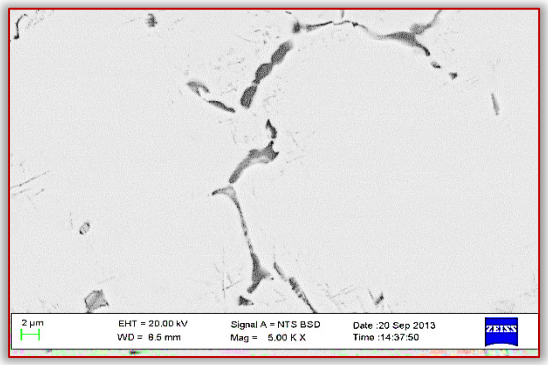
Microstructure of $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x= 0, 0.5, 1 at.%) and XRD patterns of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10) at.% alloy are respectively presented in Figure 1 and 2.

When 0.05 at.% Rh was substituted for Cr and Ti in $Ti_{25}V_{40}Cr_{35}$, the resulting structure was primary BCC (V) with intergranular Laves phase and a eutectic region surrounding the intergranular Laves regions, as shown in Figure 1. A similar structure was observed with addition of 0.10 at.% Rh but the laves phase was more prominent compared to 0.05 at.% alloy.

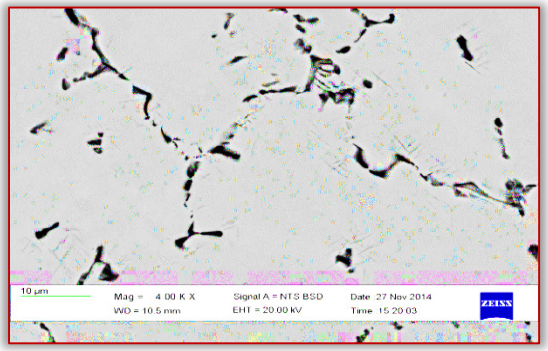
The XRD pattern in Figure 2 shows the main peak of BCC (V) and minor peak of C14 laves corresponding to the dark intergranular αTi phase in the micrograph. EDS of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10) is presented in Tables 1-2.



x = 0 at.%



x = 0.05 at.%



x = 1 at.%

Figure 1: Microstructure of $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x= 0, 0.5, 1 at.%)

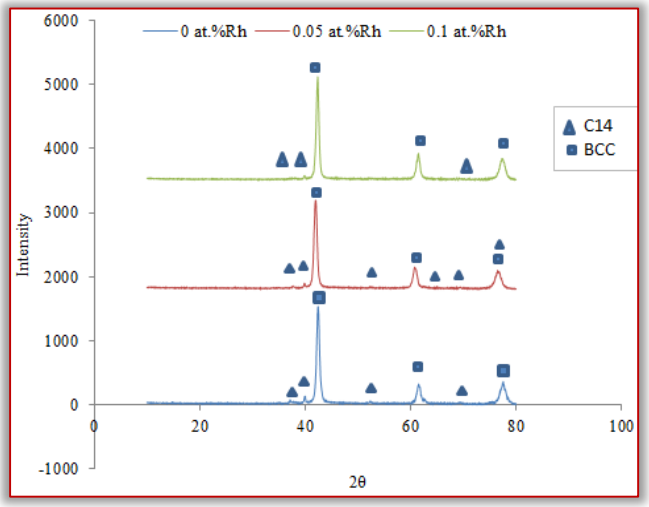


Figure 2: XRD patterns of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10) at.% alloy

Table 2 shows that with addition of 0.05 at.% Rh, there was no significant increase in cell volume of Laves and that of BCC. However, in the as-cast 0.10 Rh alloy, the cell volume of BCC increased from 27.67 Å^3 in Rh-free to 27.75 Å^3 while that of Laves decreased from 36.24 Å^3 to 34.48 Å^3.

The average of five Vickers hardness values of the as-cast 0, 0.05 and 0.10 at.% Rh samples are 415, 410 and 413 MPa respectively. This implied that the hardness of the as-cast $Ti_{25}V_{40}Cr_{35}$ alloy decreased slightly with Rh addition. The Laves phase has higher hardness than BCC (V) (Basak *et al.*, 2008). Table 1 shows higher proportion of BCC phase and lower proportion of harder Laves phase in the Rh-containing alloys, this could be responsible for the reduction in hardness.

Table 1: EDS of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10)

Sample	Phases XRD	Compositions * (at.%)			
		Ti	V	Cr	Rh
0 at.% Rh	BCC (V)	22.0 (0.7)	42.8 (0.46)	35.2 (0.82)	
	αTi	66.1 (1.6)	18.9 (1.2)	15.0 (0.8)	
0.05 at.% Rh	BCC (V)	28.5 (3.8)	38.8 (2.2)	32.7 (1.7)	
	αTi	71.8 (5.8)	14.6 (3.0)	13.5 (2.8)	0.5 (0.4)
0.10 at.% Rh	BCC (V)	20.10 (2.8)	42.4 (3.2)	37.5 (6.1)	
	αTi	62.3 (6.3)	19.1 (3.4)	18.6 (3.2)	0.5 (0.4)

*Standard deviation in parentheses

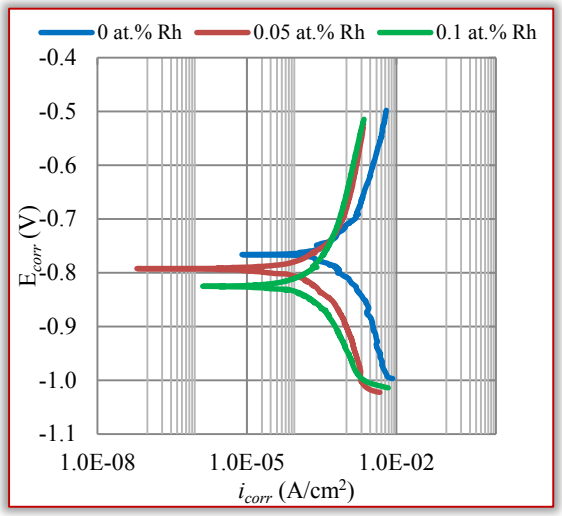
Table 2: EDS of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10)

Sample	Vickers hardness (MPa)	Phase proportion (% area)	Phase description			
			Space group (No.)	A	C	Cell vol. (Å3)
0 at.% Rh	415	82.5	Im3m (229)	3.0246		27.67
		17.5	P63/mmc (194)	2.98	4.72	36.24
0.05 at.% Rh	410	88.7	Im3m (229)	3.0257		27.70
		11.3	P63/mmc (194)	2.98	4.73	36.25
0.10 at.% Rh	413	83.0	Im3m (229)	3.0275		27.75
		17.0	P63/mmc (194)	2.95	4.67	34.48

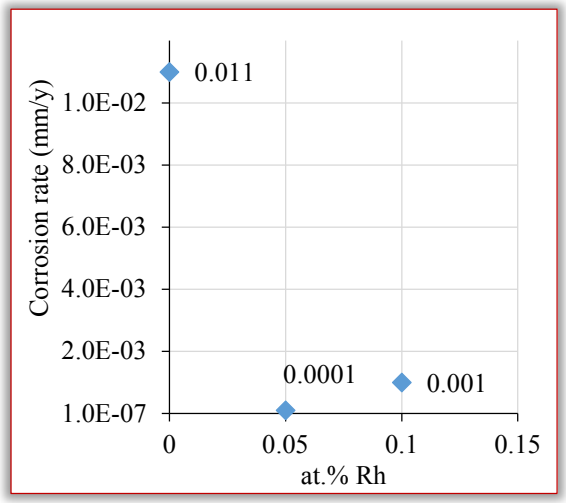
The Tafel's curve and the corresponding corrosion rate for the as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ (x = 0, 0.05, 0.10) at.% alloy is shown in Figure 3.

Figure 3(a) shows that addition of Rh decreased E_{corr} from -767 mV in Rh-free alloy to -793 mV in 0.05 Rh and -825 mV in 0.10 Rh. The corrosion current also decreased with increase in Rh: from 1 µA/cm^2 in Rh-free alloy to 0.77 µA/cm^2 with addition of 0.05 Rh, it further decreased to 0.37 µA/cm^2 with addition of 0.10 Rh alloy.

In Figure 3(b), addition of 0.05 Rh decreased the corrosion rate from 0.0110 to 0.0009 mm/y but only to 0.001 mm/y with addition of 0.10 Rh. Rhodium is one of the noble metals known as good corrosion inhibitors, so the observed reduction in corrosion rate with addition of Rh agrees with literature. The observed decrease in corrosion rate can be explained by substituting lower electronegativity elements Ti (1.54 Pauling scale) and Cr (1.66) with the higher electronegativity Rh (2.28); since high electronegativity favours a reduction in corrosion rate (Abrashev, *et al.*, 2010). For all the three alloy conditions, the lowest corrosion rate was found with addition of 0.05 Rh, followed by a slight increase in the rate with addition of 0.10 Rh.



(a)



(b)

Figure 3: (a) Pottentiodynamic curve (b) corrosion rate of as-cast $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ ($x = 0, 0.05, 0.10$) at.% alloy

CONCLUSIONS

The following conclusions were drawn from the results of hardness and corrosion rate of $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ ($x = 0, 0.05, 0.10$) at.% alloys being investigated:

- All the $Ti_{25-0.5x}V_{40}Cr_{35-0.5x}Rh_x$ ($x = 0, 0.05, 0.10$) at.% alloys have BCC (V) as the primary phase and αTi as the intergranular secondary phase.
- Rhodium, Rh decreased the E_{corr} from -767 mV to -793 mV for 0.05 Rh and -825 mV for 0.10 Rh. The corrosion current also decreased from 1 μA/cm^2 in Rh-free alloy to 0.77 μA/cm^2 with addition of 0.05 at % Rh and 0.37 μA/cm^2 with addition of 0.10 at.% Rh. Addition of 0.05 at. % Rh decreased the corrosion rate from 0.0110 to 0.0009 mm/y and to 0.001 mm/y with addition of 0.10 at.% Rh.
- Hardness of the alloy electrode decreased with addition of rhodium.
- Like other PGM, rhodium inhibits corrosion rate of $Ti_{25}V_{40}Cr_{35}$ alloy, addition of 0.05 at.% Rh is sufficient to reduce the corrosion rate, further addition of Rh is uneconomical since it does not substantially decrease the corrosion rate further.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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CORRELATION BETWEEN ERGONOMICS AND ECONOMICS

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Abstract: Ergonomics offers a wonderful common ground for labor and management collaboration, for invariably both can benefit managers, in terms of reduced costs and improved productivity, employees in terms of improved safety, health, comfort, usability of tools and equipment, including software, and improved quality of work life. Of course, both groups benefit from the increased competitiveness and related increased likelihood of long–term organizational survival that ultimately is afforded. Clearly, to enable our profession to approach its tremendous potential for humankind, the professional human factors/ ergonomics community, must better document the costs and benefits of their efforts and proactively share these data with their colleagues, business decision makers, and government policymakers. It is an integral part of managing their profession.

Keywords: Ergonomics, economics, correlation, applications, design and redesign, musculoskeletal disorders, human factors, macro ergonomics

INTRODUCTION

One of the clearest ways to delineate a discipline is by its unique technology. At its recent workshop, the HFES Strategic Planning Task Force noted, as have others internationally, that the technology of human factors/ergonomics is human–system interface technology. Thus, the discipline of human factors can be defined as the development and application of human–system interface technology.

Human–system interface technology deals with the interfaces between humans and the other system components, including hardware, software, environments, jobs, and organizational structures and processes. Like the technology of other design–related disciplines, it includes specifications, guidelines, methods, and tools. As noted by the Strategic Planning Task Force, we use our discipline's technology for improving the quality of life, including health, safety, comfort, usability, and productivity. As a science we study human capabilities, limitations, and other characteristics for the purpose of developing human–system interface technology. As a practice, we apply human–system interface technology to the analysis, design, evaluation, standardization, and control of systems. It is this technology that clearly defines us as a unique, stand–alone discipline that identifies who we are, what we do, and what we offer for the betterment of society.

Although they may come from a variety of professional backgrounds, such as psychology, engineering, safety, the rehabilitation professions, or medicine, it is their professional education and training in human–system interface technology that qualifies persons as human factors/ergonomics professionals. Indeed, the discipline needs both the breadth and richness of these professional backgrounds as well as the education and training in the unique technology of human factors/ergonomics.

Human factors/ergonomics professionals have long recognized the tremendous potential of our discipline for improving people's health, safety, and comfort and both human and system productivity. Indeed, through the application of our unique human–system interface technology, we have the potential to truly make a difference in the quality of life for virtually all peoples on this globe. In fact, we know of no profession where so small a group of professionals has such tremendous potential for truly making a difference.

In light of our potential, why is it, then, that more organizations, with their strong need to obtain employee commitment, reduce expenses, and increase productivity, are not banging down our doors for help, or creating human factors/ergonomics positions far beyond our capacity to fill them? Why is it that federal and state agencies are not pushing for legislation to ensure that human factors/ ergonomics factors are systematically considered in the design of products for human use and work environments for employees? Why is it that both industry associations and members of Congress sometimes view us as simply adding an additional expense burden and, thus, increasing the costs of production and thereby decreasing competitiveness? In response to these questions, from my experience, at least four contributing reasons immediately come to mind.

First, some of these individuals and organizations have been exposed to bad ergonomics – or what, in a recent article on this topic, Ian Chong (1996) labels "voodoo ergonomics" – either in the form of products or work environments that are professed to be ergonomically designed but are not, or in which the so–called ergonomics was done by incompetent persons. This, indeed, is a concern, particularly when persons lacking professional training pass themselves off as ergonomists or human factors professionals or tout their services as a panacea for almost anything. It is one of the major reasons that both establishing educational standards for professional education in human factors/ergonomics and professional certification have become top priority issues for the International Ergonomics Association and, indeed, for many national human factors/ergonomics societies and governmental groups, such as the European Union.

Another reason, well known to us, is that "everyone is an operator" (Mallett, 1995). Everyone "operates" systems on a daily basis, such as an automobile, computer, television, and telephone; thus, it is very easy to naively assume from our operator experience that human factors are nothing more than "common sense."

Most experienced ergonomists have their own personal list of "common sense" engineering design decisions that have resulted in serious accidents, fatalities, or just plain poor usability. Buy me a beer and I'll be glad to tell you some of my personal ergonomics "war stories." We also would refer you to Steve Casey's book, *Set Phasers on Stun* (Santa Barbara, CA: Aegean).

Third, we believe we sometimes expect organizational decision makers to proactively support human factors/ergonomics simply because it is the right thing to do. Like God, mother, and apple pie, it is hard to argue against doing anything that may better the human condition, and so that alone should be a compelling argument for actively supporting the use of our discipline. In reality, managers have to be able to justify any investment in terms of its concrete benefits to the organization – to the organization's ability to be competitive and survive. That something "is the right thing to do" is, by itself, an excellent but decidedly insufficient reason for managers actually doing it.

Finally, and perhaps most important, as a group, we have done a poor job of documenting and advertising the cost–benefits of good ergonomics – of getting the word out that most often, good ergonomics is good economics. In fact, that the ergonomics of economics is the economics of ergonomics.

As one attempt to rectify this situation, we want to share with you a broad spectrum of ergonomics applications that my predecessor as HFES president, Tom Eggemeier, and we have collected from within the United States and elsewhere, in which the costs and economic benefits were documented.

ERGONOMICS APPLICATIONS

– Forestry Industry

My first set of examples deal with forestry. A coordinated series of joint projects were undertaken by the Forest Engineering Technology Department of the University of Stellenbosch and Ergotech – the only true ergonomics consulting firm in South Africa – to improve safety and productivity in the South African forestry industry.

Leg protectors

In one project, an anthropometric survey was conducted of the very heterogeneous work force to provide the basic data for redesigning leg protectors for foresters. The South African forestry industry is populated with a wide variety of ethnic groups having widely varying anthropometric measurements. The original protector, obtained from Brazil, was modified to ergonomically improve the types of fastening and anthropometric dimensions, as well as to incorporate improved materials. Included in the ergonomic design modification process was an extensive series of usability tests over a six–month period.

Then, in a well–designed field test, this ergonomically modified leg protector was introduced in a eucalyptus plantation for use by persons responsible for ax/hatchet debranching. Among the 300 laborers, an average of ten injuries per day was occurring with an average sick leave of five days per injury. During the one–year period of the test, not a single ax/hatchet leg injury occurred, resulting not only in the considerable savings in human pain and suffering but also in a direct net cost savings to the company of $250,000. Use of the leg protectors throughout the South African hardwood forestry industry is conservatively calculated to save $4 million annually (Warkotsch, 1994).

Tractor–trailer redesign

A second study involved ergonomically improving the seating and visibility of 23 tractor–trailer forwarding units of a logging company with an investment of $300 per unit. This resulted in a better operating position for loading, improved vision, and improved operator comfort.

As a result, down times caused by accident damage to hydraulic hoses, fittings, and the like went down by $2,000 per year per unit, and daily hardwood extraction was increased by one load per day per vehicle. All told, for a total investment of $6,900, a hard cost savings of $65,000 per year was achieved – a 1 to 9.4 cost–benefit ratio (Warkotsch, 1994).

Other innovations

Other innovations by this same collaborative effort between Stellenbosch University, Ergotech, and various forestry companies have included:

(a) the development of a unique, lightweight, environmentally friendly pipe type of timber chute for more efficient and safe transporting of logs down slopes;

(b) redesign of three–wheeled hydrostatic loaders to reduce both excessive whole–body vibration and noise;

(c) classifying different terrain conditions – including ground slope, roughness, and other conditions – and determining the most effective tree harvesting system (method and equipment) for each; and

(d) developing ergonomic checklists and work environment surveys tailored to the forest industry. All are expected to result in significant cost savings, as well as greater employee satisfaction and improved quality of work life (Warkotsch, 1994).

We believe this is a good example of what ergonomics potentially can contribute to any given industry when there is a true collaborative effort and commitment.

– C–141 Transport Aircraft

Some 35 years ago, I joined the U.S. Air Force's C–141 aircraft development system program office as the project engineer for both human factors and the alternate mission provisions. The C–141 was to be designed so that its cargo compartment, through the installation of alternate mission kits, could be reconfigured for cargo aerial delivery, carrying paratroopers and paratroop jumping, carrying passengers, or medical evacuation. As initially configured, anything that did not absolutely have to be included in the aircraft for straight cargo carrying was placed in one of the alternate mission kits, making them heavy and complex and requiring considerable time and effort to install.

By meeting with the intended user organization, the Air Force Material Air Transport Command, and discussing their organizational design and management plan for actual utilization of the aircraft, I was able to identify numerous kit components that rarely ever would be removed from the airplane. Using these data, I worked with the Lockheed design engineers to reconfigure the kits to remove these components and, instead, install them permanently in the aircraft.

As documented by the engineering change proposals, this effort greatly simplified the system and reduced actual operational

aircraft weight and, thus, related operating and maintenance costs for more than 200 aircraft over the past 35 years. The changes also reduced installation time and labor and storage requirements for the kits. In addition, it saved over $2 million in the initial cost of the aircraft fleet. I believe this is a good illustration of how macro ergonomic considerations can result in highly cost–effective micro ergonomic design improvements to systems.

These and numerous other cost–benefit human factors evaluations and improvements to the C–141's design came at a total cost of less than $500,000 of professional human factors effort and resulted in over $5 million in cost savings – better than a 1 to 10 cost–benefit ratio. I believe the aircraft's truly exceptional safety record and related untold savings in lost aircraft avoided can, at least in part, be attributed to having had a sound human factors engineering development effort.

– Materials Handling Systems

One group that does a somewhat better job of documenting the costs and benefits of its ergonomic interventions than many of us is the faculty of the Department of Human Work Sciences at Lulea University of Technology in Sweden. The following examples are from the department's Division of Environment Technology's work with steel mills. The basic approach to ergonomics analysis and redesign in these projects was to involve employee representatives with the Lulea faculty. For each project, the economic "payoff" period was calculated jointly with the company's management.

 # Steel pipes and rods handling & stock–keeping system

A semiautomatic materials handling and stock–keeping system for steel pipes and rods was ergonomically redesigned. The redesign reduced the noise level in the area from 96 db to 78 db, increased production by 10%, dropped rejection from 2.5% to 1%, and paid back the redesign and development costs in approximately 18 months. After that, it was all profit.

 # Tube manufacturing handling and storage system

In a tube manufacturing facility, a tube handling and storage system had an unacceptably high noise level and high rejection rate from damage, required heavy lifting, and had inefficient product organization and a poor safety record. Ergonomic redesign eliminated stock damage, improved stock organization, reduced lifting forces to an acceptable level, reduced the noise level by 20 db; and has, to date, resulted in zero accidents and in a productivity increase with a payback period of only 15 months.

 # Forge shop manipulator

In a forge shop, the old manipulator was replaced with a new one, having an ergonomically designed cabin and overall better workplace design. In comparison with the old manipulator, whole body vibration was reduced, noise was reduced by 18 db, operator sick leave dropped from 8% to 2%, productivity improved, and maintenance costs dropped by 80%.

PRODUCT DESIGN OR REDESIGN

The economic benefit of ergonomic design or redesign of a product can be assessed in several ways – for example, by its impact on (a) the value of the company's stock, (b) sales, (c) productivity, or (d) reductions in accidents. Four very different kinds of products are provided here as illustrations of each of these beneficial economic impacts.

 # Replacement for forklift truck lines

Alan Hedge and his colleagues at the Human Factors Laboratory at Cornell University participated with Pelican Design, a New York industrial design company, and the Raymond Corporation in the design and development of a new generation of forklift trucks to replace Raymond's two existing product lines. Human factors design principles were given prime consideration, and an "inside–out" human–centered approach was taken, with the form of the truck being built around the operator's needs. The goal was to maximize operator comfort, minimize accident risks, and maximize productivity by optimizing task cycle times. At the time the development project was begun, Raymond's market share had eroded from its former position of dominance in the market of over 70% of sales to about 30%, and it was shrinking.

The new narrow isle and swing–reach truck lines were introduced in the United States in 1992, and the swing–reach line was introduced in Europe in 1993. Order books at Raymond are full, and the company is once again enjoying success. Raymond stock has risen from around $6 per share at the start of the project to around $21 today (Alan Hedge, personal communication).

 # TV and VCR remote controls

Thomson Consumer Electronics first developed its highly successful approach to user–centered design when it developed System Link, an ergonomically oriented remote control that can operate various types of products made by different manufacturers. The original Thomson remote control design differed little from the competition's: a rectangular box with rows of small, identical buttons. It is the one in the middle of the picture at left ("before").

Using the company's user–centered design approach, the initial design was replaced with the new ergonomic one, shown on the left in the "after" picture, which, among other things, was easier to grasp, used color–coded, soft–touch rubber buttons in distinctive sizes and shapes, and separated the VCR and TV buttons above and below the keypad. When introduced in 1988, this new, ergonomically designed System Link remote control gained the jump on the competition, and Thomson has since sold millions of them. As a result of this success, user–centered ergonomic design has become a key aspect of all new Thomson development projects (March, 1994).

 # DSS system

A more recent highly successful example is Thomson's RCA DSS satellite digital television system. All aspects, including the on–screen display and remote control, utilized user centered design and received extensive ergonomic attention (March, 1994). These units now are selling like hotcakes.

 # CRT display

The CRT display used by directory assistants at Ameritech (a U.S. regional telephone company) were ergonomically redesigned by Scott Lively, Richard Omanson, and Arnold Lund to meet the goal of reducing average call processing time. Included in the redesign were replacement of an all–uppercase display with a mixed–case display and the addition of a highlighting feature for the listing selected by the directory assistant.

Based on extensive before–and after measurements, results showed a 600–ms reduction in average call operating time after introduction of the ergonomically redesigned CRT display.

Although seemingly small, this reduction represents an annual savings of approximately $2.94 million across the five–state region served by Ameritech (Scott Lively and Arnold Lund, personal communication).

 # Training system redesign

In a related effort, done jointly with North western's Institute for Learning Sciences, the traditional lecture and practice training program for new directory assistants was replaced by an ergonomically designed computer–based training program that incorporates a simulated work environment and error feedback. As a result, operator training time has been reduced from five days to one and a half days (Scott Lively, personal communication).

 # Center high–mounted automobile rear stop lamp

The center high–mounted stop lamp (CHML) is perhaps the best–known ergonomic improvement to a widely used consumer product. In the 1970s, the National Highway Traffic Safety Administration (NHTSA) sponsored two field research programs that demonstrated the potential of adding a CHML to reduce response times of following drivers and, thus, avoid accidents. In the mid–1970s, this ergonomic innovation and three other configurations were installed in 2,100 Washington, D.C.–area taxicabs. The CHML configuration resulted in a 50% reduction in both rear–end collisions and collision severity. Following several additional field studies, Federal Motor Vehicle Safety Standard 108 was modified to require all new passenger cars built after 1985 to have CHMLs.

Based on analyses of both actual production costs for the CHMLs and actual accident data for the 1986 and 1987 CHML–equipped cars, NHTSA calculated that when all cars are CHML equipped (1997), 126,000 reported crashes will be avoided annually at a property damage savings of $910 million per year. Addition of the savings in medical costs would, of course, considerably increase this figure. The total cost of the entire research program was $2 million and for the regulatory program, $3 million (Transportation Research Board, National Research Council, 1989). A $5 million dollar investment for a projected $910 million annual return: not a bad ergonomics investment by the federal government!

 # Poultry de–boning knife

A conventional type butcher's knife was being used for de–boning chickens and turkeys at a poultry packaging plant. The knife did a poor job of de–boning, and a high incident rate of carpal tunnel syndrome, tendinitis, and tenosynovitis resulted in a $100,000 per annum increase in worker compensation premiums.

A new, ergonomically designed pistol–shaped knife was introduced by ergonomist Ian Chong, principal of Ergonomics, Inc., of Seattle, Washington. Less pain and happier cutting crews were reported almost immediately. Over a five–year period, upper extremity work–related musculoskeletal disorders were greatly reduced, line speeds increased by 2% to 6%, profits increased because of more efficient de–boning, and $500,000 was saved in workers' compensation premiums (Ian Chong, personal communication). This is a good example of how a simple, inexpensive ergonomic solution sometimes can have a very high cost–benefit payoff.

– Workstation Redesign

 # Food service stands

Using a participatory ergonomics approach with food service personnel, my USC colleague, Andy Imada, and George Stawowy, a visiting ergonomics doctoral student from the University of Aachen in Germany, redesigned two food service stands at Dodger Stadium in Los Angeles (Imada and Stawowy, 1996). The total cost was $40,000. Extensive before–and–after measures demonstrated a reduction in average customer transaction time of approximately 8 seconds. In terms of dollars, the increase in productivity for the two stands was approximately $1,200 per baseball game, resulting in a payback period of 33 games, or 40% of a single baseball season. Modification of these two stands was relatively costly because, as the development prototypes, they consumed considerable time and effort. Modifying the other 50 stands in Dodger Stadium can now be done at a price of $12,000 per stand, resulting in a payback period of only 20 games. Potentially, the resulting productivity increases can be used to reduce customer waiting time, thereby also increasing customer satisfaction (Andrew Imada, personal communication).

This modification effort is but one part of a macro ergonomics intervention project to improve productivity. Imada anticipates that ongoing work to improve the total system process – including packaging, storage, and delivery of food products and supplies, and managerial processes – eventually will result in a much greater increase in productivity.

 # Fine assembly workstations

Typical workstations at a major electronics assembly plant result in poor postures and resultant work–related musculoskeletal disorders. Valery Venda of the University of Manitoba has designed a new type of fine assembly workstation that utilizes a TV camera and monitor. Not only does the TV camera provide a greatly enlarged image of the assembly work, but it enables the worker to maintain a better posture and more dynamic motion (see photos next page).

Based on extensive comparative testing of the old and new workstations, a 15% higher productivity rate is obtained with the new one. Venda reports that the average value of products assembled per worker per shift at these types of workstations varies between $15,000 and $20,000. Thus, the additional value produced by one worker per day using the new workstation will be $2,250 to $3,000 per day. Although it is too early to say precisely, Venda predicts the new workstations eventually will decrease occupational injuries for these jobs by 20% (Valery Venda, personal communication).

REDUCING WORK–RELATED MUSCULOSKELETAL DISORDERS

Given the importance of this issue, and the rather considerable attention and debate that has resulted from the introduction of proposed workplace ergonomics regulations at both the federal and state (e.g., California) levels, and two Canadian provinces, I have included five examples of documented, highly successful ergonomics intervention programs.

 # AT&T Global

AT&T Global Information Solutions in San Diego, California, employs 800 people and manufactures large mainframe computers.

Following analyses of their OSHA 200 logs, the company identified three types of frequent injuries: lifting, fastening, and keyboarding. The company next conducted extensive work site analyses to identify ergonomic deficiencies. As a result, the company made extensive ergonomic workstation improvements and provided proper lifting training for all employees. In the first year following the changes, workers compensation losses dropped more than 75%, from $400,000 to $94,000.

In a second round of changes, conveyor systems were replaced with small, individual scissors–lift platforms, and heavy pneumatic drivers with lighter electric ones; this was followed by moving from an assembly line process to one where each worker builds an entire cabinet, with the ability to readily shift from standing to sitting.

A further reduction in workers compensation losses to $12,000 resulted. In terms of lost work days due to injury, in 1990 there were 298; in both 1993 and 1994 there were none (Center for Workplace Health Information, 1995a). All told, these ergonomic changes have reduced workers compensation costs at AT&T Global over the 1990– 1994 period by $1.48 million. The added costs for these ergonomic improvements represent only a small fraction of these savings.

 # Red Wing Shoes

Beginning in 1985 with (a) the initiation of a safety awareness program that includes basic machine setup and operation, safety principles and body mechanics, CTDs, and monthly safety meetings; (b) a stretching, exercise and conditioning program; (c) the hiring of an ergonomics advisor; and (d) specialized training on ergonomics and workstation setup for machine maintenance workers and industrial engineers, the Red Wing Shoe Company of Red Wing, Minnesota, made a commitment to reducing WMSDs via ergonomics.

The company purchased adjustable ergonomic chairs for all seated operators and anti–fatigue mats for all standing jobs; instituted continuous flow manufacturing (which included operators working in groups), cross training and job rotation; ergonomically redesigned selected machines and workstations for flexibility and elimination of awkward postures and greater ease of operation; and modified production processes to reduce cumulative trauma strain. As a result of these various ergonomics interventions, workers compensation insurance premiums dropped by 70% from 1989 to 1995, for a savings of $3.1 million. During this same period, the number of OSHA–reportable lost–time injury days dropped from a ratio of 75 per 100 employees working a year to 19 per hundred. The success of this program is attributed to upper management's support, employee education and training, and having everyone responsible for coordinating ergonomics. I also would note the total systems perspective of this effort (Center for Workplace Health Information, 1995b).

 # Ergonomics training and follow–up implementation

In 1992, Bill Brough of Washington Ergonomics conducted a one–day seminar for cross–disciplinary teams of engineers, human resource management personnel, and safety/ergonomics committee members from seven manufacturing companies insured by Tokyo Marine and Fire Insurance Company, Ltd.

The seminar taught the basic principles of ergonomics and provided the materials to implement a participatory ergonomics process. The training focused on techniques for involving the workers in evaluating present workplace conditions and making cost–effective improvements. The class materials provided the tools for establishing a baseline, setting improvement goals, and measuring results.

In six of the companies, the seminar data and materials were used by the teams to implement a participatory ergonomics program with the workers and received both funding from management and support from labor. The seventh company did not participate in the implementation of the training. Follow–up support was provided by a senior loss control consultant for Tokyo Marine.

For the six companies that did participate, reported strain–type injuries dropped progressively from 131 in the six months prior to the training to 42 for the six–month period ending 18 months later. The cost of these injuries for the six months prior was $688,344. For the six–month period ending 18 months later, the injury costs had dropped to $72,600, for a net savings over 18 months of $1,348,748, using the six months prior as the baseline.

Worker involvement reportedly created enthusiasm and encouraged each individual to assume responsibility for the program's success. According to Brough, the reduction of injuries resulted from a commitment to continuous improvement and was obtained by many small changes, not a major singular event. For the one company that did not participate in implementing the training, the number of reported strain injuries was 12 for the six months prior to training and 10, 16, and 25, respectively, for the next three six–month periods. In short, things got worse rather than better (Bill Brough, personal communication and supporting documentation).

Coupled with both management's and labors' active support, Tokyo Marine traces these reductions in strain–type injuries for the six participating companies directly back to Brough's participatory ergonomics training program and related materials. A good example of what can happen when you couple collaborative management labor commitment with professional ergonomics.

 # Deere and Company

One of the best–known successful industrial safety ergonomics programs is that at Deere and Company, the largest manufacturer of agricultural equipment in North America. In 1979, Deere recognized that traditional interventions like employee lift training and conservative medical management were, by themselves, insufficient to reduce injuries. So the company began to use ergonomics principles to redesign and reduce physical stresses of the job.

Eventually, ergonomics coordinators were appointed in all of Deere's U.S. and Canadian factories, foundries, and distribution centers. These coordinators, chosen from the industrial engineering and safety departments, were trained in ergonomics. Today, job evaluations and analyses are done in–house by both part–time ergonomics coordinators and wage–employee ergonomics teams and committees. The company has developed its own ergonomics checklists and surveys. The program involves extensive employee participation.

Since 1979, Deere has recorded an 83% reduction in incidence of back injuries, and by 1984 it had reduced workers compensation costs by 32%. According to Gary Lovestead, each year hundreds to

thousands of ergonomics improvements are implemented; and today, ergonomics is built into Deere's operating culture (Center for Workplace Health Information, 1995c).

 # Union Pacific Railroad

In the early 1980s, the Palestine Car Shop near Dallas, Texas, had the worst safety statistics of the Union Pacific Railroad's shop operations. Of particular note was the high incidence of back injuries. For example, in 1985, 9 of 13 lost time injuries were back injuries, and 579 lost and 194 restricted or limited work days accumulated. Only 1,564 cars were repaired that year, and absenteeism was 4 percent (Association of American Railroads, 1989).

The University of Michigan Center for Ergonomics computer model for back compression was modified and expanded for easy application to the railroad environment and packaged by the Association of American Railroads. The AAR–Back Model was introduced at the Palestine Car Shop to identify job tasks that exceeded acceptable back compression values, and equipment supporting various jobs requiring lifting was redesigned. For example, a coupler knuckle storage table was designed for storing the 90 lb. knuckles (see photo). Previously, they were manually piled on the ground and then lifted from there. In addition, a commercial back injury training program, Pro–Back, was adopted, and every employee was taught how to bend and lift safely. Finally, management attitude and priorities about safety were conveyed through weekly meetings with safety captains from each work area and quarterly "town hall" meetings with all shop employees.

From 1985 to 1988, the total incidents of injuries went from 33 to 12, back incidents from 13 to 0, lost days from 579 to 0, restricted days from 194 to 40 (all from minor, non–back injuries), and absenteeism from 4% to 1%. Number of cars repaired per year went from 1,564 in 1985 to 2,900 in 1988, an increase in dollar value of $3.96 million. Union Pacific calculates the cost–benefit ratio as approximately 1 to 10 (Association of American Railroads, 1989).

 # IBM job aids

Soon after IBM started shipping its Display writer product to customers, a report came back that customer setup of the product was failing. Follow–up by ergonomist Daniel Kolar, president of Info Xfer, a usability consulting firm in Austin, Texas, determined that the problem was in frequent errors in the packing line. The packers had no idea what they were doing because they had inappropriate documentation to work with. Dan conducted a task analysis and then used it to develop a highly pictorial "Texas–sized" storyboard that detailed the specific packing steps at each station.

Following installation of the storyboard, the shipping error rate dropped from 35 per hundred to less than one in a thousand. IBM's cost–effectiveness people calculated the savings at $2 million over a two–year period (Kolar, personal communication).

HUMAN FACTORS TEST AND EVALUATION

One of the regional U.S. telephone companies, NYNEX, developed a new workstation for its toll and assistance operators, whose job is to assist customers in completing their calls and to record the correct billing. The primary motivation behind developing the new workstation was to enable the operators to reduce their average time per customer by providing a more efficient workstation design.

The current workstation had been in use for several years and employed a 300–baud, character–oriented display and a keyboard on which functionally related keys were color coded and spatially grouped. This functional grouping often separated common sequences of keys by a large distance on the keyboard. In contrast, the proposed workstation was ergonomically designed with sequential as well as functional considerations; it incorporated a graphic, high–resolution, 1200–baud display, used icons, and in general is a good example of a graphical user interface whose designers paid careful attention to human–computer interaction issues.

Under the name Project Ernestine, Wayne Gray and Michael Atwood of the NYNEX Science and Technology Center and Bonnie John of Carnegie Mellon University (1993) designed and conducted a comparative field test, replacing 12 of the current workstations with 12 of the proposed ones. In addition, they conducted a goals, operators, methods, selection rules (GOMS) analysis (Card, Moran, & Newell, 1980) in which both observation–based and specification based GOMS models of the two workstations were developed and used.

Contrary to expectations, the field test demonstrated that average operator time was 4% slower with the proposed workstation than with the existing one. Further, the GOMS analyses accurately predicted this outcome, thus demonstrating the validity of the GOMS models for efficiently and economically evaluating telephone operator workstations. Had this test and evaluation not been conducted and the proposed, presumably more efficient workstation been adopted for all 100 operators, the performance decrement cost per year would have been $2.4 million. A good example of the value of doing careful human factors test and evaluation before you buy (Gray et al., 1993).

MACRO ERGONOMICS

 # Petroleum distribution company

Several years ago, Andy Imada of the University of Southern California began a macro ergonomic analysis and intervention program to improve safety and health in a company that manufactures and distributes petroleum products. The key components of this intervention included an organizational assessment that generated a strategic plan for improving safety, equipment changes to improve working conditions and enhance safety, and three macro ergonomic classes of action items. These items included improving employee involvement and communication and integrating safety into the broader organizational culture.

The program utilized a participatory ergonomics approach involving all levels of the division's management and supervision, terminal and filling station personnel, and the truck drivers. Over the course of several years, many aspects of the system's organizational design and management structure and processes were examined from a macro ergonomics perspective and, in some cases, modified. Employee–initiated ergonomic modifications were made to some of the equipment, new employee–designed safety training methods and structures were implemented, and employees were given a greater role in selecting new tools and equipment related to their jobs.

Two years after initial installation of the program, industrial injuries had been reduced by 54%, motor vehicle accidents by 51%, off–the–job injuries by 84%, and lost work days by 94%. By four years later, further reductions occurred for all but off–the–job injuries, which shrunk 15% to a 69% sustained improvement (Nagamachi & Imada, 1992).

The company's area manager of operations reports that he continues to save one–half of one percent of the annual petroleum delivery costs every year as a direct result of the macro ergonomics intervention program. This amounts to a net savings of approximately $60,000 per year for the past three years, or $180,000, and is expected to continue (Andrew Imada, personal communication). Imada reports that perhaps the greatest reason for these sustained improvements has been the successful installation of safety as part of the organization's culture. From my first–hand observation of this organization over the past several years, I would have to agree.

 # Implementing TQM at L. L. Bean

Rooney, Morency, and Herrick (1993) have reported on the use of macro ergonomics as an approach and methodology for introducing total quality management (TQM) at the L.L. Bean Corporation, known internationally for the high quality of its clothing products.

Using methods similar to those described above for Imada's intervention, but with TQM as the primary objective, over a 70% reduction in lost–time accidents and injuries was achieved within a two–year period in both the production and distribution divisions of the company. Other benefits, such as greater employee satisfaction and improvements in additional quality measures, also were achieved. Given the present emphasis in many organizations on implementing ISO 9000, these results take on even greater significance.

CONCLUSIONS

The above are but a sample of the variety of ergonomic interventions that we, as a profession, are capable of doing to improve not only the human condition but the bottom line as well. From my 35 years of observation and experience, only rarely are truly good ergonomics interventions not beneficial in terms of the criteria that are used by managers in evaluating the allocation of their resources.

As many of the above ergonomics interventions also illustrate, ergonomics offers a wonderful common ground for labor and management collaboration, for invariably both can benefit – managers, in terms of reduced costs and improved productivity, employees in terms of improved safety, health, comfort, usability of tools and equipment, including software, and improved quality of work life. Of course, both groups benefit from the increased competitiveness and related increased likelihood of long–term organizational survival that ultimately is afforded.

Clearly, to enable our profession to approach its tremendous potential for humankind, we, the professional human factors/ ergonomics community, must better document the costs and benefits of our efforts and proactively share these data with our colleagues, business decision makers, and government policymakers. It is an integral part of managing our profession.

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ISSN: 2067–3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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Al–Mg–Mn BASED COMPOSITES FOR TRICYCLE CONNECTING ROD: A REVIEW

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Abstract: Global trend in automobile design of engineering systems encourages cost effective, lighter materials with enhanced strength to weight ratio for easy handling, fuel economy and optimal efficiency in service. However, automobile engines that use carbon steel connecting rods are characterised by low efficiency due to heavy mass. Recent demand for higher engine performance requires connecting rods produced from aluminium alloy based Nano and hybrid composites. This study seeks to review literature on particulate agro wastes as reinforcement in metal matrix composites for possible use in producing tricycle connecting rod. From the extensive literature reviewed, the use of agro wastes nanoparticles as reinforcement for automotive applications is rare. The primary search revealed that Nanoparticles of agro wastes can be produced by ball milling and when characterised could be a suitable reinforcement material for metal matrix composites. Most of the literature reviewed used single reinforcement. The use of dual reinforcement is scanty particularly for local agro wastes. Utilisation of Carbonised and non–carbonised nanoparticles of periwinkle, coconut and palm kernel shells as reinforcement to produce Nano and hybrid composites for production of tricycle connecting rod has not been reported. Furthermore, the base material of waste Al–cans can be recovered through secondary melting and used for the development and characterisation of hybrid agro waste nanoparticle reinforced aluminium alloy composites.

Keywords: Al–Mg–Mn, Mechanical Properties, Nano/hybrid composite, Connecting rod, Review

INTRODUCTION

Composites are made of two or more distinct materials with enhanced properties. The constituent materials, not only differ in chemical composition and form, but are insoluble in each other. Composites possess properties that are more superior to the properties of the individual constituent materials functioning individually (Callister**,** 2007). Hybrid composite consist of a single matrix, enhanced with two or more reinforcements. They provide opportunity to combine different materials ranging from organic to inorganic. Dimensional stability, light weight, high strength along fibre reinforcing direction and thermal stability are among the desirable properties of hybrid composites (Adeosun *et al*., 2014; Valery and Evgeniy, 2013).

Aluminium and its alloys have found wide range of applications in construction, packaging, food and transportation industries due to its excellent corrosion resistance and light weight. Low mechanical properties of aluminium and its alloys have limited their applications as structural materials in the automobile, aerospace and military industries where improved mechanical properties and structural stability are prerequisites. Low mechanical properties of aluminium and its alloys have been addressed overtime by researchers through work hardening, solid solution strengthening, age or precipitation hardening and development of aluminium matrix composites (AMC) using synthetic and or natural fillers. Among metallic alloys, aluminium alloys remain the most considered metallic alloy as a matrix for producing metallic composites. This is due to combined ductility, resistance to corrosion, light weight, good thermal and electrical properties of aluminium alloys (Deng *et al*, 2007; Li *et al*., 2011; Alaneme and Bodurin, 2013; Das *et al.,* 2014, Bello *et al.,* 2017) which have been revealed earlier in this write–up and their ease of availability. Many studies in literature were aimed at improving the mechanical properties of aluminium and its alloys. Use of expensive synthetic fillers such as silicon carbide, alumina and graphite have increased cost of production and limited applications of AMC in commercial vehicles (Das *et al.,* 2008; Goto, 2005; Kok, 2005).

Industrial wastes and organic particles have become attractive alternative reinforcement to synthetic fillers due to their availability, low cost, high specific strength, stiffness, natural renewability and environmental friendliness. Research has shown that the use of those organic particles at micro size level to reinforce aluminium alloys yielded improved mechanical properties (Prasad and Krishna, 2011). An innovation that will yield promising result is the reinforcement of aluminium alloy with nanoparticles obtained from organic wastes such as periwinkle shell (PWS), palm kernel (PKS) and coconut shells (CNS) and the selective combination of two organic nanoparticles to produce hybrid reinforcement for modifying structures of aluminium alloys (Rino *et al.,*2012). This attempt can lead to synergetic interaction of selected nanoparticles within the alloy matrix with higher improvement in mechanical properties than the case when each of the nanoparticles will be used as reinforcement independently.

Varieties of aluminium based alloys and composites have been produced overtime in the quest to develop appropriate materials for varied applications. Aluminium alloys 2014, 2024 were developed and used in the construction of highly stressed parts in aircraft. Aluminium alloys 7075 and 7079 were developed for high static strength in aircraft construction. Aluminium alloy based metal matrix composites such as continuous fibre reinforced boron/aluminium, graphite/aluminium together with

discontinuous reinforced metal matrix composites (MMCs) such as silicon–carbide particulate reinforced aluminium, and graphite particulate reinforced aluminium were developed for use in spacecraft to offer maximum resistance to atmospheric factors such as radiation and electromagnetic interference (Suraji, 2001).

COMPOSITES

A composite is a combination of two or more different materials or phases having recognisable interface to form a new structure, whose properties and performance characteristics are different and superior to the properties of the individual constituents taken separately. (Callister**,** 2007) defined hybrid composite as a multi layered material with mixed fibres or particles consisting of two or more reinforcements which differ from one another in a single matrix phase. The constituents are combined in such a way that they keep their individual physical phases and are not soluble in each other i.e. do not form a new chemical compound. This basic fact remains one of the motivating factors for research and development of composite materials overtime. Composites are designed to take advantage of the properties of all the components involved and they exhibit wide range of physical and chemical properties including high stiffness, light weight, dimensional stability, chemical resistance, thermal stability and good strength to weight ratio, which are not evident in monolithic materials. These desirable properties are required in modern engineering designs and applications for improved and efficient performance (Rino *et al.,* 2012). Composites have high specific strength (strength per unit volume) far higher than those of titanium and aluminium. The specific strength of both aluminium and polymer matrix composites are far higher than that of steel and titanium. This makes it possible to develop composite materials possessing the same strength and stiffness as structures made of metals, but whose weight is lighter than structural metals. In most engineering systems, metallic components have been replaced by composites due to the high specific strength of composites.

Composites have found applications in automobile, aerospace and more recently in marine, sports, recreation and defence industries (Das *et al.,* 2014), due to their good damping capacity, satisfactory level of resistance to corrosion, high specific strength, excellent wear resistance, low co–efficient of thermal expansion and high thermal resistance (Kok, 2005; Rino *et al.,*2012; Prasad and Krishna, 2011). Basically, two categories of constituent materials or phases are evident in composites – matrix and reinforcing phase. The primary phase that is continuous in the composite material and is in most cases the one present in a greater quantity is the matrix. It is the base material into which the reinforcement is embedded. The body constituent of the matrix gives the composite its bulk form. The matrix is usually more ductile. It is the outer material that binds together and provides form and protects the reinforcement from environmental and mechanical damage, thus keeping it stiff and undamaged from external forces. The matrix also transfers stress between the reinforcing fibres (Callister**,** 2007). Several metallic materials have been used as matrix for producing metal matrix composites. This ranges from metals for industrial applications such as aluminium, magnesium, copper and their alloys to oxides, nitrides, carbides, hydrates and borides.

The dispersed (reinforcing) phase is the second constituent of the composite. It is embedded in the matrix in a discontinuous form. The secondary phase is usually harder, stronger and stiffer than the matrix. It enhances the mechanical properties of the matrix, bears the load applied to the matrix and offers strength and rigidity to the composite. The reinforcement is a structural constituent which determines the internal structure of the composite.

Reinforcements can either be particulate or fibrous. The dimensions of the reinforcement determine its capability of distributing its properties to the composite. Alumina, carbon, thermoplastics, boron, silicon nitride, silicon carbide and steel are the frequently used synthetic reinforcements for developing composites. Intense researches are presently exploiting the reinforcing potentials of natural fillers such as PKS, CNS, PWS, egg shells, banana peels, bagasse and yam peels for the development of composites suitable for many engineering applications.

Composites are classified based on reinforcing material structure or on the matrix materials. On the bases of reinforcement, composites are classified as, fibre reinforced, particulate reinforced composite, structural composites and Nano composites. Based on matrix materials, composites are grouped into:

— ceramic matrix composites (CMC),
— polymer matrix composites (PMC) and
— metal matrix composites (MMC) (Josmin *et al.*, 2012).

The reinforcement could be continuous or discontinuous; it increases stiffness, strength and the temperature resistance capacity of the composite but reduces ductility, fracture toughness and density of the metal matrix composite. Based on shape, reinforcement material may be classified into: fibres, whiskers, flakes and particles or platelets. A fibre is a particle longer than 100 μm with aspect ratio (A–R) greater than 10:1. Fibre reinforced composite is characterised by the length of fibre being much greater than its cross–sectional dimension. However, ratio of length to the cross–sectional dimension (L/D), known as the aspect ratio, can vary considerably. Fibres can either be short or long. Short fibres are discontinuous and have breaks throughout the material. Fibres are responsible for high strength and stiffness ratio to weight of composites. For better strength of the components and maximum load transfer, the fibre should be continuous. A reinforcement having long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly in brittle matrices. Whiskers are thin hair like crystals of exceptional mechanical strength used specially as reinforcement for developing structural composite materials. Whiskers of various materials such as carbides, halides, metals, oxides and organic compounds under controlled conditions have been prepared and used as reinforcements for metal matrix composites. Although whisker reinforced metal matrix composites offer higher strength than particle reinforced composites, their production cost is, however higher and often experience breakage and damage during secondary fabrication (Hunt, 1991). A flake is flat plate like material, having no definite shape or orientation. Thin flakes offer attractive features for an effective reinforcement. They have primarily two–dimensional geometry and thus impacts equal strength in all directions in their plane compared to fibres that are

unidirectional reinforcements. Flakes when laid parallel can be packed more closely than fibres or spherical particles. Mica flakes are used in electrical and heat insulating applications. Mica flakes is embedded in a glassy matrix to produce composites that can be machined easily and are used in electrical applications. Aluminium flakes are commonly employed in paints and other coatings in which they orient themselves parallel to the surface of the coating and gives them exceptionally good properties. Silver flakes are employed where good conductivity is required. A particle is non–fibrous and generally has no long dimension apart from platelets. In particle reinforced composites the matrix is reinforced by a dispersed phase in form of particles. The merits of particles as reinforcing agent include the following:

- they are the most common and cheapest reinforcements;
- they produce discontinuous reinforcements with isotropic properties;
- composites reinforced with particles could be fabricated into a wide range of product forms using conventional fabrication methods, thereby making them affordable (Odorico, 1990).

Particles dimension are approximately equal in all directions. Particles shape and size play vital roles in reinforcement. The shape of the reinforcing particle may be either spherical, cubic, platelet or any regular or irregular geometry. The arrangement of the particle reinforcement may be random (composites with random orientation of particles) or with a preferred orientation (composites with preferred orientation of particles). In particulate reinforced composites the orientation of the particles is considered for practical purposes to be random.

In general, particles are not very effective in improving fracture resistance. However, particles of rubber like substances in brittle polymer matrices improves fracture resistance by promoting and arresting cracking or cracks in brittle matrices. Previous study shows that angular particles act as stress raisers, rounded or global particles improves impact properties, spherical particles gives better ductility than angular shaped particles (Odorico, 1990). Fine particles strengthen the composites more than coarse particles due to closer inter–particle spacing. Coarse particles are easily incorporated in liquid melts; they are susceptible to both cracking and gravity settling which could results to poor mechanical properties and heavily segregated casting. In particle reinforced composite, as volume fraction increases the composite strength increases due to interaction between particles and dislocation movement within the matrix.

The most commonly used particles for reinforcing aluminium alloy matrix includes, silicon carbide, due to its favourable mechanical properties and density, Al_2O_3 due to its inertness and oxidation resistance. Graphite improves wear properties, B_4C due to neutron capturing properties and the composites are used in nuclear applications. The choice of a particle combination depends on the desired properties. Particles of lead are mixed with copper alloys and steel to improve machinability. Particles place constraints on the plastic deformation of the matrix material due to their inherent hardness relative to the matrix. Uniformly distributed reinforcement of fine particles improves mechanical properties and elevated temperature properties (Kahl and Leupp, 1990; Ray,1995).

REVIEW OF LITERATURE

Al–Cu matrix composites reinforced with Nano sized SiC by combining semi solid stirring with ball milling technology was fabricated. Precursor powders of Sic and Al–Cu alloy powders was fabricated by mixing calculated quantity of Nano–sized SiCp, (Purity 99.9wt.% and approximately 60nm in diameter) with Al–Cu alloy powder (99% pure) with average size of about 10μm using mechanical ball milling with zirconium balls at a speed of 150rpm for 50 hours. The ball to powder weight ratio used was 8:1. An electric resistant furnace was used to melt the Al–Cu alloy at 933K in air and then cooled to a semi–solid condition at 873K. The precursor powder was then introduced into the molten metal and then stirred with a graphite coated rod at a speed of 500rpm, before pouring into a preheated steel die. Both the Al–Cu and the composite were homogenized for 10 hours at 758K to avoid segregation. With the aid of a 200–ton hydraulic press, the materials were extruded at 773K with the extrusion ratio of 16 to a batten shaped samples. The extruded samples were solutionised at 773K for 2 hours and aged at 433K for 18 hours. Extruded samples were machined into dog–bone shaped tensile samples with a gauge cross section of 5.0mm x 2.5mm and gauge length of 30.0mm for tensile test using a servo–hydraulic material testing system (MTS) at a constant strain rate of $3x10^{-4}$ s^{-1} at room temperature. Results of microstructural examinations carried out with Olympus optical microscope, field emission microscope and transmission microscope revealed that the α–Al dendrites of the composites were strongly refined especially in the 3wt.% Nano sized SiCp reinforced composite. Yield strength, ultimate tensile strength and fracture strain of the cast Al–Cu were enhanced from 175MPa, 310MPa and 4% to 220 MPa, 410MPa, and 6.3% respectively. The significant improvement in mechanical properties was attributed to the refinement of the α–Al dendrites, Nano–sized SiCp strengthening and good interface combination between the SiCp and Al–Cu alloy (Feng *et al*., 2017). The preparation, characterization and mechanical properties evaluation of Al356.1 Aluminium alloy matrix composite reinforced with MgO nanoparticles was carried out. Nano size MgO were synthesized through combustion reaction process in a ceramic crucible containing mixture of magnesium oxide (MgO), nitric acid (HNO_3) and crystal sugar ($C_6H_{12}O_6$) used as fuel with little quantity of double distilled water. The ceramic crucible containing the mixture was placed in a preheated muffle furnace maintained at 850±5°C. As the mixture boils it result into a transparent gel which forms white foam that expand and fill the vessel. This was followed by a reaction initiated at the interior of the mixture and the appearance of a flame in the surface of its foam that continued rapidly throughout the entire volume until a white powder with an extremely porous structure was formed. The composite was produced by adding MgO (0.5, 1.0, 1.5, and 2.0 wt. %) into molten metal in a resistance furnace equipped in a string system at constant rate of 150 RPM for 20 minutes. At 850°c the mixture was cast into sample specimens with steel circular die for mechanical and microstructural analysis. Results of the experimental investigation depicted that the nanocomposite containing 1.5 wt.% MgO Nano powder fabricated at 850°c have homogenous reinforcement of MgO in Al356.1. Both wear

properties, tensile and hardness values were equally improved (Girisha and Chittapa, 2013). The mechanical properties of aluminium alloy reinforced with carbon black (CB) using back pressure equal angular pressing (BPECAP) was studied. 2 and 5wt. % nanoparticles of carbon in the form of carbon black (CB) were thoroughly mixed with particles of pure aluminium and then consolidated at 400 by equal channel angular pressing into fully dense bulk composite with the application of back pressure. The results of study showed increase in yield strength from 58–260 Mpa and hardness value from 37.1–96.5 (Goussous *et al*., 2009). The analysis of Nano –Al_20_3/2024 Composites prepared by the combination of solid – liquid mixed castings technique and ultrasonic treatment was investigated. The composite was synthesized by applying ultrasonic vibration on the composite melt during solidification process. Microstructural examination of the resulting composites showed reasonable distribution of Al_20_3 nanoparticles in the aluminium matrix. The subjection of the composite melt to ultra– sonic vibration during solidification was responsible to the refinement of the matrix grain microstructure and the enhanced Nano–sized reinforcement distribution (Hai *et al*., 2014). The preparation and characterisation of Nano–Al_2O_3/2024 composites by hybrid stir casting technique was carried out. The hybrid casting process consists of the combination of mechanical stir casting and electromagnetic stir casting process. Planetary ball mill rotated at a speed of 80 RPM for 12 hours was used to prepare uniform composite powers of 20μm Mg metal powder and 40nm size Al_2O_3 particles used as reinforcement. The composite was fabricated by heating 900g of Al2024 alloy in a graphite crucible placed in a resistance furnace up to 750°C for complete melting of the alloy. The graphite crucible was then placed in hybrid stir casting set–up and then stirred with the help of both mechanical stirrer as well as electromagnetic stirrer. The stirring of the melt was carried out for 2 minutes in the mushy zone under a temperature range of 620°C to 650°C to create a vortex through which the reinforcement was introduced. Current of up to 25A was used to create an electric field for the electromagnetic stirring. The melt was rotated up to 500rpm with the help of the hybrid stirring. The composite reinforcement particles pre–heated at 1100°C for 20 minutes in an inert atmosphere was injected into the melt with the aid of a stainless–steel injection tube and inert argon gas by the pressure of the inert gas. The mixture was then driven regularly for 10minutes at 400rpm by the mechanical stirrer, moved up and down to ensure uniform dispersion of reinforcement in the melt. The melt solidified under the electromagnetic field produced by 5 Amperes current since the tendency to produce shear stresses in the final product was negligible under such a low magnetic field. Analysis of the composite was carried out through scanning electron microscopy (SEM), EDAX and tensile testing. SEM micrographs revealed distributed nanoparticles in the Al2024 matrix. This was attributed to the combined effect of electromagnetic stirring coupled with mechanical stirring (hybrid stirring) that helped to refine the grain microstructure and hence enhanced the resulting distribution of Nano–particles in the melt. Tensile tests result showed that the ultimate tensile strength and yield strength improved by 43% and 86% (Kapil *et al*., 2014).

An experimental study of the tribological behaviour of aluminium hybrid nanocomposite with the additions of solid lubricant was carried out (Ravindran *et al*., 2013). Both the matrix material Al2024 and filler materials (SiC and Gr) were prepared by mechanical milling followed by a blend–press–sinter methodology. The Al2024/5wt% SiC– X wt.% graphite (X = 5 and 10) hybrid Nano composites was synthesised by powder metallurgy (PM) approach. Wear loss evaluation was carried out using pin on disc type apparatus. X – Ray Diffractometer was used to characterize the sintered samples while the observation of worn surfaces and wear debris morphology was carried out with scanning election microscope. The formation of lubricating layer on the surface of sample was used to determine the primary wear mechanism for the hybrid Nano–composites. The result of the experimental study showed that the Nano–composite reinforced with 5wt% SiC and 10wt% Gr showed the highest enhancement in tribological performance. Increasing the reinforcement content led to increase in both hardness and wear resistance of the hybrid Nano–composite.

(Devaraju *et al*., 2013) studied the influence of adding Gr_p/Al_2O_3p with SiCp on the wear properties of aluminium alloy 6061–T6 hybrid composites via friction stir processing. The hybrid composite was synthesized by incorporating mixture of (SiC + Gr) and (SiC + Al_2O_3) particles of 20μm average size on an aluminium alloy 6061–T6 plate using friction stir processing (FSP). Test results showed that the combined pinning effect of both SiC and Al_2O_3 assisted by the high hardness of Al_2O_3 helped to produce a hybrid composite with enhanced hardness and wear properties. Microstructural analyses revealed uniform dispersion of SiC, Al_2O_3 and Gr in the nugget zone (NZ). The addition of Gr micro particles rather than Al_2O_3 with SiC particles was observed to decrease the micro hardness of the aluminium alloy 6061–T6 surface hybrid composite, but significantly increased the dry sliding wear resistance of the hybrid composite.

The synthesis and characterisation of Al6061–fly ash–SiCp composite was carried out by modified stir casting route. The composite was produced by adding various weight percentages of SiC particulates and a constant weight percentage of fly ash (FA) to the aluminium alloy. In each case the mixture was stirred thoroughly to ensure homogeneous distribution of both reinforcements. Magnesium was added to the melt to improve the wettability of both SiC and FA in the Al6061 matrix. Casting into a permanent mould was carried out at 800°C. After the solidification and cooling, the composites were prepared for micro–structural and mechanical properties investigations. Results of their investigation revealed that hardness and tensile strength were enhanced as the weight percent of SiC increases in the aluminium matrix with constant weight percent of FA. Homogeneous dispersion of FA and SiC was also revealed by the optical and scanning electron micrographs. The addition of FA was also reported to have prevented the dissolution of SiCp and promoted the formation of aluminium carbide (David *et al*., 2013).

(Venkat *et al*., 2013) explored the use of fly ash and graphite particles as low–cost reinforcing materials for enhancing the tribological and mechanical properties of AlSi10Mg alloy matrix.

The AlSi10Mg/fly ash/graphite (Al/FA/Gr) hybrid composite was synthesised by stir casting technique. Dry sliding wear characteristics of the developed hybrid composites were studied using pin–on–disc machine by varying load and weight fraction of fly ash. Wear test was carried out at a constant sliding speed of 2m/s and sliding distance of 2400m. Their research findings showed that the hybrid composites exhibited higher hardness and tensile strength compared to both the unreinforced alloy and Al/Gr composites. Both wear rate and coefficient of friction (COF) of the composites was reduced owing to the addition of FA and Gr particles. The load bearing capacity of hard fly ash particles and the formation of lubricating film of graphite between the sliding interfaces were reported to be responsible for the enhancement in the tribological characteristics of the composites. As the applied normal load increased the COF and the wear rate of both unreinforced aluminium alloy and composite decreased. Increase in the FA content resulted in a decrease in both COF and wear rate of the hybrid composites, with the 9wt. % FA and 3wt. % Gr reinforced composite exhibiting the highest wear resistance and lowest COF at all the applied loads. In the mild wear regime of Al alloy and composite, abrasive wear and delamination were dominant. Plate–like wear debris was generated during delamination wear due to subsurface deformation and crack propagation. Adhesive wear with the formation of transfer layers was reported to be the dominant wear mechanism in the severe wear regime.

The effect of alumina (Al_2O_3), fly ash and hybrid reinforcement on the mechanical properties A356 aluminium alloy hybrid composites were studied. A356 ingots were cut and placed inside a cast iron crucible of 4kg capacity and then heated to a temperature of 30°C above the melting point to obtain complete melting. The liquid A356 aluminium alloy was kept at 800°C for approximately 8 minutes while being stirred at 500rpm.

Before the introduction of the reinforcement, the scum at the surface of the liquid was removed and 1wt% of magnesium was injected into the crucible to enhance the wettability between the reinforcement and the matrix. Reinforcement particles (100μm) pre–heated to 400°C was added in the vortex generated during stirring using a turbine stirrer. 0.5% Hexachloro ethane tablet was added for degassing while stirring before pouring the molten mixture into a cast iron mould pre–heated at 300°C. The temperature inside the crucible was raised by 100°C further and held for 30 minutes to minimize porosity and then allowed to cool to room temperature. In each case 3000g of A356 alloy and 4, 8, and 12wt% fly ash, alumina, hybrid reinforcement was utilized respectively to produce A356–fly ash, A356 –alumina and A356–hybrid composites.

Hardness test of the composites was carried out with a Highwood HWMMT–X7 micro hardness tester. Compression test was carried out as per ASTME9 test standard while tensile test was conducted according to ASTME8–95 test standard on 300KN machine capacity with specimen dimensions of 12.50 ± 0.05 and 62.50 ± 0.05–gauge diameter and gauge lengths respectively.

Microstructural results revealed that the produced composites possessed refined grain structure. Hybridisation enhanced the diminutive density of the composites as the percentage reinforcement addition increases. Porosity was found less in both fly ash and hybrid reinforced composites. The A356 – 12wt% Al_2O_3 composite exhibits the maximum hardness. The addition of fly ash, alumina and hybrid reinforcement resulted in increased compressive and tensile strength (Kulkarni *et al*., 2016).

REMARKS

This review has validated the possibility of the synthesis of nanoparticles of PWS, PKS and CNS through mechanical milling. The study has equally revealed that the matrix material (aluminium alloy) could be recovered through secondary melting of assorted brands of waste aluminium cans. The extent of work carried out overtime to enhance the mechanical properties of aluminium alloy has been reflected. Extensive literature search revealed that aluminium alloy has been reinforced with nanoparticles of SiC (Gaurang *et al*., 2016), MgO (Girisha and Chittappa, 2013), Al_2O_3 (Hai *et al*., 2014), carbon black (Goussous *et al*., 2009).

The combination of more than one filler (hybriding), including SiC/Gr, Al_2O_3/SiC, (Devaraju *et al*., 2013), FA/SiC (David *et al*., 2013), FA/Gr, Al_2O_3/ FA (Kulkarni *et al*., 2016) has also been used to reinforce aluminium alloys to produce composites with enhanced mechanical properties. However, the use of hybrid PWS/CNS, PWS/PKS and CNS/PKS nanoparticles as reinforcement for aluminium alloys have not received attention in literature. Research findings in all the reviewed papers are in good correlation, especially in the experimental results of Ravindran *et al.,*2013., David *et al*., 2013., Feng *et al.,* 2017., Hai *et al*., 2014 and Vencat *et al*., 2013), who reported increase in hardness, strength and wear resistance as reinforcement content increases.

CONCLUSION

Although substantial works have been carried out to improve the properties of aluminium alloys for possible automobile applications, notwithstanding use of periwinkle, coconut and palm kernel shell Nano particles for developing eco–friendly aluminium matrix Nano and hybrid composites is very scarce. This has formed the basis of the ongoing PhD study on sustainable aluminium metal matrix composite for automobile application (Tricycle connecting rod) at Department of Metallurgical and Materials Engineering, University of Lagos, Nigeria. Findings from the investigation will be communicated in another article in Future.

Acknowledgement

The authors would like to acknowledge the support of those who contributed in improving the quality of this paper.

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ISSN: 2067-3809

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SUSTAINABLE RESOURCE OF RAW MATERIALS: NON–FERROUS METALS TURNED BACK INTO THE ECONOMY AS SECONDARY RAW MATERIALS

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Abstract: Non–ferrous metals such as aluminum, copper, magnesium or zinc are important for all manufacturing industries, sustainability, and economic growth. They are irreplaceable for many products in the automotive, aerospace, mechanical engineering, and construction sectors. Therefore, non–ferrous metals are very important to the economy, competitiveness, and industrial development. The targets in waste legislation have been a key driver to improve waste management practices, stimulate innovation in recycling, limit the use of landfilling, and create incentives to change consumer behavior. The circular economy calls for a coordinated redesign of production and consumption patterns, ensuring that cascading material and product resource use continues for as long as possible. Moving away from the "take, make, use and dispose" paradigm, the circular economy aims to extract the maximum value and utility from resources and products, encouraging principles such as zero–waste design, product–life extension and resource recovery.
Keywords: raw materials, non–ferrous metals, resource efficiency, waste hierarchy

INTRODUCTION

Raw materials are particularly crucial for the development of modern technologies and a strong industrial base. Raw materials, such as metals and minerals, have become increasingly important. It can be said that raw materials, from primary and secondary sources, are the backbone of the economy. Even if we recycle better and more, primary raw materials will continue to play an important role in the economy. But, in the same time, securing a sustainable supply of raw materials must be a key priority to the global economy, growth and competitiveness. In a circular economy, waste that can be recycled is turned back into the economy, as secondary raw materials. These materials can be traded and shipped just like primary raw materials but, at present, they still account for only a small proportion of the materials used in new productions.

Non–ferrous metals such as aluminum, copper, magnesium or zinc are important for all manufacturing industries, sustainability, and economic growth. They are irreplaceable for many products in the automotive, aerospace, mechanical engineering, and construction sectors. Their unique thermal, electrical, and isolating characteristics coupled with endless recyclability and low weight make them indispensable. Therefore, non–ferrous metals are very important to the economy, competitiveness, and industrial development.

Industrial, certain parts of commercial waste and extractive waste are extremely diversified in terms of composition and volume, and very different depending on the structure of the industry or commerce sector that generates the waste and the industrial or commercial density in a given geographical area. As a result, its management involves a need for a highly complex waste management system including an efficient collection scheme, a need to actively engage citizens and businesses, a need for infrastructure adjusted to the specific waste composition, and an elaborate financing system.

The targets in waste legislation have been a key driver to improve waste management practices, stimulate innovation in recycling, limit the use of landfilling, and create incentives to change consumer behavior. Taking waste policy further can bring significant benefits: direct savings linked with better waste management practices and a better environment. The main elements are:

- increase of the preparing for re–use and recycling practices;
- gradual limitation of the landfilling of the potential secondary raw materials;
- new measures to promote prevention and re–use;

Waste management should be improved, with a view to protecting, preserving and improving the quality of the environment, ensuring prudent and rational use of natural resources and promoting a more circular economy. Also, waste prevention, according to the waste hierarchy, is the most efficient way to improve resource efficiency and to reduce the environmental impact of waste. Therefore, resources – including the non–ferrous metals and their wastes – should be used in the most efficient way and without depleting the planet's resources. Recycled waste can be turned back into the economy as secondary raw materials.

MANAGEMENT OF RAW MATERIALS & RESOURCE EFFICIENCY

The economy currently loses a significant amount of potential secondary raw materials which are found in waste streams. Only a limited value of the waste generated was recycled, with the rest being landfilled. Therefore, we need to have significant opportunities to improve resource efficiency and create a more circular economy, extracting the maximum value and use from all raw materials, products and waste. Recent trends suggest that further progress on resource efficiency is possible and that it can bring major economic, environmental and social benefits, covering the full lifecycle: from production and consumption to waste management and the market for secondary raw materials. In fact, turning waste into a resource is an essential part of increasing

resource efficiency and closing the loop in a circular economy. It should put in place adequate incentives for the application of the waste hierarchy, in particular, by means of financial incentives aimed at achieving the waste prevention and recycling objectives, such as landfill charges.

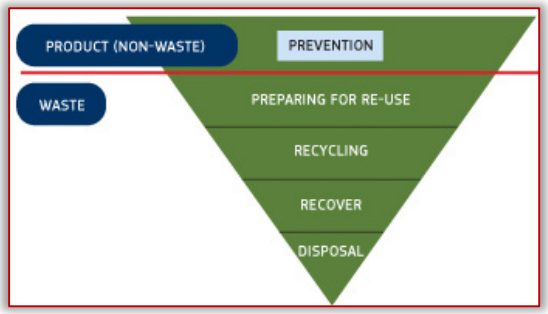

Figure 1: The waste hierarchy

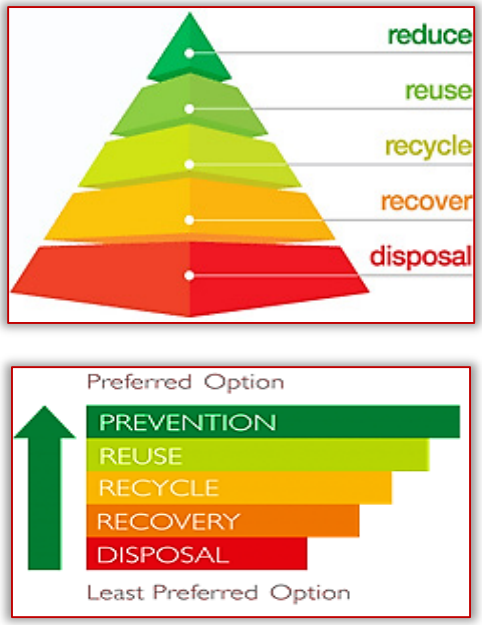

Figure 2: Preferred options in the waste hierarchy

The traditional model of economic growth – a linear economy (resource extraction – product making – waste disposal) – must therefore be replaced with a circular economy model aiming at closing the loop of resources and reducing the environmental impact of the product life cycle at all stages of the process (production, distribution, consumption).

In the linear model, mining companies extract virgin raw materials, which are subsequently processed into products by other companies. The products are sold to customers, who use them for a given time depending on the type of product. Ultimately, the products are disposed of. The disposed products are landfilled, mostly with little or no attempt to recover the products or the embedded materials.

In the linear model, mining companies extract virgin raw materials, which are subsequently processed into products by other companies. The products are sold to customers, who use them for a given time depending on the type of product. Ultimately, the products are disposed of. The disposed products are landfilled or incinerated, mostly with little or no attempt to recover the products or the embedded materials.

A radical shift is required from linear to circular thinking. End–of–life products must be considered as a resource for another cycle, while losses and stocks of unused materials must be minimized and valorized along the value chain. In addition, the interactions between materials must be considered to define the best circular solution from a systemic standpoint. The successful transition of a society to the circular economy at the global scale depends on the reliable and sustainable supply and management of raw materials. Therefore, preventing products and materials from becoming waste for as long as possible and turning wastes that cannot be avoided into a resource are key steps to achieve a circular economy. The world has streamlined its linear production systems for decades. These processes rely on virgin raw materials. This is why it is important to intensively develop technologies to utilize recycled materials. Resource efficiency has been of interest to the manufacturing industry for years, most recently expressed in several management strategies, which need to lead to minimize resource use by identifying and eliminating wasteful procedures.

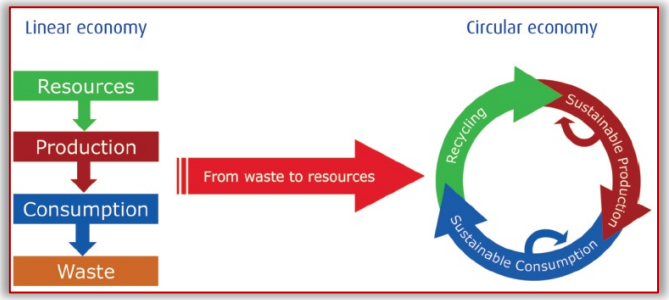

Figure 3: From waste to resources

The circular economy has the potential to preserve precious and increase scarce resources, reduce environmental impacts of resource use and inject new value into waste products, making the transition to a stronger and more circular economy where resources are used in a more sustainable way. The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re–use, and bring benefits for both the environment and the economy. The measures for changing the full product lifecycle go beyond a narrow focus on the end–of–life stage, by innovative and more efficient ways of producing.

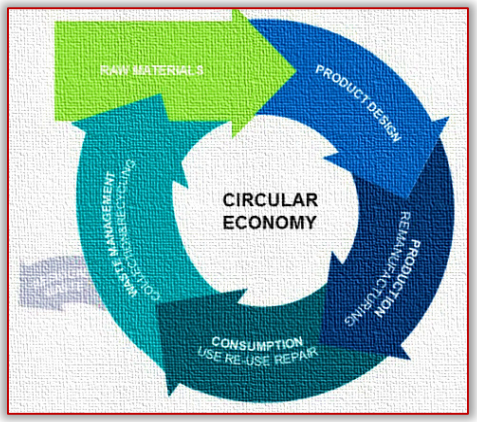

Figure 4: Conceptual diagram illustrating the "Circular Economy" in a simplified way

Resource efficiency has been of interest to the manufacturing industry for years, most recently expressed in several management

strategies, which need to lead to minimize resource use by identifying and eliminating wasteful procedures. In this sense, the circular economy suggests a setup for the production and use of goods in which resources are conserved for as long as possible. Thus, in a circular economy, resources are circulated again and again through closed loops. The useful life of products, components and materials is prolonged through repair, reuse, remanufacturing and recycling, whereby the resource efficiency is increased and the need for new products and virgin raw material is reduced or ideally eliminated.

The circular economy calls for a coordinated redesign of production and consumption patterns, ensuring that cascading material and product resource use continues for as long as possible. Moving away from the "take, make, use and dispose" paradigm, the circular economy aims to extract the maximum value and utility from resources and products, encouraging principles such as zero–waste design, product–life extension and resource recovery.

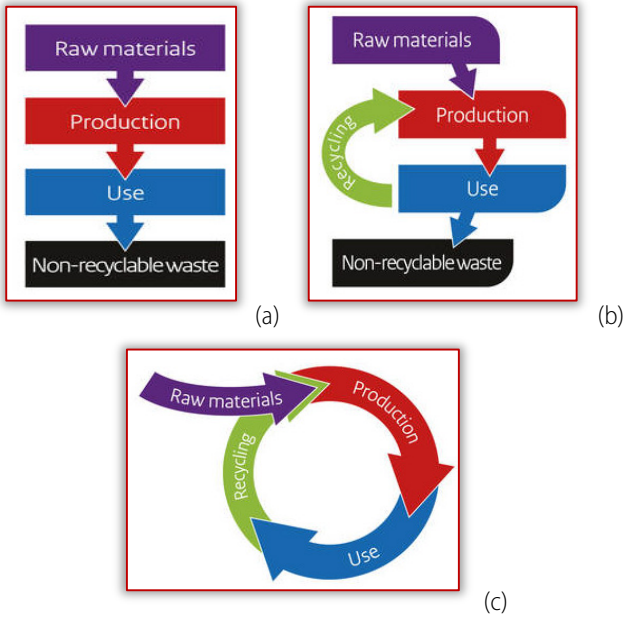

Figure 5: The resource efficiency in: (a) linear economy; (b) reuse economy; (c) circular economy

Beyond waste reduction and recycling, a more circular raw material sectors needs to search for new forms of collaborations between and across traditionally linear value chains. Circular economy strategies can offer multiple environmental benefits by keeping resources in productive use for as long as possible. Large scale system and process change, involving the entire non–ferrous industries and their supply chains, will need to be coupled with recovery and recycling on local and regional levels, working close to source, close to consumers and together with local stakeholders. Compliance with the obligation to set up separate collection systems for all wastes is essential in order to increase preparing for re–use and recycling rates. In addition non–ferrous waste should be collected separately to contribute to an increase in preparing for re–use and recycling rates of these recyclable materials.

— "preparing for re–use" means checking, cleaning or repairing recovery operations, by which waste, products or components of products that have been collected by a recognised preparation for re–use operator or deposit–refund scheme are prepared so that they can be re–used without any other pre–processing.

— "recycling process" means the recycling process which begins when no further mechanical sorting operation is needed and waste materials enter a production process and are effectively reprocessed into new products.

In a circular economy resources are kept in a circulatory system over the longest possible use phase. The materials are often used for several purposes and returned again and again in the recycling cycle. The ecological advantage of the circular economy is that it produces less waste and minimizes the extraction of resources. In fact, the aim of a circular economy is the resource–efficient and sustainable use of natural resources, their reuse and recycling within a circulatory system and the prevention of waste. The implementation of a circular economy should not be in conflict with economic interests which are served by the fact that in the system of circular economy companies generate an additional value from the materials.

Figure 6: The maximum resource efficiency

By focusing on the waste hierarchy all key stakeholders can clearly define the difference between "Reuse", "Recycling" and "Recovery". This means that our account management and supply chain teams are able to focus on the upper tiers of the waste hierarchy which supports our customer's long term sustainability strategy.

By using the guiding principles of the circular economy we can recycles more than 80% of all waste material generated. Nearly half of all waste recycled has a commodity value for our customer. These materials are no longer looked upon as waste and they are a by–product of the production process.

Recycling is an important component when replacing raw materials for a number of metals, which are recyclable and which can always be recycled without losing any of their properties. In general, recycling prevents the loss of potentially useful materials and reduces the consumption of raw materials. Thus, recycling can make a significant contribution to sustain development; at the same time the introduction of secondary raw materials in a large proportion in the production process leads to a reduction in raw material consumption. Non–ferrous metals (including aluminum) can be recovered from their waste and can be reintroduced into the production cycle by recycling without losing their qualities.

Thus, producers are increasingly focusing on a particular segment: recycling and obtaining secondary metal. The collection, sorting and supplying of secondary raw materials to industry is based on the metal recycling industry which is very active in recovering metal

from a variety of sources and consequently uses a wide range of secondary raw materials.

The most commonly used non–ferrous metals are aluminum, copper, lead, zinc, nickel, titanium, cobalt, chromium and precious metals. Millions of tons of non–ferrous scrap are recovered annually and used by smelters, refiners, ingot makers, foundries, and other manufacturers. Secondary materials are essential to the industry's survival because even new metals often require the combined use of recycled materials.

CONCLUSIONS

The rapidly growing consumption of the resources, including materials, need to find alternative solutions. Today, we extract and use around 50% more natural resources than we did just 30 years ago. Therefore, we need to become more sustainable. A significant portion of the material is recyclable and therefore, needs to be given a second life through the circular economy. In order to implement viable recycling options for non–ferrous metals, technologies with high investment and environmental risks as well as important volumes are required.

Resources like minerals are extracted from the environment and used to make a commodity, which is sold, used and then deposited as trash at the end of its life. A linear economy, more commonly referred to as "take, make, waste", cannot continue indefinitely – continuing resource constraints are putting business and humanity at risk. In the linear economy resources and raw materials are extracted, processed and usually used for a specific purpose. At the end of life the products are disposed of in the landfill or thermally recycled. Linear economy is therefore often referred to as a "disposable economy". The time is now to "close the loop" and create a more circular – and vibrant – economy that incorporates repurposing, redistributing, remanufacturing and reusing resources into our processes.

A circular economy is an alternative to a traditional linear economy in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each lifecycle. The circular economy is important because it creates sustainable opportunities for growth, helps to reduce waste, drive greater resource productivity and delivers a more competitive economy.

In a world which is increasingly demanding sustainability, non–ferrous metal recycling has become a very important practice. Millions of tons of non–ferrous scrap are recovered annually and used by smelters, refiners, ingot makers, foundries, and other manufacturers. Secondary materials are essential to the industry's survival because even new metals often require the combined use of recycled materials. The recovered materials are melted down in a furnace, poured into casters and shaped into ingots. These ingots are either used in the foundry industry or they can be transformed into flat sheets and other wrought products, which are then used to manufacture new products. Aluminum offers intelligent and practical solutions to recovering for recycling.

With the worldwide volume of wastes processed increasingly sourced from consumer and light industrial waste streams, the percentage of valuable non–ferrous metals has dramatically increased. This trend, coupled with ever increasing waste minimization and environment protection legislation, has driven the need for integrated non–ferrous recovery plants.

Non–ferrous metals, including aluminum do not degrade during the recycling process and thus can be recycled an infinite number of times. Thus, non–ferrous recovery and recycling has become increasingly important – both domestically and globally. The trends are continually increasing resource recovery rates with a particular focus on reduction of losses to and diversion from landfill. The general trend is for improvements to be sought in every area possible – new ways of applying existing technologies are sought to gain improvements along with the development of new technologies for solutions to existing and emerging applications.

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ISSN: 2067–3809

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SOUND VISUALISATION METHODS – IDENTIFICATION AND LOCALIZATION OF INDUSTRIAL NOISE SOURCES

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Abstract: The noise pollution of the population is currently one of the major environmental quality problems, especially near industrial noise sources. For this reason, noise source operators seek to reduce noise emissions from industrial plants. Various types of noise reduction measures can be applied in industrial plants. Comprehensive knowledge of noise sources and implementation of noise measurements is a first step in applying noise abatement measures. Noise visualization tools can be used for comprehensive knowledge of noise sources. Noise visualization tools allow the identification and location of noise sources and serve as a basis for designing noise abatement measures. Afterwards, these tools can be subsequently used to verify the effectiveness of the measures implemented.
Keywords: noise, visualization, measurements

INTRODUCTION

Noise visualization allows you to find the connection between the sighted and the heard. The result of noise visualization is acoustic images, where the colored fields show noise emission from individual parts of the visualized object. Noise visualization is carried out using noise visualization tools [2].

The basic design elements of these devices are sensors, especially microphones. The microphones are arranged in microphone arrays and together with the sensing device it create microphone field.

Noise visualization tools currently use different principles. The basic principles of noise visualization are beamforming, acoustic holography, focalization and direct methods.

These basic principles of noise visualization have their advantages and limitations. Manufacturers apply these methods to noise visualization tools. The design of these tools varies depending on the visualization principle used. The main differences between these devices are the frequency ranges, the measuring distances and the size of the object under investigation [2].

The fields of application of these devices are diverse and apply in different areas of industry.

The basic task of these visualization tools is to identify and locate partial noise sources. The results are presented by acoustic images and audio videos. The result of noise visualization allows a comprehensive knowledge of the source and consequently creates a suitable basis for noise reduction measures. Other tools for understanding the acoustic properties of noise sources are psychoacoustic methods and subjective noise assessment methods. These methods make it possible to assess sound quality parameters [1].

NOISE VISUALIZATION MEASUREMENTS

Noise visualization tools are nowadays available from different producers. Noise visualizations tools are often also called acoustic cameras. Noise visualization tools consist of three basic components (Figure 1):

- microphone array,
- data recorder unit,
- notebook with post processing software.

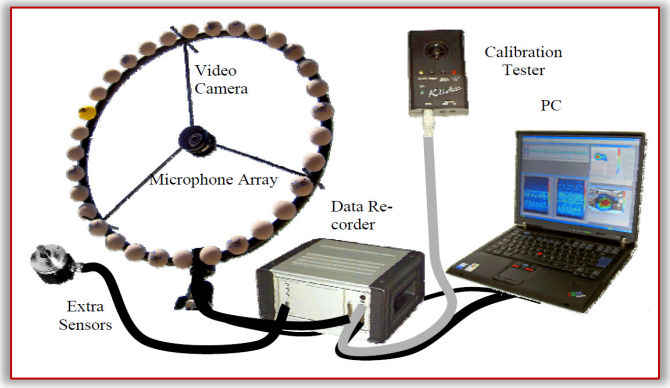

Figure 1. Basic component of noise visualization tools [11]

Noise visualization tools that are using beamforming principle are suitable for measurement distances from 1 m up to 300 m and frequency range from 300 Hz – 10 000 Hz. The measuring distance depends on the design of the microphone array. Figure 2 present different construction of beamforming microphone arrays [8].

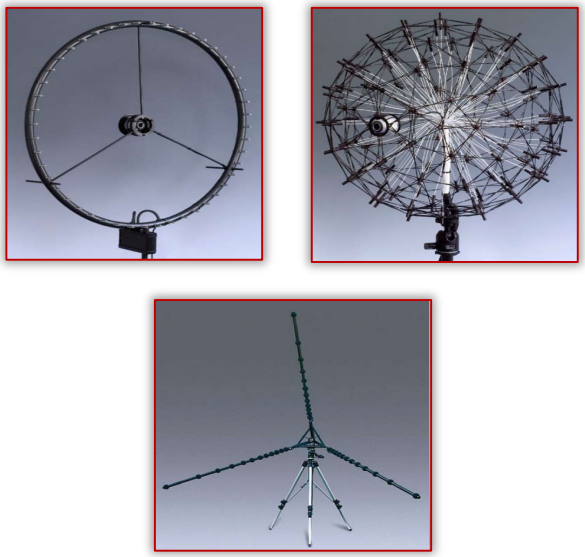

Figure 2. Microphone arrays of noise visualization tools [11]

Measurements for visualization of industrial plant noise sources were made by acoustic camera. This device visualized all the most

important noise sources of this facility. Spectral analysis was also performed to better understand the nature and nature of the transient noise.

Measurements were made to identify and locate dominant noise sources of stone mining facility. Measurements were also made to identify dominant sources and their impact on the nearest residential areas. Acoustic camera is installed during measurements (Figure 3).

Figure 3. Installed acoustic camera

RESULTS OF THE NOISE VISUALIZATION MEASUREMENTS

First series of noise visualizations measurements was realized measurements from living areas close to family houses in nearest village. Target of these measurements was to identify most critical areas in industrial site. Measurements was realized from two directions from distances 250 - 300 m. Results of the measurements presents Figure 4 and Figure 5.

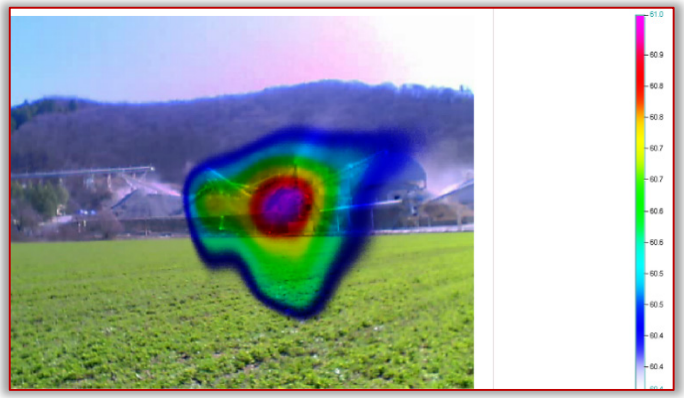

Figure 4. Noise visualization measurement of entire industrial area – south view

Figure 5. Noise visualization measurement of entire industrial area - west view

Results of these measurements clearly shows that the most critical parts of industrial area are secondary line - crushing and sorting lines.

Second series of noise visualizations measurements was focused to secondary line. These series of the measurement were realized from distances 50-70 m from the secondary line. Figures 6 - 8 show the noise emission of the visualized object over the entire frequency band. The presented acoustic images show the location of the integrated noise source

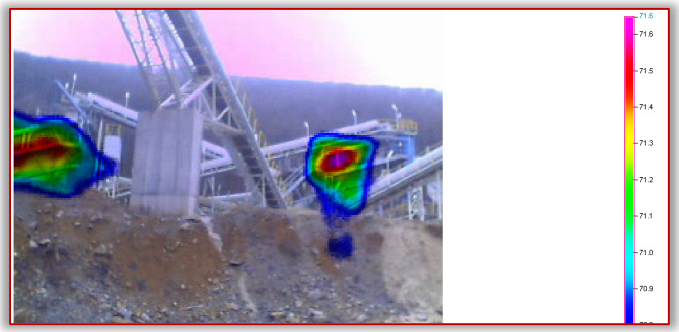

Figure 6. Noise visualization measurement of secondary line

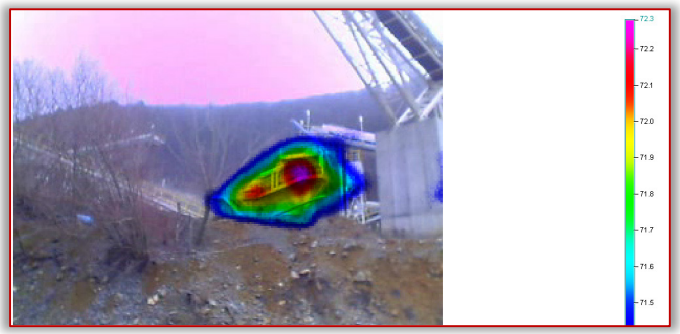

Figure 7. Noise visualization measurement of secondary line

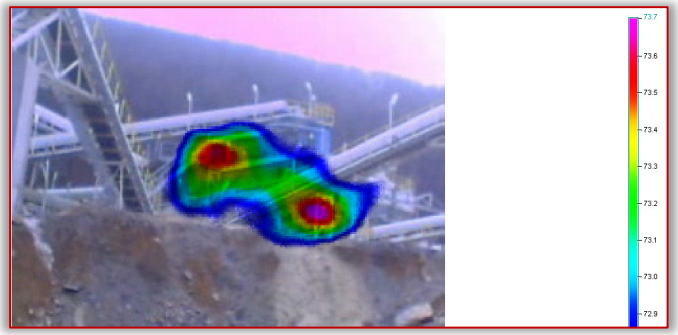

Figure 8. Noise visualization measurement of secondary line

Results of these measurements shows that the most critical of secondary line are crusher and sorter.

Third series of noise visualizations measurements was focused to individual parts of secondary line mainly (sorters and crushers). These series of the measurement were realized from distances 20-30 m from the secondary line. Figures 9-11 show the noise emission of the visualized object over the entire frequency band. The presented acoustic images show the location of the integrated noise source.

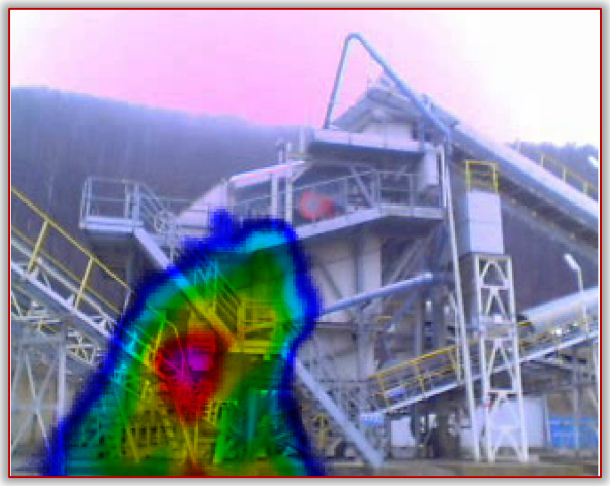

Figure 9. Noise visualization measurement of sorter 1

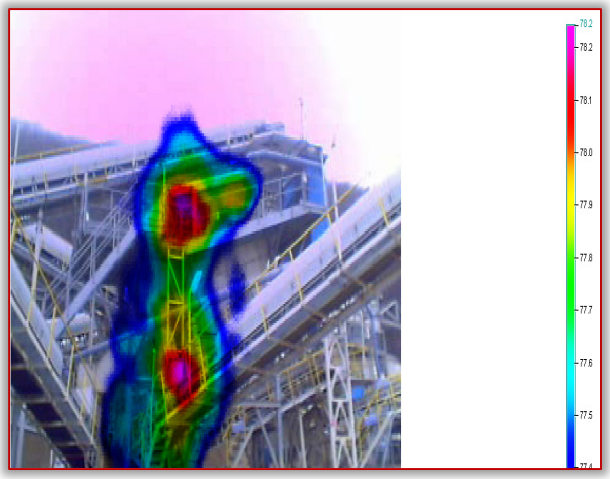

Figure 10. Noise visualization measurement of sorter 2

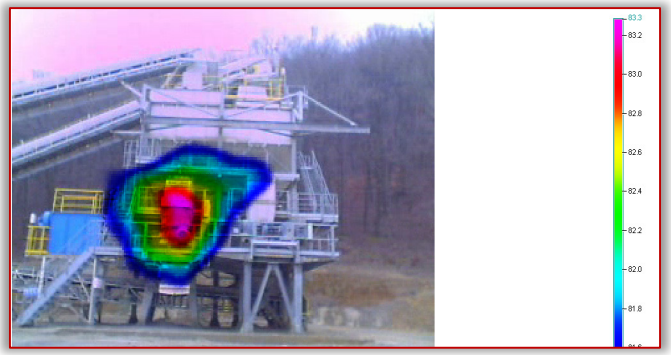

Figure 11. Noise visualization measurement of crusher

For better knowledge of noise character was generated spectrogram. Spectrogram shows dominant frequency bands of emitted noise (Figure 12).

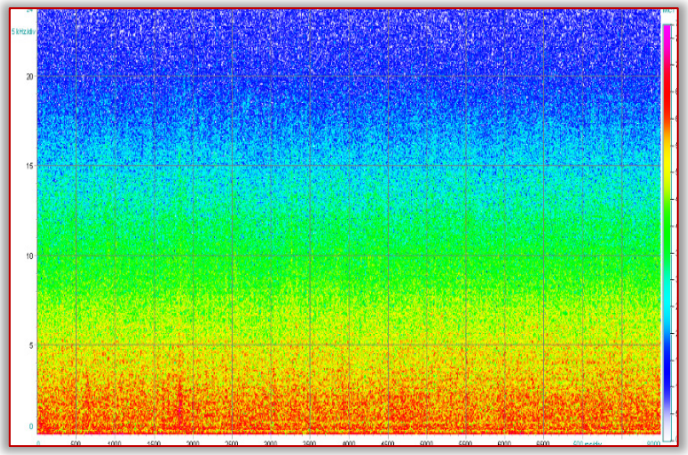

Figure 12. Noise spectrogram

CONCLUSIONS

Based on measurements of visualization of noise sources of the industrial site and secondary line we can state the following facts:

- for identification and localization of dominant noise source were realized progressive measurements from different distances,
- it has been confirmed that the secondary is the dominant source of noise due to the impact on the nearest residential zones,
- dominant noise sources (crushers and sorters) have been identified,
- specific critical points in terms of noise emissions are visualized and identified on individual objects,
- identified noise sources on these objects were confirmed by repeated measurements also from longer distances towards family houses,
- For all noise sources examined, the dominant frequency band is the frequency range from 20 - 2500 Hz, which is important in selecting suitable acoustically absorbing materials when implementing noise abatement measures.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the contract No. APVV- 15-0327 Research and development of optimization methodologies of the acoustic performance of domestic appliances emitting noise, KEGA 045TUKE-4/2018 and KEGA 041TUKE-4/2018.

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ISSN: 2067-3809

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PREDICTIVE ANALYTICS AND MODELING OF BIG DATA THROUGH MUTUAL CONTRACTION OF MAP-REDUCE AND R-PROGRAMMING LIBRARIES

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Abstract: The generation of data from every corner of the world forced the data scientists to think over it, how to handle such voluminous data while processing and storing. Therefore, to tackle this gigantic data called Big Data, its analytics has become very important. The development of innovative tools and algorithms is the need of the hour for the academic world, research study, and IT industry. The uncontrolled and continuous expansion of data sources generates heterogeneous data at a speed of light over the internet including Tweets, Facebook posts/likes, Blogs, news, articles, YouTube videos, website clicks, etc. Big data becomes a new challenge for research communities to extract meaningful information for commercial as well as personal use. There are numerous open source programming platform available free of cost for processing big data such as Hadoop, MapReduce, Hive, Flink, Spark, etc. Hadoop is an open source, distributed computing machine used for big data analytics. Map reduce is one of the most important and useful processing tools written in java language. This tool processes the large-scale data through distributed mode. It converts the large data inputs in small chunks and distributes them on different machines that are interconnected with each other in the form of a cluster. On the other hand, 'R' is another freely available statistical tool that offers a set of different types of libraries for statistical data mining. In this paper, we have presented architecture that allows coordination among MapReduce and R Libraries. This architecture will promote building predictive analytics combined with performance and flexibility for data science as it helps in exporting R libraries and process through MapReduce. The main objective of this paper is to provide in-depth analysis and relative evaluation of most up-to-date tools and models used for big data analytics.

Keywords: Big Data analysis, Data streaming, MapReduce, R libraries, Hadoop, Hive, Flink, Spark

INTRODUCTION

The sudden increase of information that is being generated online by means of social media, internet, and worldwide communications has increasingly rendered data-driven learning. A new study revealed that over 4 million queries are being received by Google every minute, e-mails' sent by users reaches the limit of 200 million messages, 72 hours of videos are uploaded by YouTube users, 2 million chunks of content are shared over Facebook, and 277,000 Tweets are generated every minute on Twitter, Whatsapp users share 3,47,222 photos, Instagram users post 2,16,000 new photos every minute [1], [2]. The present age is the age of Big Data, where data is growing on a large scale than ever before. According to the Computer World, 70% to 80% of data is considered to be in the unstructured form in organizations [3]. The data, which derives from social media, form 80% of the data globally and report for 90% of Big Data. As stated by the International Data Corporations (IDC) annual digital universe study [4], the data are being produced too rapidly and by the estimation of 2020, it would touch the range of 44 zettabytes which would be ten times larger than it was in 2013[5].

With the amount of data growing swiftly on a large scale, there may arise a situation when conventional analytical methods lack the ability to process such voluminous data and therefore we require advanced algorithms and techniques in order to extract data values that best aligns with the user interests, which finally became the key to introduce a new technology to the world called Big Data [3].

We are aware of the fact that the data storage capacities are increasing day-by-day; secondly, we lack the tools that are as powerful as to handle such massive data. Big data analytics is gaining focus from every field of research particularly from IT industry because of its unbeatable processing power in major areas like healthcare, business firms, social media, education, banking [1], etc.

Conventional means of processing and evaluation of data mostly depend on restricted data set organized in a structured form. Such tools and technologies are unsuccessful to put in any value in big data aspects [6]. Hence, more powerful machines and innovative techniques are compulsory to process the data and in fact, the generation of data on a large scale is the point of departure for the emergence and intensification of Big Data. Gigantic and multifarious data is out of the capability of traditional data warehousing tools to process.

As the technology and services seemed to have progressed at a pace, it leads to the generation and extraction of such giant sum of data from several sources that can be heterogeneous. The need for Big Data emerges from major companies like Google and Facebook [7]. The data that is generated while using Facebook or Google is mostly of unstructured form and it seems laborious to process data that contains billions of records of millions of people. Therefore, Big Data can be stated as the quantity of data that is far-fetching from the potential of technology to pile up, handle and process in the most powerful and substantial way.

BIG DATA CHARACTERISTICS

— Volume

The massive quantity of data that is derived every second constitutes the volume of Big Data [6,8]. There are multiple numbers of sources that play a key role in producing this vast portion of data like social media, surveillance cameras, sensor data,

weather data, phone records, online transactions, etc. We are living in an age where data is generated in petabytes and zettabytes. This sudden boom in the production of data that is too large to store and analyze requires advanced tools and techniques that open the way for Big Data. To handle such voluminous data is really a big challenge for the data scientists [9].

— Velocity

Velocity is defined by how rapidly the new data is being generated. As we see how messages on social media go viral within no time, millions of photos are being uploaded by Facebook users each and every second, it takes milliseconds for the business systems to analyze social networking websites to gather message that set off the verdict to purchase or sell shares[6,8]. Big Data streaming processing method makes it possible to examine the data while it is emanated, in need of ever storing it into the database.

— Variety

Variety focuses on different forms of data like music, pictures, text, e-mails, medical records and images, weather records and log files, etc. generated from multiple sources. This means that the data produced belongs to different categories consisting of raw, unstructured, structured and semi-structured data which looks very difficult to deal with [9].

— Veracity

Veracity denotes the meaningfulness or value of data.

— Value

Value focuses on the analytics and statistical methods, knowledge extraction and decision-making [6,8]. The data that is generated and it is not analyzed and processed then it is nothing other than garbage.

— Validity

Validity and Veracity are not the same but have a similar concept. Validity means the accuracy of data for the intended usage. Veracity leads to validity if the data is properly understood, it means that we have to check properly and appropriately whether the dataset is valid for a particular application or not [9].

— Volatility

Volatility refers to the period for which we have to store the data. If volatility is not in place then a lot of storage space is wasted in storing data that is no more required, for instance a commerce company keeps the purchase history of a customer for 1 year only as after 1 year the warranty on the purchased item expires so there is no reason to store such data [9].

THE SLANT OF BIG DATA ANALYTICS

— Data identification and collection

In this phase, multiple forms of a large number of data sources are recognized on the basis of the scope of the problem. More is the number of data resources more are the chances of discovery of hidden associations and patterns among data. Tools are required to encapsulate keywords, facts, and figures from these varied data sources as shown in Figure 1.

— Data storage

The data taken from various types of data sources are composed of structured and unstructured data and it has to be stored in databases/ data warehouse for future use. Traditional databases are not capable of handling such voluminous data; hence we require more powerful databases that can accommodate Big Data like NoSQL. There are innovative and influential models and databases that have been developed and maintained by organizations like Apache, Oracle, Facebook, Google, etc. that permit interpretive tools to obtain and perform processing of data from these data warehouses.

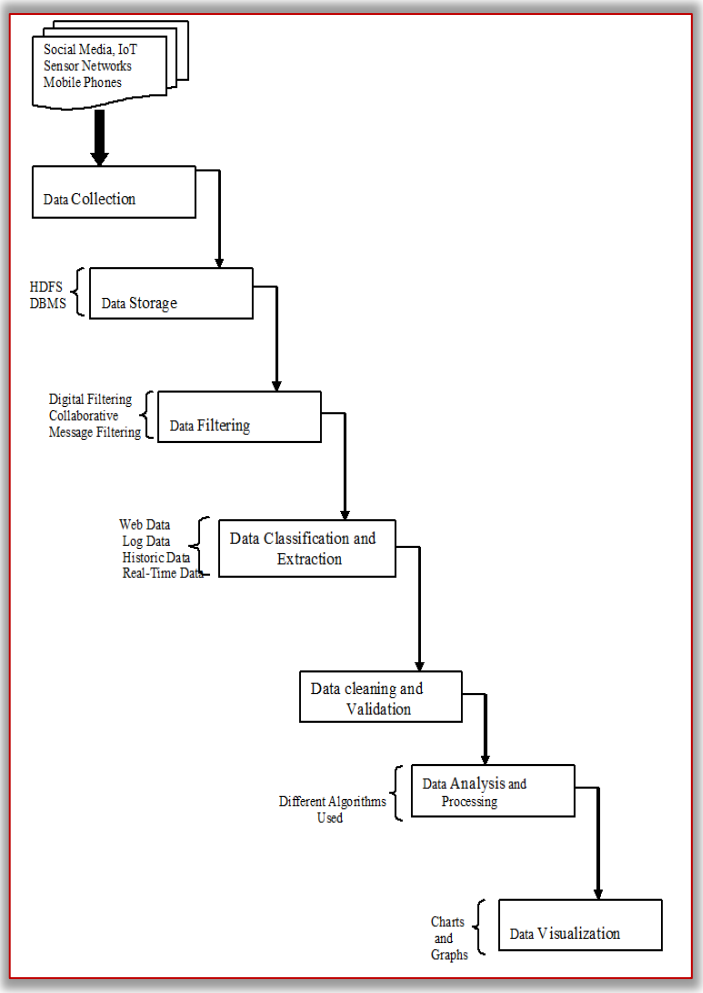

Figure 1. Data Analysis Process

— Data filtering and noise elimination

This phase plays a very important role in data analytics; the main objective of the concerned phase is to remove the redundant data, null and inconsistent data from the collected information. However, the data that has cleaned after the process of filtration might be beneficial in another context or analysis [10].

— Data classification and extraction

The data that is generated after the process of filtration goes under the classification. In this phase, the data is classified on the basis of the domain and the data that is out of a particular domain is extracted and converted into a common data format that can be used for analytics using different analytical tools [11].

By means of extraction, the data that is relevant or similar are also mined in order to reduce the data volume that is to be submitted to the analytics engine.

— Data cleansing, validation, and aggregation

This stage is used to apply validation rules on the basis of the business case. Validation rules authenticate that the data entered by the user meets the principles specified before the record is

saved. A validation rule comprises expression or formula that estimates the data in one or more fields. Even though, it may be complicated at times to put into use validation checks to the mined data due to intricacy. Aggregation is employed to merge compound data sets into smaller numbers based on common fields. This makes data processing further simpler.

— **Data analysis and processing**

This stage is responsible for actual data mining and analysis to ascertain inimitable and unknown patterns for making business decisions. The techniques used for data analytics may be different on the basis of the business case i.e. confirmatory, predictive, diagnostic or descriptive, exploratory and prescriptive [11].

— **Data visualization**

Under this phase, the results obtained from the analysis are represented into charts or graphical form so that it becomes easy to understand for the viewers.

BIG DATA ANALYTICS TOOLS

The main objective of big data analytics is to employ the most innovative and highly developed analytic tools and techniques in addition to gigantic, multiple forms of datasets like structured or unstructured, in the range of terabytes to zettabytes.

Big data comes into play for processing of voluminous data sets that are out of range from the processing, capturing and managing the potential of conventional relational databases. However, Big Data analytics tools make use of artificial intelligence, data mining and new techniques for data analysis. Some of the most important analytics tools are summarized as under:

— **Hive**

Apache Hive is an open source software project used for data query and analysis, built on top of Apache Hadoop. Although, the hive was very popular from the beginning as Facebook was developing it. These days, we on a regular basis execute millions of jobs over the Hadoop/Hive cluster having thousands of clients for a large number of applications ranging from easy summarization tasks to big commerce intelligence, support Facebook product features and machine learning applications [12].

As in the case of conventional databases, Hive also stores data in the form of tables, where each table is composed of multiple rows and each row is made of a specific number of columns. At this time, the following data types are supported:

1. Integers – big int (8 bytes), int (4 bytes), smallest (2 bytes), tiny int (1 byte). All integer types are signed.
2. Floating point numbers – float (single precision), double (double precision)
3. Strings
4. Associative arrays – map
5. Lists – list
6. Structs – struct.

Hive provides an SQL-like interface to query data that is stored in a variety of databases and file systems that amalgamate with Hadoop. The main components of the Hive are mentioned below:

» **Metascore:** The component is used to store the system directory and metadata about tables, columns, partitions, etc.
» **Driver:** It is responsible for handling and managing the hive query language statements as it moves from one phase to other through the hive.
» **Query Compiler:** After the query submission, it is query compiler which compiles HiveQL statements into a directed acyclic graph of map/reduce tasks.
» **Execution Engine:** The output from query compiler is provided as input to execution engine in the proper order of dependency.
» **Hive Server:** It is the component that makes the interface available to the user. It contains a JDBC/ODBC server by means of combining Hive with other applications.
» **Client components:** Client components include Command Line Interface (CLI), the web UI and JDBC/ODBC, driver.
» **Extensibility Interfaces:** If the user wants to make use of functions that are not available in the metastore, this component allows the user to define their own functions.

— **Apache Spark**

Spark works on Hadoop MapReduce algorithms provides a computing framework that is distributive in nature. It is efficient as it uses Memory Computing where the intermediate and output results can be stored in memory. Spark is particularly used for iterative applications like Machine Learning and Data Mining. Spark is based on the concept Resilient Distributed Datasets (RDD), which is a set of components that work in a parallel fashion with fault tolerant feature and permits users to unambiguously to store data in memory [13].

RDD is read-only data sets, loaded with an enormous set of operators to manipulate the data. Spark offers high-level APIs in python, scala and R and an engine that allows optimization. It provides a set of higher level tools like spark SQL for SQL, sparks streaming for streaming data, GraphX is used for graph processing and MLlib for machine learning. Spark SQL is like an SQL language that process queries admitted by the user. Spark Streaming is a computing model to process real-time data. It provides an API that allows integration of batch, streaming and interactive query applications. There is a parallel computation API called GraphX that is used for Spark charts and graph processing.

Spark supports a machine learning library that is scalable in nature called MLLib (Machine Learning library). The performances of Machine Learning algorithms are more efficient than Map-Reduce. MLLib includes the core algorithms primarly used for Machine Learning, such as clustering, collaborative filtering, dimensionality reduction, classification, regression and supports Sparse Matrix.

— **Apache Storm**

In December 2010, an idea strike to the mind of Nathan Marz, who thought if there exists a processing system that works on real-time data in order to save a lot of storage that is needed to store the data. The output of this idea came into the form of a new project that is called a storm.

Apache Storm enables software developers to build distributed systems that perform the processing of real-time data at a faster rate. Apache Storm is considered to be highly scalable, simple to use, and offers low delay with guaranteed high data processing. The architecture of the storm is very simple in order to build applications [14].

Apache Storm, on 17 September 2014 becomes the part of Apache family. Apache storm is an efficient tool that offers a couple of key attributes such as easy to use, fast as it processes millions of records in seconds, fault tolerant means processes data without any disturbance if a node fails to operate, the operation is performed by some other node in the cluster, reliability, and scalability which means processes the data in a parallel fashion over a number of machines that are connected with each other in order to share data.

— Map-Reduce

Map-Reduce is a programming mode, used to refine for massive data files with the implementation of coordinated and disbursed algorithms on a cluster. Map-Reduce programming structure is sparked by the Map ( ) and the Reduce ( ) function. In Map ( ) step, the Master Node or the Name Node accepts the input file and partition it into minor sub-problems, these sub-problems are then assigned to Slave Nodes or Data Nodes.

The Slave Nodes may further divide the problem into sub-subproblems. The Slave Node then handles these smaller problems and responds to the Master Node to which it is connected. In the Reduce ( ) step, the Master Node receives the result and combines them together to turn out the final result to the original problem that it has to solve [15].

R PROGRAMMING

There are various programming platforms available for processing the data and extract useful information for commercial and personal use. R programming is an important statistical programming interface available for gathering information. It is also open source, so users have no need to pay any license fee for personal use.

However, if somebody wants to use for commercial purpose then he/she is required to purchase its commercial version. R programming offers a wide range of packages and libraries for processing statistical data on a large scale. There are a variety of other related programming interfaces such as Weka and MATLAB that offers support for multiple statically operations, R-programming also supports matrix arithmetic.

Data structures of r-programming include vectors, matrices, arrays, data frames (alike tables in a relational database) and lists [16], arrays are stored in column-major order. R's extensible object system includes objects for (among others): regression models, time-series and geospatial coordinates. The scalar data type was never a data structure of R. Instead, a scalar is represented as a vector with length one [17-18]. There is a couple of libraries available in R, that supports Map-Reduce framework such as rHDFS, rmr, and rhbase.

— rHDFS

The R programming provides fundamental connectivity to the Hadoop Distributed File System through rhdfs library. The rhdfs library worked as an interface between R programming and Hadoop Distributed File System, which allows the client to access and process HDFS from the R programming interface. It can be used to browse, read, write, and modify files stored in HDFS.

The first function of rhdfs is Manipulation [19]. The users can write hdfs.copy, hdfs.move, hdfs.rename, hdfs.delete, hdfs.rm, hdfs.del, hdfs.chown, hdfs.put, hdfs.get commands as per the need and the format of data plus domain of data. In order to Read or Write files through rhdfs library, it has different commands such as hdfs.file, hdfs.write, hdfs.close, hdfs.flush, hdfs.read, hdfs.seek, hdfs.tell, hdfs.line.reader, hdfs.read.text.file.

The Directories handling commands are hdfs.dircreate, hdfs.mkdir.

— rmr

The rmr library provides Map-Reduce functionalities in R programming. The Hadoop clients may write Map-Reduce programs in R programming in a more productive and more elegant way. It provides a great statistical working environment for researchers. The R Programming clients may access big data analysis techniques by using Map-Reduce programming functionality on its console.

The rmr library must not be seen as data streaming, even it can be used as a streaming architecture. The Client can perform Hadoop streaming through R programming without any of those libraries since the language support stdin and stdout access [20].

— rhbase

The rhbase library provides connectivity functionalities in R programming. There is a wide range of versions available in R programming with rhbase library. The library comes with convenient functions to browse, and manipulate (read, write, and modify) files stored in the Hadoop Distributed File System.

WORKING PRINCIPLE OF R-LIBRARIES WITH MAP-REDUCE

Map-Reduce is an open source software that provides a platform for processing huge volumes of heterogeneous data in a most efficient way and produces striking results. It works on a distributed computing platform and supports Java programming language.

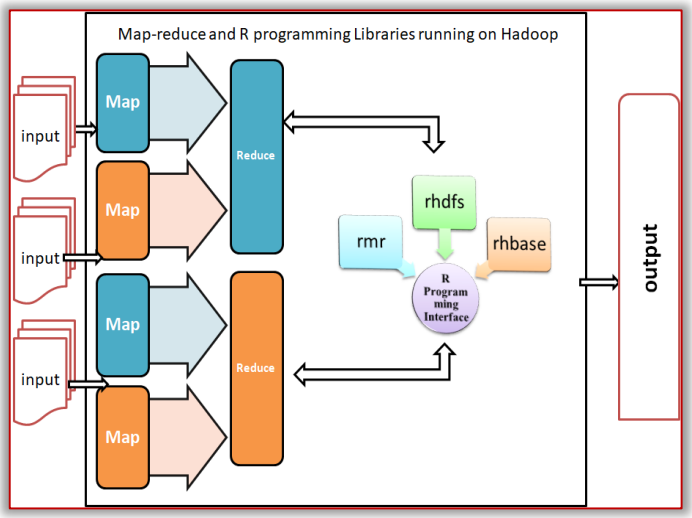

Figure 1. The architecture of Map-educe and R Programming libraries

Hadoop is proficient to run Map-Reduce programs that are written in diverse languages: Java, weka, Python, and C++. All of the programs of map-reduce are parallel in nature. It is a combination of Map and Reduces and the working principle of Map-Reduce is covered in previous Section.

The inputs given to the Hadoop platform are divided into various fixed size job. These jobs have also assigned as mapping or map function. The next phase of Map-Reduce consumes the yield of the Map function. Now the main task is to merge the relevant records from Map function output. In proposed architecture (Figure 1), the

related chunks have clubbed together along with their respective occurrence.

The outputs from the shambling phase are aggregated. Now Reduce function combines values from shambling phase and returns a single output value. Reduce function does not work on the perception of data locality. The resultant value of every Map job is fed to the Reducer. Map resultant values have been transferred to the machine where Reduce task is executing. Disparate the Map job, the output of the Reducer function has to be stored in the Hadoop File System.

The main function of R-Hadoop file system also collaborates to process the data. All of these three libraries run independently to manipulate the partitioned job and then produce consolidate output. The data manipulation power of R is competent and the turnaround time of R-programming language is really amazing as compared to other data manipulation platforms.

CONCLUSION

Big data analytics has boosted the IT industry as it has proven to be a very important tool to mine valuable patterns and unknown correlations of the potential consumer market, client preferences, buying attributes and a lot of other information from intricate data sources. The existing data processing techniques are not capable to handle this massive, varied and complex data. Nowadays e-commerce and digital markets have become hot areas which play a key role in the generation of Big Data and are gaining so much popularity that the commerce industry depends on online transactions and services to a great extent.

In this paper, we have presented architecture that allows coordination among Map-Reduce and R libraries. This architecture will promote building predictive analytics combined with performance and flexibility for data science as it helps in exporting R libraries and process through Map-Reduce. The main objective of this paper is to provide in-depth analysis and relative evaluation of most up-to-date tools and models used for big data analytics.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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INFLUENCE OF SUGAR CANE BAGASSE ASH AND SAW DUST ASH ON CHARACTERISTICS OF CONCRETE BRIDGE SUBSTRUCTURES EXPOSED TO CRUDE OIL CONTAMINATED ENVIRONMENT

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Abstract: Two different concrete mixes containing 0%, and 20% mixture of sugar cane begasse ash and saw dust ash were prepared and cured in portable water of 0%, 5%, 10%, 15%, 20% , 25% and 30% contamination with crude oil. The compressive strengths of concrete specimens were evaluated at the 3rd, 7th, 14th, 28th, and 56th days. The compressive strength of the concrete specimens increased with increase in age and decreased with increase in contamination of curing water with crude oil. The concrete specimens containing 20% percentage replacement of cement with mixture of sugar cane bagasse ash and saw dust ash showed increase in compressive straight, split tensile strength and slump values. The research therefore concluded that mixture of sugar cane bagasse ash and saw dust ash should be used as partial replacement of cement in production of high performance concrete for bridge substructures exposed to crude oil contaminated environment.
Keywords: bridge substructures, compressive strength, crude oil contaminated environment, high performance concrete, slump

INTRODUCTION

A bridge is a structure which provides passage over an obstacle without closing the way underneath. The required passage may be for a rail track, road, or pedestrians etc. The obstacle to be crossed may be traffic, deep valley full of water, river etc. Before constructing a bridge at a particular site, it is essential to consider some factors such as: need for the bridge, present and future traffic volume, characteristics of the stream/river, sub soil conditions, cost of the project, alternative sites available and their relative merit, aesthetics etc (Gupta and Gupta, 2010). Figures 1a, b and c show typical bridge substructures and superstructures. A bridge is a structure, including supports, erected over a depression or an obstruction, as water, highway or railway and having a track or passageway for carrying traffic or other moving loads and having an opening measured along the center of the roadway of more than 20 feet (6.09600 meters) between under-copings of abutments or extreme ends of openings for multiple boxes. The bridge length is the greater dimension of the structure measured along the center of the roadway between the backs of abutment back walls or between ends of bridge floor. The bridge roadway width is the clear width of the structure measured at right angles to the center of the roadway between the bottom of the curbs or, if curbs are not used, between the inner faces of parapet or railing. The bridge substructures are all that part of the structure below the bearings of simple and continuous spans, skewbacks of arches and top of footings of rigid frames; including back walls, wing walls, and wing protection railings. The bridge superstructures are all that part of the structure above the bearings of simple and continuous spans, skewbacks of arches and top of footings of rigid frames; excluding back walls, wing walls and wing protection railings (Ohio department of transportation Columbus [ODOT], 2013, Oregon department of transportation [ODOT], 2015, Arizona department of transportation [ADOT], 2008, Tennessee department of transportation [TDOT], 2015, Colorado department of transportation [CDOT], 2011, North Carolina department of transportation [NCDOT], 2012, Florida department of transportation [FDOT], 2010 and Indiana department of transportation [INDOT], 2014). A bridge is a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 6.5m between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it also may include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening (Portland cement association [PCA EB233], 2005).

Ejeh and uche (2009) investigated the effect of crude oil spill on concrete materials. They conclude that the undiluted crude oil has the highest deterioration effect in concrete materials, when compared with the values of the control medium (water). They also suggested that mixing and curing water should be free of crude oil spill to ensure durability and stability of cement- based structures, as the compressive strength of material will be adversely affected if otherwise.

American concrete institute (AC1 232.1R, 2000) and American concrete institute (ACI 232.2R, 2002) defined pozzolan as a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divide form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Natural pozzolan is defined as either raw or calcined natural material that has pozzolanic properties. The natural pozzolans in the raw or calcined state are designated as class N pozzolans and are describe in the specification as " Raw or calcined natural pozzolans that comply with the applicable requirements for the class". Raw or processed natural pozzolans are used in the production of hydraulic- cement concrete and mortars in two ways: as an ingredient of blended cement, or as a mineral admixture (AC1 232.1R 2000, and American society for testing and materials (ASTM

C618, 2015). A ternary mixture is simply a mixture of three components. In the case of a ternary mixture of cementitious materials, for example the component could be Portland cement, fly ash, and slag. Likewise, the combination could be a blended cement (already a binary mixture) and slag. Ternary mixtures are becoming more prevalent because they can enhance performance and reduce cost. The reduction in cost is associated with the fact that most supplementary cementations materials are by-products. However the used of these materials also decrease the amount of Portland cement that must be manufactured. This makes the cement industry more sustainable (ASTM C618 2015, AC1 232.1R 2000, ACI 232,2R 2002).

1a)

(1b)

(1c)

Figure 1a, b and c. Bridge substructures and superstructures

Artificial pozzolans are finely divided cementations material other than Portland cement, consisting of mainly of fly ash, ground blast furnace slag, or silica fume (Micro silica), and have been considered in the production of high-strength concrete because of the required high cementitious materials content and low water cementitious material ratio. These materials can help control the temperature rise in concrete at early ages and may reduce the water demand for a given workability. However early straight gain of the concrete may be decreased (American concrete institute [ACI 211.4R], 2008 and ASTM C618). This research therefore aims at evaluating the influence of ternary mixed containing sugar cane bagasse ash and saw dust ash on compressive strength of concrete bridge substructures exposed to crude oil contaminated environment.

MATERIALS AND METHODS

— Materials

Cementitious materials, fine aggregate and coarse aggregate

The hydraulic cement used in this study conforms to the specifications of American association of state highway and transportation officials (AASHTO M 85, 2016). The saw dust ash and sugar cane bagasse ash used have the same properties with the class F fly ash in line with the specifications of ASTM C618 (2015), ACI 232.1R (2000), ACI 232.2R (2002) as shown in the Tables 1. The fine aggregate used in this study satisfied the specifications of American association of state highway and transportation officials (AASHTO M6, 2013) and, the course aggregate used satisfied the specifications of American association of state highway and transportation officials (AASATO M80, 2013). Both aggregate conform to the specifications of American society of testing and materials (ASTM C33/C33M, 2016).

Table 1. Average chemical composition of sugar cane ash and saw dust ash.

Chemical composition	Percentage composition (%)	
	Saw dust ash	Sugar cane bagasse ash
SiO_2	65.62	56.70
Al_2O_3	5.69	6.81
Fe_2O_3	2.16	15.52
CAO	9.82	9.30
MgO	4.23	4.50
SO_3	0.04	-
Na_2O	2.38	0.12
K_2O	7.89	3.46
LOI	2.89	1.08
$SiO_2+Al_2O_3+Fe_2O_3$	73.47	79.03

Crude oil, mixing water and curing water

The crude oil used in this study satisfied the specifications of American society of testing and materials (ASTM D2892, 2016), American society of testing and materials (ASTM D1298-12b, 2012) and American society of testing and materials (ASTM D8056, 2016). The mixing water and curing water for 0% contamination of curing water with crude oil conform to the specifications of Washington state department of transportation (WSDOT M23-50, 2016), FDOT (2010), NCDOT (2012), CDOT (2011) and PCA EB 233 (2005).

— Methods

Physical properties of fine and coarse aggregate

The sieve analysis was conducted for fine and coarse aggregate in accordance with American society of testing and materials (ASTM C136M, 2014). The specific gravity and water absorption of the fine and coarse aggregate were conducted in accordance with American association of state highway and transportation officials (AASHTO T84, 2013) and American association of state highway and transportation officials (AASHTO T85, 2013) respectively. The aggregate crushing value and the Los-Angeles abrasion value tests were conducted for the coarse aggregate in accordance with ASTM C33/C33M – 16el (2016) , American society of testing and materials

(ASTM C131/C131M, 2014), and American concrete institute (ACI 201.2R, 2016).

Mix design and slump test

The concrete mixes were designed and batched in accordance with the specifications of ACI 211.4R (2008), ODOT (2013), ODOT (2015), and ADOT (2008). The mixing water confirms with the specifications of TDOT (2015), CDOT (2011), NCDOT (2012), FDOT (2010) and INDOT (2014). The water cement ratio was maintained at 0.55 and the maximum size of coarse aggregate used was 19mm. The slump test was carried out to determine the consistency of the fresh concrete and it is in conformance with WSDOT M23-50 (2016), ODOT (2013), ODOT (2015), and ADOT (2008).

Curing media

The concrete specimens marked D1 were cured in portable water medium conforming to WSDOT M23-50 (2016), FDOT (2010), NCDOT (2012), CDOT (2011) and PCA EB 233 (2005). The concrete specimens marked D2, D3, D4, D5, D6 and D7 were cured in portable water/crude oil media of 5%, 10%, 15%, 20%, 25% and 30% by weight of crude oil. The portable water / crude oil media were prepared to represent different concentration of crude oil contamination of the environment.

Compressive strength and splitting tensile strength

The concrete specimens were of 150mm diameter and 300mm long. The compressive strength of the specimens was evaluated at the 3rd, 7th, 14th, 28th, and 56th day age. The average compressive strength value for each age was recorded as the compressive strength in accordance with the specifications of WSDOT M23-50 (2016), FDOT (2010), NCDOT (2012), CDOT (2011) ODOT (2013), ODOT (2015), ADOT (2008), TDOT (2015), CDOT (2011), NCDOT (2012), INDOT (2014), ACI 201.2R (2016) and PCA EB 233 (2005). The splitting tensile strength was conducted in accordance with WSDOT M23-50 (2016), and PCA EB 233 (2005). The concrete cylindrical specimens used for the splitting tensile strength test were of 150mm diameter and 300mm long.

RESULTS AND DISCUSSION

— Properties of crude oil used and aggregate characteristics

Table 2 shows the results of the laboratory analysis of the crude oil specimen used in this study. The results satisfied the specifications of the ASTM – D2892 (2016).

Table 2. Results of the laboratory analysis of the crude oil specimen

S/N	Parameters	Values
1.	Specific gravity @ 60°F or 15.55°C	0.85
2.	API specific gravity at 60°F or 15.55°C	36.80
3.	Density at 60°F or 15.55°C	0.84
4.	Pour point	3.8°C
5.	Sulfur content, % weight	0.13
6.	Colour	Dark brown
7.	Salinity T.B at 0.10% BS & W	46
8.	Acid number	0.38
9.	Reid vapour pressure	6.41 psig
10.	Water and sediment content pct (%)	0.9
11.	Iron weight, PPM	0.83
12.	Nickel weight PPM	4.0
13.	Vanadium wt.ppm	1.89

Table 3 shows the combine sieve analysis results of the fine and coarse aggregate from Table 3 it can be seen that the aggregate used were well graded of 19.00mm maximum size. The results shown in Tables 3 and 4 show that the fine and coarse aggregate used in this study satisfied the specifications of ASTM C33/C333M – 16E1 (2016), WSDOT M23-50 (2016), AASTHTO M80 (2013), FDOT (2010), and NCDOT (2012).

Table 3. Physical properties of fine and coarse aggregate

S/N	Properties	Fine aggregate	Coarse aggregate
1.	Specific gravity	2.61	2.73
2.	Water absorption (%)	2.10	3.0
3.	Los Angeles abrasion value (%)	-	29
4.	Aggregate crushing value (%)	-	24

Table 4. Combined aggregate gradation (fine and coarse aggregate)

Serve size (mm)	Percentage retained (%)	Cumulative percentage retained (%)	Percentage passing (%)
25	0.00	0.00	100
19	3.42	3.42	96.58
12.5	21.21	24.63	75.37
9.5	13.10	37.73	62.27
4.75	12.42	50.15	49.85
2.36	10.85	61.00	39.00
1.18	15.84	76.84	23.16
0.6	6.11	82.95	17.05
0.3	8.31	91.26	8.74
0.15	4.72	95.98	4.02
0.075	2.22	98.17	1.83

— Concrete mix design and curing media

Tables 5 and 6 show the concrete mix design of the specimen containing 0% and 20% replacement of cement with sugar cane bagasse ash and saw dust ash respectively.

Table 5. Concrete mix design of 1: 2: 3 for specimens containing 0% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

Concrete cylindrical specimen mark	Percentage contamination of curing water with crude oil (curing media) (%)	Water cement ratio	Cement (kg/m^3)	Fine Aggregate Kg/m^3	Coarse Aggregate Kg/m^3
0D1	0	0.55	400	800	1200
0D2	5	0.55	400	800	1200
0D3	10	0.55	400	800	1200
0D4	15	0.55	400	800	1200
0D5	20	0.55	400	800	1200
0D6	25	0.55	400	800	1200
0D7	30	0.55	400	800	1200

The water cement ratio in Table 5 was kept content for all specimens containing 0% and 20% sugar cane bagasse ash and saw dust ash. The fine aggregate to total aggregate ratio is 0.4. The physical properties of the aggregates shown in Table 3, the combine sieve analysis results shown in Table 4 and the design

mixes shown in Tables 5 and 6 conform with the specifications of ACI 211.4R (2008), ODOT (2013), ODOT (2015), ADOT (2008), TDOT (2015), INDOT (2014), PCA EB 233 (2005), NCDOT (2012), WSDOT M23-50 (2016), CDOT (2011) and FDOT (2010), which specified 20% maximum replacement of cement with fly ash or processed pozzolan materials, minimum cement content as 300 to 360 kg/m^3 and fine aggregate to total aggregate ration of 0.35 to 0.45 for standard and high performance concrete.

Table 6. Concrete mix design of 1: 2: 3 for specimens containing 20% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

Concrete cylindrical specimen mark	Percentage contamination of curing water with crude oil (curing media) (%)	Water cementitious materials ratio	Cementitious materials Kg/m^3			Fine Aggregate Kg/m^3	Coarse Aggregate Kg/m^3
			Cement	Sugar cane bagasse ash	Saw dust ash		
20D1	0	0.55	320	40	40	800	1200
20D2	5	0.55	320	40	40	800	1200
20D3	10	0.55	320	40	40	800	1200
20D4	15	0.55	320	40	40	800	1200
20D5	20	0.55	320	40	40	800	1200
20D6	25	0.55	320	40	40	800	1200
20D7	30	0.55	320	40	40	800	1200

— Concrete characteristics

From Tables 7 and 8 and Figures 2 and 4 it can be observed that compressive strength of all the concrete specimens' decreases with increase in crude oil contamination of the curing water but increases with increase in age irrespective of the degree of contamination of curing water with crude oil. The 28 and 56 days compressive strength of concrete specimens containing 20% mixture of sugar cane bagasse ash and saw dust ash are higher than that of concrete specimens containing 0% mixture of sugar cane bagassse ash and saw dust ash as shown in Figures 3, 5, and 6.

Concrete specimens containing 20% mixture of sugar cane bagasse ash and saw dust ash show increase in slump values and low strengths at early age and higher strength at later age which is in agreement with the properties on natural and processed pozzolan materials stated in ACI 211.4R (2008), ODOT (2013), ODOT (2015), ADOT (2008), TDOT (2015), INDOT (2014), PCA EB 233 (2005), NCDOT (2012), WSDOT M23-50 (2016), CDOT (2011) and FDOT (2010).

The 28 days compressive strengths of all the concrete specimens for 0% and 20% mixture of sugar cane bagasse ash and saw dust ash satisfied the minimum compressive strength range of 31N/mm^2 to 41N/mm^2 for high performance concrete for bridges as specified by the ACI 211.4R (2008), ODOT (2013), ODOT (2015), ADOT (2008), TDOT (2015), INDOT (2014), PCA EB 233 (2005), NCDOT (2012), WSDOT M23-50 (2016), CDOT (2011) and FDOT (2010). Table 9 shows higher splitting tensile strengths for concrete specimens containing 20% mixture of sugar cane bagasse ash and saw dust ash.

Table 7. Fresh and hardened properties of concrete specimens containing 0% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

Concrete cylindrical specimen mark	Percentage contamination of curing water with crude oil (curing media) (%)	Slump (mm)	Density (kg/m3)	Compressive strength N/mm2				
				3 days age	7 days age	14 days age	28 days age	56 days age
0D1	0	73	2423	16.84	26.36	35.24	41.61	46.64
0D2	5	73	2423	14.66	24.70	33.10	39.87	44.24
0D3	10	73	2423	14.04	24.00	32.14	38.68	43.83
0D4	15	73	2423	13.36	22.51	30.15	37.16	41.79
0D5	20	73	2423	12.87	21.69	29.00	36.76	39.11
0D6	25	73	2423	11.63	19.60	26.24	33.22	36.86
0D7	30	73	2423	10.23	17.93	24.35	32.09	35.51

Table 8. Fresh and hardened properties of concrete specimens containing 20% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

Concrete cylindrical specimen mark	Percentage contamination of curing water with crude oil (curing media) (%)	Slump (mm)	Density (kg/m3)	Compressive strength N/mm2				
				3 days age	7 days age	14 days age	28 days age	56 days age
20D1	0	89	2438	12.47	20.06	28.19	46.87	51.80
20D2	5	89	2438	10.73	18.76	26.48	44.06	48.88
20D3	10	89	2438	10.03	17.71	25.71	41.75	46.34
20D4	15	89	2438	9.09	16.01	24.12	40.08	44.11
20D5	20	89	2438	8.21	14.65	23.20	39.04	41.88
20D6	25	89	2438	7.43	13.21	20.99	36.04	40.08
20D7	30	89	2438	6.88	11.89	19.48	34.30	38.42

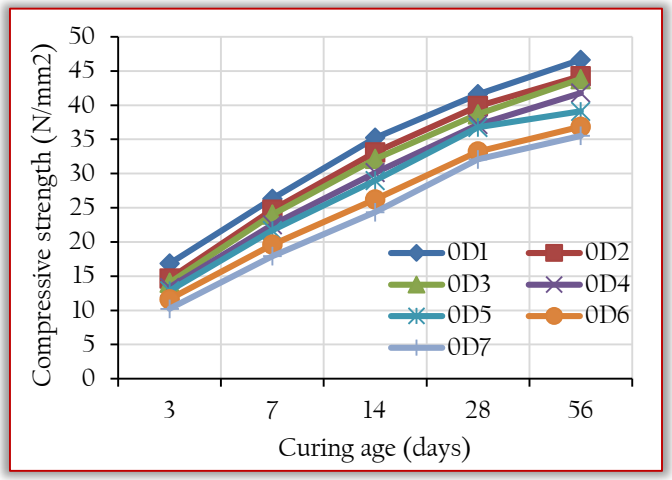

Figure 2. Relationship between the compressive strength and curing age of concrete specimens containing 0% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

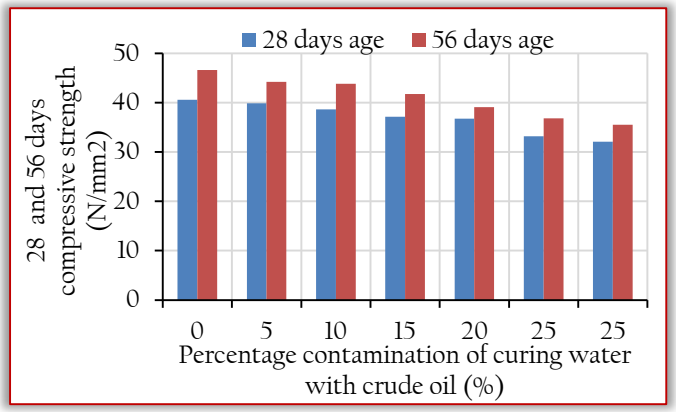

Figure 3. Relationship between the percentage contaminations of curing water with 28 and 56 days compressive strength of concrete specimens containing 0% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

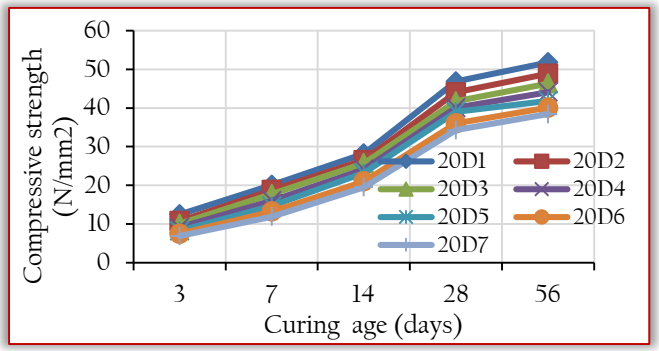

Figure 4. Relationship between the compressive strength and curing age of concrete specimens containing 20% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

Table 9. 7 and 28 days splitting tensile strengths

Percentage contamination of curing water with crude oil (curing media) (%)	Split tensile strength of concrete specimens containing 0% sugar cane bagasse ash and saw dust ash		Split tensile strength of concrete specimens containing 20% sugar cane bagasse ash and saw dust ash	
	7 days	28 days	7 days	28 days
0	2.98	3.09	3.11	3.50
5	2.33	2.40	2.68	2.84
10	2.10	2.21	2.41	2.61
15	2.04	2.11	2.26	2.34
20	1.69	1.91	2.00	2.18
25	1.37	1.59	1.82	2.00
30	1.23	1.39	1.51	1.78

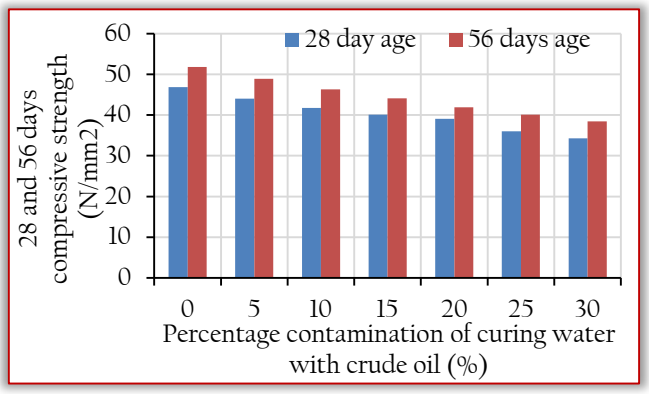

Figure 5. Relationship between the percentage contaminations of curing water with 28 and 56 days compressive strength of concrete specimens containing 20% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

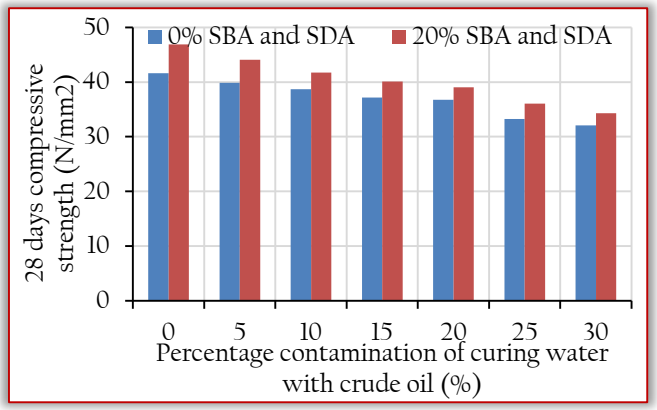

Figure 6. Relationship between the percentage contaminations of curing water with 28 days compressive strength of concrete specimens containing 0% and 20% sugar cane bagasse ash (SBA) and saw dust ash (SDA)

CONCLUSIONS

The following conclusions were made at the end of this study:

- Increase in crude oil contamination of the environment will negatively affect the compressive strength and split tensile strength of concrete bride substructures exposed to crude oil contaminated environment.
- Concrete specimen containing 20% mixture of sugar cane bagasse ash and saw dust ash show significant increase in slump values and in later days compressive strength.
- Concrete specimen containing 20% mixture of sugar cane bagasse ash and saw dust ash satisfied the minimum compressive strength range of 31N/mm^2 to 41N/mm^2 for high performance concrete for bridges as specified by the ACI 211.4R (2008), ODOT (2013), ODOT (2015), ADOT (2008), TDOT (2015), INDOT (2014), PCA EB 233 (2005), NCDOT (2012), WSDOT M23-50 (2016), CDOT (2011) and FDOT (2010).
- Sugar cane bagasse ash and saw dust ash should be used where available in high performance concrete production particularly in crude oil contaminate environment
- The use of ternary mixes should be encouraged. They are cost effective considering the quantity of cement that will be saved. Ternary mixtures also ensure sustainable cement and concrete industries.
- The use of high performance concrete for concrete bridge works should be encouraged particularly in crude oil contaminated environment.

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ISSN: 2067-3809

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VERIFICATION OF SLIDING RATIO OF AIRFOIL THROUGH CFD

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Abstract: Blades are very essential parts of HAWT (horizontal axis wind turbine). The lift/drag ratio is an important criteria of the aerodynamic efficiency of airfoil. In this study CFD (Computational Fluid Dynamics) analysis is performed for the verification of sliding ratio (C_l/C_d) of NACA airfoil 63(4)-221. CFD analysis is conducted at low Reynolds number in range of $x10^5$ as well as high Reynolds number in the range of $x10^6$. Angle of attack is taken in the range of 4° to 7°. For present work the blade length is taken 14 meters, which is a new design of blade for RRB V27-225 kW horizontal axis wind turbine blade (HAWT). Then results obtained from CFD analysis are compared with the available literature.
Keywords: HAWT, CFD, ANSYS, airfoil, angle of attack, sliding ratio

INTRODUCTION

Wind interacts with horizontal axis wind turbine rotor and converts its kinetic energy into useful energy. Wind turbine blade undergoes various types of aerodynamic forces due to wind turbulence. An airfoil is the cross-sectional shape of a blade of wind turbine. When wind flows over an airfoil, it develops aerodynamic forces. The lift is the force component perpendicular to the direction of blade motion while drag is parallel component to the direction of motion. There are three different ways to analyze flow around wind turbine that are field testing, analytical/semi-empirical models and CFD. The first one gives precise results, but highly complex and expensive. The second is one not universally reliable, while CFD offers the best way to direct measurements.

LITERATURE SURVEY

Anitha et al. (2018) carried out development of wing airfoil for the efficient aerodynamic performance. The optimal shape of the airfoil produces improved lift coefficient and reduced drag within the design constraints. In this study, genetic algorithm, particle swarm optimization methods was used to the optimization of airfoil shape for airfoil NACA-4412 in software MATLAB environment. Bartl et al. (2019) performed surface pressure, Lift and drag measurements on a wing section of the NREL-S826 wind turbine airfoil. Eight different Reynolds number taken range from 0.5×10^5 to 6.0×10^5. With the measurements of two types of Reynolds number averaged Navier-Stokes (RANS) simulations were conducted. Out of which one includes a laminar to turbulent transition model. The lift and drag behavior controlled by low Re < 0.7×10^5, that is related to the existance of laminar separation bubbles (LSBs) on the suction side of the profile.

Bianchini et al. (2016) demonstrated that, when airfoil rotates perpendicular to flow direction, it can be hypothetically transformed into an equivalent airfoil with a camber line defined by their arc of rotation. In such situation, the symmetric airfoil generally useful for Darrieus blades that actually act like virtually cambered to ensure the attended performance. To complete these analyses it was focuses on the on the aerodynamics of airfoil at the starting of the rotor. It was concluded that, symmetric airfoils shown a counter intuitive nonsymmetric starting torque over the revolution. Fuglsang et al. (2004) presented the designing and experimental verification of the Risø-B1 airfoil family at variable pitch control and wind speed. Seven airfoils were designed while thickness to chord ratios is taken between 15% and 53%. The airfoil was designed to gain maximum lift while maintaining high aerodynamic performance. The design optimization was carried out with a Risø in-house multi-disciplinary optimization tool. Wind tunnel testing was performed for Risø-B1-18 and Risø-B1-24 in the VELUX wind tunnel, Denmark, at a Re = 1.63106. For both airfoils the predicted target performance were achieved.

Li et al. (2015) investigated the aerodynamic behaviour of RAE2822 in ground effect with FVM (finite volume method) based on the averaged Navier-Stokes equations. The performance of many eddy-viscosity turbulence models were assessed by comparing with the existing experimental data of NACA-4412 in ground effect. Realizable k-epsilon model showed high capability of predicting the characteristics of flow. In the study of this ground effect on airfoil RAE-2822, high lift/drag ratio can be achieved in medium AOA (angle of attack).

To gain the increased power economically through wind turbine, the aerodynamic behavior of profile of the blade must be improved. The key parameters are the lift & drag coefficient to analyze the wind-turbine blade performance. To gain the highest power from the turbine the maximum lift/drag ratio is required. Talukder et al. (2016) performed a comparative analysis for aerodynamic performance of NREL S819 and S821 airfoils based on finite volume approach using a CFD method. Changing the angle of attack and wind speed, different aerodynamic parameters such as lift coefficient, drag coefficient and pressure distribution over the airfoils were determined computationally. The results from computations were confirmed experimentally by testing the airfoils wooden models in a wind tunnel subsonic open circuit suction type. The comparison with the experimental data indicates that the CFD approach applied in this investigation can precisely predict the aerodynamic behavior of the wind-turbine blades.

Tenguria et al. (2017) performed CFD analysis of a blade as well as airfoil of HAWT using k-ω SST model. In this study, NACA 63(4)-221 airfoil profile was chosen for the modeling and then performs blade analysis. The lift & drag forces were find out for the blade at various AOA (angle of attack). The length of blade was taken 38.98 m, which is a redesigned blade for VESTAS V82-1.65MW HAWT blade. Results obtained from simulation were verified with the experimental work

found in literature. Patil and Thakare (2015) studied the drag and lift forces of wind turbine blade at various Reynolds number and AOA. In this work NACA0012 airfoil profile was taken for analysis of blade. The drag and lift forces were find out by CFD analysis at various AOA from 0 degree to 80 degree for the Reynolds number in the range from 10000 to 800000. The validation of this work was done by comparing the result obtained from experimental results obtained by Sandia National Laboratories (SNL). It was concluded that result obtained by CFD analysis are very close with results published at SNL [8].

Standish and Van (2003) proposed the blunt trailing edge airfoils that are especially for the large wind turbine blades inboard region. Blunt trailing edge airfoils provide improvement in lift force as well as structural benefits including easiness of manufacturing and handling. Several computational techniques were applied, including a viscous/inviscid interaction method and three Reynolds-averaged Navier-Stokes methods. Sharma (2016) investigated to find out the most appropriate design of airfoil for using in low speed aircrafts. The airfoil S819, S1223, S1223 and S8037 RTL was chosen for study. The CFD method was used for analysis of airfoils. The numerical simulation performed using ANSYS FLUENT for low speed and high-lift airfoil. The coefficient of moment and Lift/Drag ratio of the airfoils find out for the comparative analysis of airfoils. The S1223 RTL airfoil was selected as the most appropriate design for the Mach number from 0.10 to 0.30 and for the specified boundary conditions. BEMT (Blade element momentum theory) is widely used for prediction of aerodynamic performance of wind turbine. But the reliability of the airfoil data is a significant aspect for the accurate prediction of power and aerodynamic forces. Mostly 2D wind tunnel tests of airfoils are done with constant span to establish the airfoil characteristics data used in BEM codes. Due to three dimensional effects, a BEM code using airfoil data received from two dimensional wind tunnel tests will not yield the correct loading and power. Consequently, two dimensional airfoil data have to be corrected before using in a BEM code. Yang et al. (2014) considered the MEXICO rotor (Model Experiments in Controlled Conditions rotor) where airfoil data are extracted from CFD results. The comparison shows that the re-calculated forces by using airfoil data extracted from CFD have good agreements with the experiment.

In present work CFD analysis is carried out for airfoil NACA 63(4)-221 for redesigning the blade of RRB V27-225 kW HAWT. In this work the viscous spalart allmaras model is used. Spalart-Allmaras model is a one equation model which solves a transport equation for a viscosity-like variable, referred to as the Spalart-Allmaras variable. In its original form, the model is effectively a low-Reynolds number model. The Spalart–Allmaras model was developed for aerodynamic flows. The computational effort is lower compared to the commonly used two-equation models. This model is preferable in large part due to its robustness.

GOVERNING EQUATIONS

The continuity equation for the two dimensional, steady and incompressible flow is:

$$\nabla.(\rho V) = \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} = 0 \qquad (1)$$

For viscous flow in x direction the momentum equation is:

$$\rho\frac{Du}{Dt} = \frac{\partial\rho}{\partial x} + \frac{\partial\tau_{xx}}{\partial x} + \frac{\partial\tau_{yx}}{\partial y} + \frac{\partial\tau_{zx}}{\partial z} + \rho f_x \qquad (2)$$

Where due to characteristics of the two dimensional flow in continuity equation the term $\frac{\partial(\rho w)}{\partial z}$ and in momentum equation, $\frac{\partial \tau_{zx}}{\partial z}$ drop out. In all simulations a standard k-ω SST model has been used for turbulent viscosity.

In equation: ρ = Density of fluid; V = Velocity vector; ρV = Mass flux; ∇ = Vector operator; ∇.(ρV) = Divergence of ρV; ρu, ρv = Rate of mass entering in x, y direction respectively; τ = Shear stress; f_x = External force; $\rho\frac{Du}{Dt}$ = Substantial time derivative of velocity; u = Velocity vector in x direction

BOUNDARY CONDITION AND GEOMETRY

In present analysis, an airfoil from the 6 series of NACA laminar wing section family is used. The airfoil maximum relative thickness is 21%, which is situated at 35% of the chord length. The Reynolds number taken for the simulation in the range of $x10^5$ and $x10^6$ and turbulence intensity is set at 10%. A turbulent flow solver is used in ANSYS Fluent, where spalart allmaras model is used.

Calculation was performed for the "linear" region, i.e. for angles of attack (AOA) ranging from 4° to 8°, because of greater reliability of both computed and experimental values in this region. The selected airfoil profile has 50 no. vertices and it is created in ANSYS GUI with two edges upper and lower. The mesh is generated in ANSYS workbench and then boundary conditions are applied using ANSYS Fluent. Figure 1 is showing the airfoil profile of NACA 63(4)-221.

Once the airfoil edges were created then boundary layers are generated around the airfoil. Figure 2 to 5 are showing the meshed around airfoil at different angle of attack. The mesh generated is uniformly distributed around airfoil for accurate prediction.

CFD ANALYSIS OF AIRFOIL 63(4)-221 for 14 m HAWT BLADE USING ANSYS Fluent

— Preprocessing

Preparation of CAD Model

2D CAD model of NACA airfoil 63(4)-221 is generated using ANSYS design modeler. Figure 1 shows modelling of NACA airfoil 63(4)-221. Coordinates are shown in table 1 named airfoil specification of NACA 63(4)-221. (Eggleston, D. and Stoddard, F., 1987.)

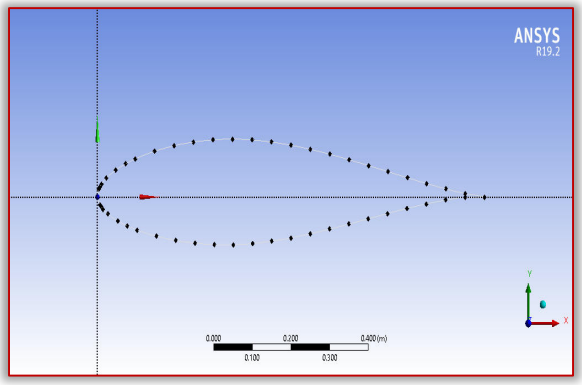

Figure 1: Modelling of NACA airfoil 63(4)-221

Table 1: Airfoil specification of NACA 63(4)-221

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0.00000	0.0000	0.00000	0.00000
0.00367	0.01627	0.00633	-0.01527
0.00600	0.02001	0.00900	-0.01861
0.01075	0.02628	0.01425	-0.02414
0.02292	0.03757	0.02708	-0.03385
0.04763	0.05375	0.05237	-0.04743
0.07253	0.06601	0.07747	-0.05753
0.09753	0.07593	0.10247	-0.06559
0.14767	0.09111	0.15233	-0.07765
0.19792	0.10204	0.20208	-0.08612
0.24824	0.10946	0.25176	-0.09156
0.29860	0.11383	0.30140	-0.09439
0.34897	0.11529	0.35103	-0.09469
0.39934	0.11369	0.40066	-0.09227
0.44969	0.10949	0.45031	-0.08759
0.50000	0.10309	0.50000	-0.08103
0.55027	0.09485	0.54973	-0.07295
0.60048	0.08512	0.59952	-0.06370
0.65063	0.07426	0.64937	-0.05366
0.70071	0.06262	0.69929	-0.04318
0.75073	0.05054	0.74927	-0.03264
0.80067	0.03849	0.79933	-0.02257
0.85056	0.02693	0.84944	-0.01347
0.90039	0.01629	0.89961	-0.00595
0.95018	0.00708	0.94982	-0.00076
1.00000	0.00000	1.00000	0.00000
LE Radius: 0.0265, slope of radius through LE 0.0842			

Mesh generation

Generate the mesh of airfoil in the Ansys mesh software at different angle of attack. Figure 2 shows meshing at AOA=6°. Table 2 shows variables taken for meshing around the airfoil.

Table 2: Variables for meshing around airfoil

Mesh Type	Quadrilateral
No. of Nodes	90985
No. of Element	90259

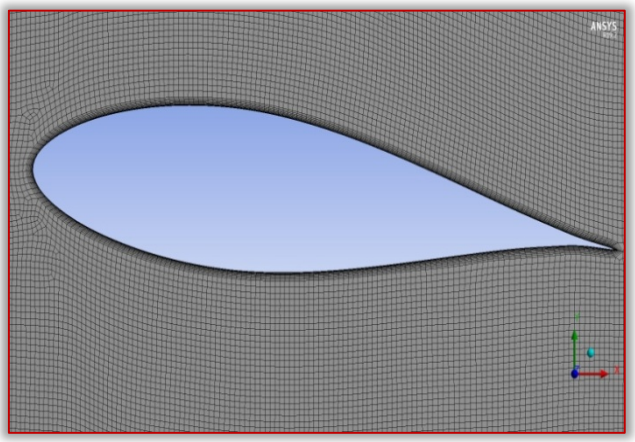

Figure 2. Mesh around Airfoil-NACA 63(4)-221at AOA=6°

Fluent setup

After mesh generation define the following setup criteria in the ANSYS fluent as shown in table 3. Pressure outlet conditions are shown in table 4.

Table 3: Setup criteria

Problem Type	2D
Type of Solver	Pressure-based solver
Physical model	Viscous spalart allmaras (1 equation)
Material Property	Flowing fluid is air
Density of air	1.225 kg/m^3
Viscosity	1.7894e-05

Table 4: Pressure outlet condition

Gauge pressure	0 Pa
Turbulent viscosity ratio	10

— Solution

Step 1-Solution Initialization

In this step Initialization of the solution is conduct to get the initial solution for the problem.

Step 2- Run Solution

Run the solution by giving 500 no of iteration for solution to converge. Following solution method is used for achieving solution (table 5).

Table 5: Solution Method details

Pressure velocity coupling Scheme	COUPLED
Pressure	Second order upwind
Momentum	Second order upwind
Modified turbulence viscosity	First order

— Post processing

Post processing is performed for viewing and interpretation of the result. The result can be viewed in various formats like graph, value, animation etc.

Table 6: CFD analysis results of NACA airfoil 63(4)-221 at various angle of attack and wind speed for low Reynolds number (x 10^5)

Angle of attack	Reynolds No.	Wind speed (m/s)	Drag Coefficient, C_d	Corrected drag coefficient, C_d	Lift coefficient, C_l	C_l/C_d ratio
4°	397061.74	6.0	0.02210	0.00884	0.62642	70.84730
4°	463238.70	7.0	0.02132	0.00852	0.63290	74.21159
4°	529415.66	8.0	0.02067	0.00827	0.63763	77.10047
4°	595592.61	9.0	0.02015	0.00806	0.64141	79.54481
4°	661769.57	10.0	0.01977	0.00790	0.64420	81.45355
5°	397061.74	6.0	0.02428	0.00971	0.73659	75.81421
5°	463238.70	7.0	0.02345	0.00938	0.74386	79.27356
5°	529415.66	8.0	0.02277	0.00911	0.74993	82.30328
5°	595592.61	9.0	0.02225	0.00890	0.75451	84.75457
5°	661769.57	10.0	0.02185	0.00874	0.75797	86.68825
6°	397061.74	6.0	0.02697	0.01078	0.84647	78.45724
6°	463238.70	7.0	0.02606	0.01042	0.85649	82.14612
6°	529415.66	8.0	0.02536	0.01014	0.86410	85.15458
6°	595592.61	9.0	0.02481	0.00992	0.87008	87.64042
6°	661769.57	10.0	0.02443	0.00977	0.87335	89.34293
7°	397061.74	6.0	0.03026	0.01210	0.94445	78.01681
7°	463238.70	7.0	0.02926	0.01170	0.95695	81.76109
7°	529415.66	8.0	0.02850	0.01140	0.96644	84.76180
7°	595592.61	9.0	0.02794	0.01117	0.97352	87.08039
7°	661769.57	10.0	0.02755	0.01102	0.97854	88.79193
8°	397061.74	6.0	0.03444	0.01377	1.02858	74.66238
8°	463238.70	7.0	0.03328	0.01331	1.04528	78.51610
8°	529415.66	8.0	0.03243	0.01297	1.05799	81.55338
8°	595592.61	9.0	0.03182	0.01272	1.06720	83.83720
8°	661769.57	10.0	0.03138	0.01255	1.07394	85.53898

From Figure 3 to 11 shows Pressure distribution, Velocity distribution and Velocity vector for selected airfoil at different wind

velocity and angle of attack = 6°. These CFD results were also find out for other angle of attack as mention in table 6 and 7. In these tables lift force L, drag force D, lift coefficient C_l, drag coefficient C_d and C_l/C_d ratio is shown. It is clear from these results that angle of attack 6° give highest lift coefficient and C_l/C_d ratio. Values are shown in table 6 and 7 for different Reynolds number in the range of 10^5 and 10^6 separately. Correction factor = 0.4 multiplied to drag coefficient, to get corrected drag coefficient as explained by G. Ramanujam et al. (2016)

Table 7: CFD analysis results of NACA airfoil 63(4)-221 at various angle of attack and wind speed for high Reynolds number

Angle of attack	Reynolds No.	Wind speed (m/s)	Drag Coefficient, C_d	Corrected drag coefficient, C_d	Lift coefficient, C_l	C_l/C_d ratio
5°	3000000	43.79	0.01817	0.00727	0.79151	108.8538
5°	6000000	87.58	0.01679	0.00671	0.80456	119.7539
5°	9000000	131.37	0.01612	0.00645	0.81149	125.8039
6°	3000000	43.79	0.02050	0.00820	0.91548	111.6134
6°	6000000	87.58	0.01906	0.00762	0.93096	122.0591
6°	9000000	131.37	0.01835	0.00734	0.93834	127.7784
7°	3000000	43.79	0.02324	0.00929	1.03333	111.1205
7°	6000000	87.58	0.02170	0.00868	1.05209	121.1616
7°	9000000	131.37	0.02098	0.00839	1.06111	126.4341
8°	3000000	43.79	0.02658	0.01063	1.15129	108.2804
8°	6000000	87.58	0.02499	0.00999	1.17661	117.6745
8°	9000000	131.37	0.02419	0.00967	1.18780	122.7468

RESULTS

— Pressure distribution around Airfoil

The static pressure contour is shown in Figure 3, 6 and 9 for angle of attack 6 degree, because at this angle of attack C_l/C_d ratio is maximum as given table 6 and 7. The pressure at the bottom surface of airfoil for incoming flow is more than upper surface so the incoming air can effectively push the airfoil upward normal to flow direction of air.

— Velocity distribution around Airfoil

The Velocity distribution contour is shown in Figure 4, 7 and 10 for angle of attack 6 deg.

— Velocity vector around Airfoil

The Velocity vector contour is shown in Figure 5, 8 and 11 for angle of attack 6 deg.

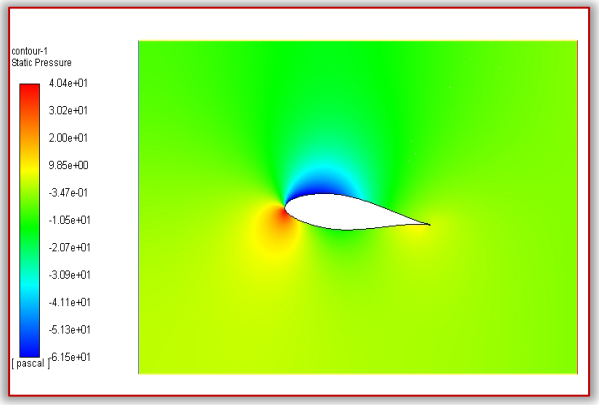

Figure 3. Pressure distribution around Airfoil-NACA 63(4)-221 at AOA=6°and v=8 m/s

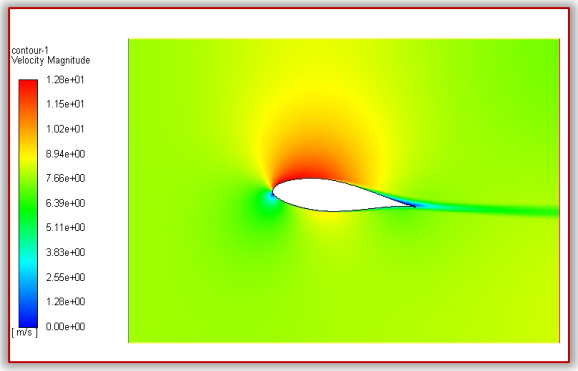

Figure 4. Velocity distribution around Airfoil-NACA 63(4)-221 at AOA=6° and v=8 m/s

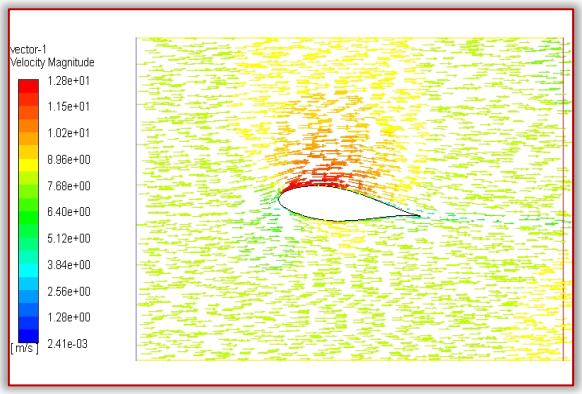

Figure 5. Velocity vector around Airfoil-NACA 63(4)-221 at AOA=6° and v=8 m/s

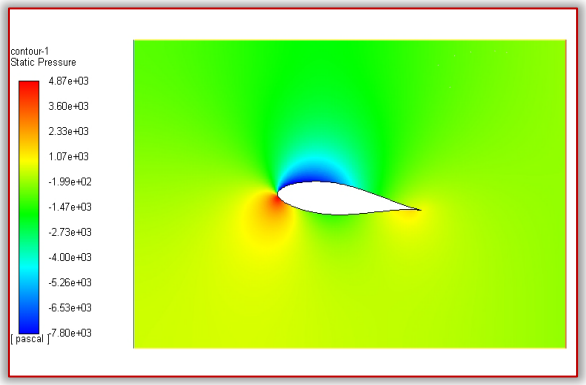

Figure 6. Pressure distribution around Airfoil-NACA 63(4)-221 at AOA=6° and v=87.58 m/s

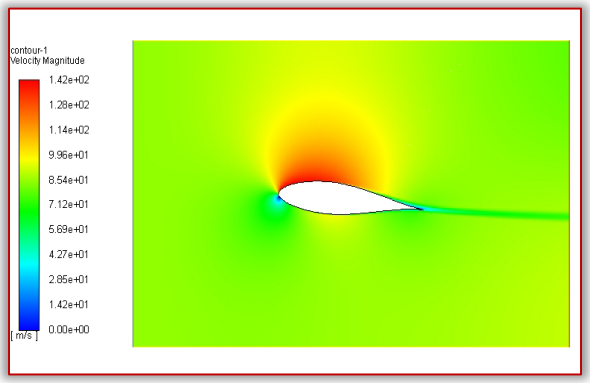

Figure 7. Velocity distribution around Airfoil-NACA 63(4)-221 at AOA=6° and v=87.58 m/s

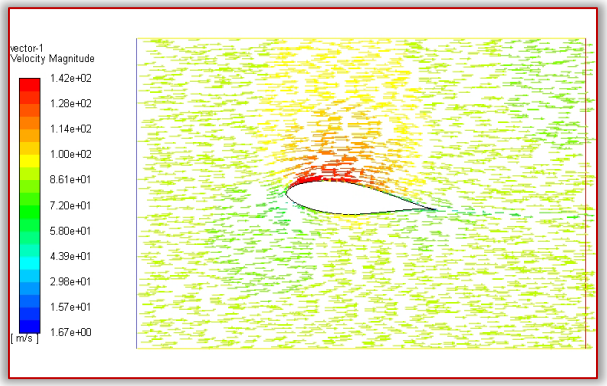

Figure 8. Velocity vector around Airfoil-NACA 63(4)-221 at AOA=6° and v=87.58 m/s

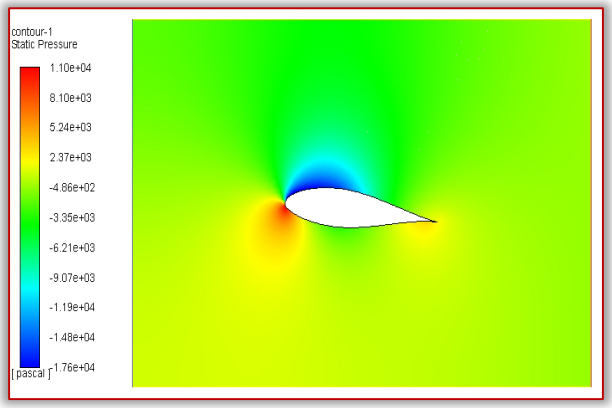

Figure 9. Pressure distribution around Airfoil-NACA 63(4)-221 at AOA=6° and v=131.37 m/s

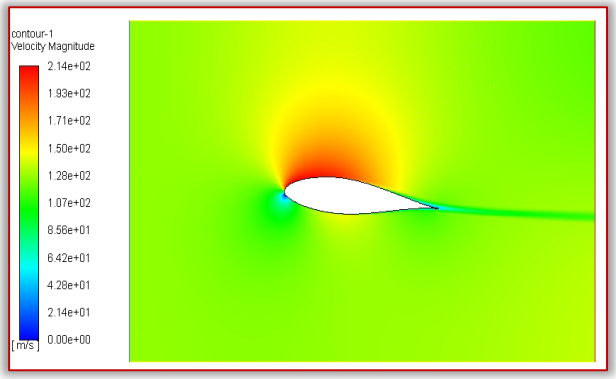

Figure 10. Velocity distribution around Airfoil-NACA 63(4)-221 at AOA=6° and v=131.37 m/s

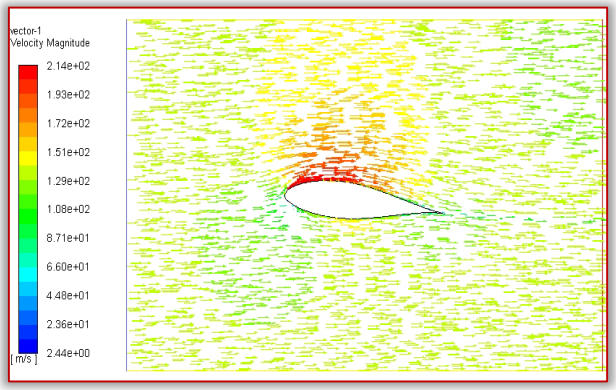

Figure 11. Velocity vector around Airfoil-NACA 63(4)-221 at AOA=6° and v=131.37 m/s

COMPARISON OF SIMULATION AND EXPERIMENTAL RESULTS

There are two forces and one moment works on an airfoil. The force component which is normal to the incoming flow stream is known as lift force and the component which is acting parallel to the flow stream is known as drag force. In this analysis, first of all simulation is carried out and then results are being verified with results available in previous literature.

Here simulation is done for angle of attack 4° to 8°. Results shows the ratio lift coefficient to drag coefficient (C_l/C_d) increases with increasing angle of attack from 4° to 6° and then again decreasing with further increasing AOA. Hence AOA=6° shows maximum C_l/C_d ratio for both condition of low and high Reynolds number (Figure 12 and 13). This can be further use in blade design process. It is also find out that for any fix value of AOA, the C_l/C_d ratio increases with increasing wind velocity or increasing Reynolds. Lift coefficient also increases with increasing angle of attack 4° to 8° and Reynolds number, while drag coefficient decreases.

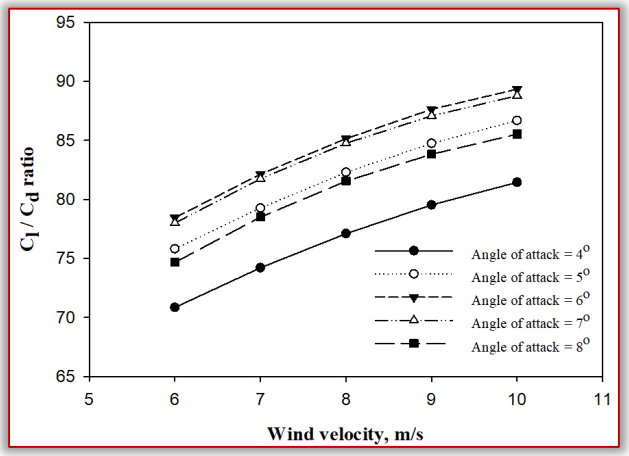

Figure 12. C_l/C_d ratio at different angle of attack for different wind velocity at low Reynolds number (x 10^5)

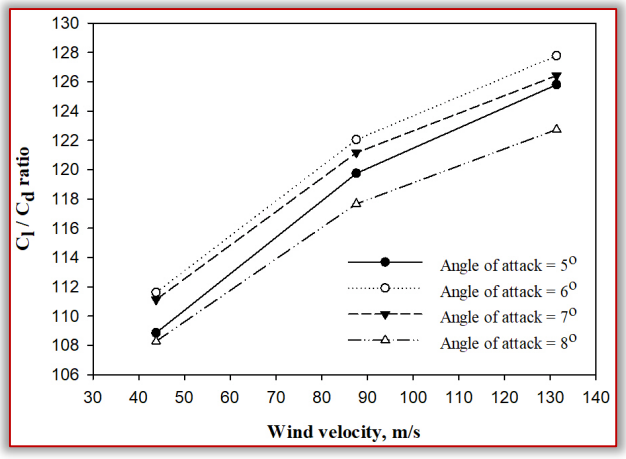

Figure 13. C_l/C_d ratio at different angle of attack for different wind velocity at high Reynolds number (x 10^6)

CONCLUSION

In this work CFD analysis of wind turbine blade is done in ANSYS Fluent. For this analysis spalart allmaras model is used for obtaining lift coefficient and drag coefficient at different angles of attack. The results obtained from simulation are compared with experimental results found in literature. It is found that sliding ratio is maximum at angle of attack = 6° at low and high Reynolds number, shown in

Figure 12 and 13. It is also found that the pressure at lower surface of airfoil is more and velocity is higher on the upper surface of airfoil.

Acknowledgements

The authors would like to acknowledge the research support from the Rabindranath Tagore University, Bhopal, India.

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ISSN: 2067-3809

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EVALUATION OF BUCKLING CHARACTERISTICS OF STRUCTURAL-SIZE *Pycnanthus angolensis* AND *Vitex doniana* AS TIMBER COLUMN UNDER COMPRESSION

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Abstract: Structural reliability was examined on the lesser-used timber species such as Akomu (Pycnanthus angolensis) and Eriri (Vitex doniana) which can be good substitute to the well-known species. The strength and physical properties of these timber species were determined to predict their suitability as structural material. Forty lengths of timber species of 50 x 50 mm cross-section were purchased from timber markets in Ilorin, Kwara State, Nigeria. The prevailing environmental conditions during the test were 31 °C and 64 % relative humidity. The properties tested were air dry density, moisture content and compressive strength parallel to grain of forty test specimens each of lengths, 200, 400, 600 and 800 mm in accordance with the British Standard BS 373 (1957). Mean air-dried moisture content for Akomu and Eriri were 11.12 and 13.29 %, respectively. Mean density of Akomu and Eriri were 644.58 and 889.84 kg/m^3, respectively. The typical derived equations to relate the stress and strain for Akomu and Eriri were $y = 1097.8x - 2.9858$ and $y = 1033.7x - 2.5309$, respectively. Results of reliability analysis show that Akomu and Eriri timber have reliability index of 0.68 and 0.63, respectively for a service life of 50 years, provided other serviceability conditions are met.

Keywords: Akomu, Buckling characteristics, Compressive strength, Eriri, Reliability

INTRODUCTION

Timber, a natural and renewable material, has a high strength-to-weight ratio and is easy to work on (Apu 2003). Different timber species have different strength characteristics, and also within a species these characteristics may vary. Therefore, in practice, a classification system of strength classes is used. Strength properties mean the ultimate resistance of a material to applied loads. Timber strength varies significantly depending on species, loading condition, load duration, and a number of assorted material and environmental factors (Jimoh et al. 2018). The exact quantity of wood and non-wood forest products in Nigeria cannot be easily estimated (Alamu and Agbeja 2011). However, studies have revealed that forest reserves occupy about 10 million hectares in Nigeria, which accounts for about 10% of a land area of approximately 96.2 million hectares (Alamu and Agbeja 2011; NPC 2006). Physical properties are the quantitative characteristics of timber and its behaviour to external influences other than applied forces. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications (Winandy 1994).

Mechanical properties are the characteristics of a material in response to externally applied forces. They include elastic properties, which characterize resistance to deformation and distortion, and strength properties, which characterize resistance to applied loads (Rahmon, et al. 2017). Since timber is anisotropic, mechanical properties also vary in the three principal axes. Property values in the longitudinal axis are generally significantly higher than those in the tangential or radial axes. Flexural (bending) properties are critical. Bending stresses are induced when a material is used as a beam, such as in a floor or rafter system (Jamala et al. 2013).

The main characteristic of these timber species under investigation is their buckling characteristics when subjected to compressive loading (Jimoh et al. 2017). The environment, the weather condition and the soil affect the growth of trees as well as their strength properties. Most of the timber strength properties recorded in British and European codes were based on timber obtained from trees on those areas and the laboratory tests were conducted there. Since all our timber structures are constructed of timber from Nigeria, there is the great need to determine their strength properties and subject them to structural reliability analysis in order to prove their degree of structural performances (Aguwa 2010).

The reliability, R(t) of an item is defined as the ability of an item to perform a required function under stated conditions without failure for a stated period of time. Reliability coefficients range from 0.00 to 1.00, with higher coefficients indicating higher levels of reliability. However, reliability specifically measures the consistency of an item. According to Leitch 1988, reliability index using constant failure rate (CFR) model is as given in equation (1) and λ is assumed constant with time.

$$R(t) = e^{-\lambda t} \quad (1)$$

where: R(t) = reliability index; λ = constant rate of failure; t = variable time and the failure rate (λ) is express as in equation 2:

$$\lambda = \frac{1 - d}{T} \quad (2)$$

where: T is the time (years), expected life span of timber, and d: the average compressive strength rate.

Nowak 2004 reported that the structural reliability is the probability that a structural system will satisfy the purpose for which it was designed and efficiently serve the period for which it was designed to without attaining a given limit state. One of the Objectives for structural design is to fulfill certain performance criteria related to safety and serviceability. One of such performance criteria is usually formulated as a limit state, that is, a mathematical description of the limit between performance and non-performance (Thelandersson 2003). Parameters used to describe limit states are loads, strength and stiffness parameters, dimensions and geometrical

imperfections; since the parameters are random variables, the outcome of a design in relation to limit state is associated with uncertainty (Aguwa 2010). A significant element of uncertainty is also introduces through lack of information about the actual physical variability. The evaluation of structural safety requires therefore, the consideration of the uncertainties (Benu et al. 2004). The aim of this study is to evaluate the structural reliability of Nigerian grown Akomu and Eriri timber species as a column material under compression. The specific objectives are; to conduct experiments on the Nigerian Akomu and Eriri timber species with a view to establishing their physical and strength properties, to determine the buckling behaviours of the selected timber species for different heights, to predict the critical buckling load for the selected timber species, derive continuous equations for the selected timber species as column structural material, to estimate the reliability of the Nigerian Akomu and Eriri timber species, and to add value to our locally available and affordable structural material thereby increasing the local content of the construction industry in Nigeria, resulting in less dependence on foreign materials.

MATERIALS AND METHOD

The study was conducted in Kwara State, North central, Nigeria. It is a state that lies within longitudes 5°00′00″East of Greenwich meridian and latitudes 8°30′00″ North of the Equator. To achieve the aims and objectives of the project, the physical and mechanical properties were carried out in accordance with BS EN 408 (1995) and BS 373 (1957).

A survey was carried out at eight timber markets within Ilorin, Nigeria. Forty lengths of each sample was cut from six randomly picked logs of timber from sawmills. It was ensured that the logs selected were free of defects and were as straight as possible before purchase. The timber samples were marked to distinguish individual timbers from different logs.

The tests were carried out on pieces which were conditioned at the standard environmental temperature of (30 ± 2) °C and (65 ± 5) % relative humidity. The timber species were naturally seasoned naturally for seven months to attain moisture content equilibrium environmentally.

The wood species were sized to standard size of 50 x 50 mm with heights of 200, 400, 600 and 800 mm at the University of Ilorin wood workshop for the compression test, 50 x 50 x 25 mm for the determination of moisture content of the timber specimens. Forty test specimens were prepared for each test.

— Physical Properties

» **Density determination** - In this study, only the air dry density has been determined. The specimens for density determination were completely free from knots, checks, flaws and any other defects. The volume of the specimens was calculated measuring the dimensions of length, width and thickness with the help of a Vernier scale. The density was obtained by determining the air-dry mass per unit volume for each of the test specimens.

» **Moisture Content -** The moisture content of the test piece was determined on each section taken from each test pieces. The sections were full cross section (50 x 50 mm), free from knots and resin pockets. And also those pieces were cut from a region where failure occurred for moisture content determination. The test specimen has dimension 50 x 50 x 50 mm. The pieces were weighed and then dried in an oven at a temperature of 103 ± 2 °C (217 ± 4 °F) until the weights were constant.

The percentage moisture content is mathematically calculated from equation (3) as;

$$W = \frac{M_1 - M_2}{M_2} \text{ x } 100 \qquad (3)$$

where: M_1 is the initial weight; in grams and M_2 is the mass, in grams, after oven drying.

— Compressive Strength Parallel to Grain Determination

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, at the Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin was used to test the compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

» **Buckling load determination**

UTM was used to determine the mechanical properties of Akomu (*Pycanthus angolensis)* and Eriri (*Vitex doniana)*.

» **Procedures:**

preparation of specimens, nominal size (50 x 50 x 200 mm), (50 x 50 x 400 mm), (50 x 50 x 600 mm) and (50 x 50 x 800 mm)
placing the specimen vertically between the cross heads.
input specimen dimensions and weight.
input the speed rate of the applied load (13.02, 26.04, 39.06 and 52.08 mm/min) for (200, 400, 600 and 800 mm) respectively.
run test.
a load-defection curve and other relevant data (stress and strain at yield, stress and strain at failure, maximum load and young's modulus etc.) are generated and shown on the output device.
stop test at the point of failure. point of failure was observed from load-deflection curve.
failure mode of specimen such as shear, split, lateral deflection and crushing were recorded before the applied load is lifted.

$$\text{Speed rate} = \frac{A_2 \text{ x } l_2}{A_1 \text{ x } l_1} \text{ x } v \qquad (4)$$

Where, A_1 is standard cross-sectional area and its equal to (20 x 20 mm^2), L_1 is standard specimen height and its equal to (60 mm), A_2 is the nominal cross-sectional area of test specimen and its equal to (50 x 50 mm^2), L_2 is the nominal height of test specimen and its equal to (200, 400, 600 and 800 mm), v is the standard load speed rate and its equal to 0.625 mm/min.

Example:

For 200 mm specimen:

$$\text{Speed rate} = \frac{50 \text{ x } 50 \text{ x } 200}{20 \text{ x } 20 \text{ x } 60} \text{ x } 0.625 = 13.02 \text{ mm/min}$$

— Stress and Strain Relationship

Stress and strain values are generated from Load against deflection curves which plotted automatically by the Universal Testometric Machine.

$$\text{Stress } (\sigma) = \frac{\text{Force(N)}}{\text{Area}(mm^2)} \qquad (5)$$

$$\text{Strain } (\varepsilon) = \frac{\text{Deflection(mm)}}{\text{Length(mm)}} \quad (6)$$

RESULTS AND DISCUSSION

— Results of Density

The density of timber is its mass per unit volume at a specified value of moisture content of each sample. The density of an air-dried timber has a direct relationship with the strength of the timber. Hence, the strength properties increase as the timber density increases, that is, the higher the density, the higher the strength of the timber. From the experimental results, it was observed that the average density of Akomu is 644.58 kg/m^3 with standard deviation of 59.72 and coefficient of variation of 9.22 while that of Eriri is 887.84 kg/m^3 with standard deviation of 31.05 and coefficient of variation of 3.48 as presented in Table 1. This implies that Eriri has higher yield strength than Akomu. This can be confirmed from the results of compression test.

Table 1: Average density of Akomu and Eriri Timber species

Species	Average Density (kg/m^3)	
	Akomu	Eriri
Minimum	487.87	851.04
Maximum	720.02	957.75
Mean	644.58	887.84
Standard Deviation	31.05	59.72
COV (%)	3.48	9.22
95% Confidence limit	634.96<x<654.20	869.33<x<906.34
99% Confidence limit	631.93<x<657.23	863.52<x<912.16

— Results of Moisture Content

Moisture content is the ratio of the weight of water present in the air-dried timber sample to the oven-dry weight. It was observed that the average moisture content for Akomu timber was 11.12 % with standard deviation of 16.42 and coefficient of variation of 14.75 and for Eriri was 13.29 % with standard deviation of 10.77 and coefficient of variation of 8.14 as can be seen in Table 2. This result is satisfactory, since it is less than the maximum recommended moisture content of 25 - 30 % for an air-dry sample. At this moisture content the likelihood of decay of the timber is greatly reduced. The strength of timber is also affected by its moisture content increasing as the moisture content reduces and vice versa.

Table 2: Average moisture content of Akomu and Eriri Timber species

Species	Average Moisture Content (%)	
	Akomu	Eriri
Minimum	9.09	5.26
Maximum	13.73	45.68
Mean	11.12	13.29
Standard Deviation	10.77	16.42
COV (%)	8.14	14.75
95% Confidence limit	7.78<x<14.46	8.20<x<18.38
99% Confidence limit	6.73<x<15.51	6.60<x<19.98

— Failure modes of Akomu and Eriri samples

A structural size timber will normally fail by buckling, compression or a combination of both buckling and compression depending on the ratio of its height to its cross-sectional dimension. The slenderness ratio affords a means of classifying columns and their failure mode. A short column under the action of an axial load will fail by direct compression before it buckles, but a long column loaded in the same manner will fail by buckling. The buckling mode of deflection generally occurs before the axial compression stresses can cause failure of the material by yielding of that compression member. This is demonstrated in Table 3. It was observed that the long sections (400, 600 and 800 mm) exhibited buckling while the short sections (200 mm) failed mostly due to shear. Figure 1 – 3 shows the various failure modes experienced.

Table 3: Failure modes of specimens

Akomu				Eriri			
Specimen ID	Height (mm)	Failure mode	Observed deflection (mm)	Specimen ID	Height (mm)	Failure mode	Observed deflection (mm)
A1	208.00	Shear	-	D1	200.00	Shear	-
B1	205.00	Shear	-	E1	200.00	Shear	-
C1	200.00	Shear	-	F1	202.00	Splitting	-
A2	402.00	Buckling	5.0	D2	398.00	Buckling	13.0
B2	403.00	Buckling	5.0	E2	397.00	Shear	-
C2	402.00	Buckling	10.0	F2	401.00	Buckling	3.0
A3	597.00	Buckling	25.0	D3	598.00	Buckling	14.0
B3	598.00	Buckling	10.0	E3	600.00	Buckling	14.0
A4	801.00	Buckling	14.0	F3	595.00	Buckling	5.0
B4	800.00	Buckling	40.0	D4	803.00	Buckling	22.0
C4	801.00	Buckling	23.0	E4	801.00	Buckling	15.0
				F4	812.00	Buckling	21.0

Figure 1: Failure mode of 200mm (Shear)

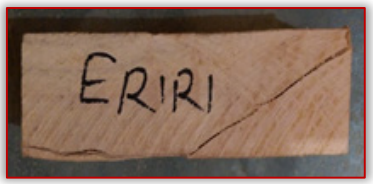

Figure 2: Failure mode of 200mm (Splitting)

Figure 3: Failure mode of 200mm (Buckling)

— Stress-strain relationship results

The results of the stress-strain relationship are presented in the Table 4 and 5. The mean stress in compression at yield for 200, 400, 600 and 800 mm heights of Akomu were; 30.104, 29.544, 18.530 and 15.434 N/mm^2 respectively. The mean stress in compression at yield for 200, 400, 600 and 800 mm heights of Eriri were; 26.429, 30.774, 33.311 and 26.365 N/mm^2 respectively.

The equations of stress-strain relationship of Akomu and Eriri timber species are shown in equation (7) and (8) as presented in the Figures 4 and 5. The maximum stress of Akomu sections can be estimated using the equation:

$$y = 1097.8x - 2.9858 \quad (7)$$

The maximum stress of Eriri sections can be estimated using the equation:

$$y = 1033.7x - 2.5309 \quad (8)$$

Table 4: Typical Stress-Strain Relationship for Akomu

Strain	Stress (200mm)	Stress (400mm)	Stress (600mm)	Stress (800mm)	Average Stress
0.000	0.000	0.000	0.000	0.000	0.000
0.001	0.065	0.052	0.078	0.086	0.070
0.002	0.296	0.237	0.404	0.295	0.308
0.003	0.772	0.657	0.905	0.591	0.731
0.005	1.228	1.162	1.449	0.859	1.174
0.006	2.153	2.089	2.290	1.294	1.957
0.007	3.265	3.363	3.204	1.817	2.912
0.008	5.037	4.782	4.288	2.509	4.154
0.009	7.051	6.498	5.380	3.431	5.590
0.011	9.117	8.391	6.709	4.310	7.132
0.012	11.509	10.313	8.126	5.444	8.848
0.013	13.958	12.484	9.693	6.588	10.681
0.014	16.375	14.511	11.193	7.684	12.441
0.015	18.758	16.635	12.688	8.930	14.253
0.016	20.864	18.580	14.006	10.052	15.875
0.017	22.787	20.435	15.270	11.016	17.377
0.019	24.405	22.244	16.218	12.014	18.720
0.020	25.818	23.944	17.066	12.691	19.880
0.021	27.003	24.622	17.605	12.985	20.553
0.022	27.828	25.435	17.903	13.133	21.075

Table 5: Typical Stress-Strain Relationship for Eriri

Strain	Stress (200mm)	Stress (400mm)	Stress (600mm)	Stress (800mm)	Average Stress
0.000	0.000	0.000	0.000	0.000	0.000
0.002	0.041	0.052	0.454	0.077	0.156
0.003	0.365	0.260	1.420	0.275	0.580
0.005	1.103	0.699	2.519	0.679	1.250
0.007	2.735	1.387	4.116	1.380	2.405
0.009	4.471	2.764	6.001	2.515	3.938
0.010	6.827	4.559	8.193	3.827	5.852
0.012	9.393	7.209	10.550	5.536	8.172
0.014	12.201	10.393	13.097	7.527	10.805
0.015	15.047	13.876	15.745	9.647	13.579
0.017	17.539	17.295	18.443	12.048	16.331
0.019	19.618	20.476	20.940	14.237	18.818
0.020	21.093	23.297	23.425	16.531	21.087
0.022	22.245	25.527	25.748	18.630	23.038
0.024	23.095	27.190	27.790	20.390	24.616
0.026	23.708	28.352	29.374	21.944	25.845
0.027	24.255	29.178	30.655	23.235	26.831
0.029	24.677	29.728	31.296	24.259	27.490
0.031	24.973	29.924	31.504	25.092	27.873
0.034	25.336	29.400	31.504	25.686	27.982

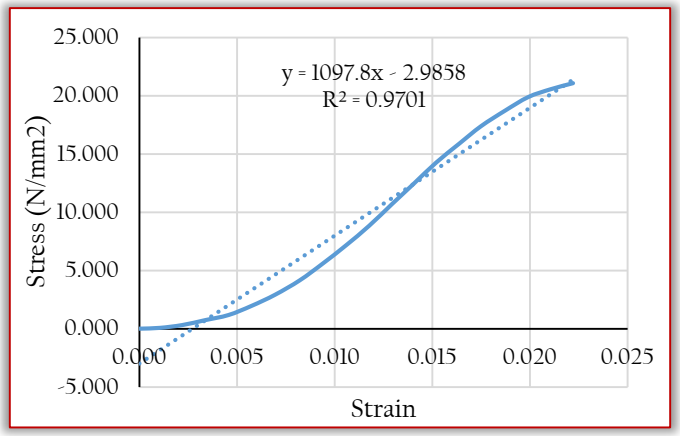

Figure 4: Typical Stress-strain curve for Akomu

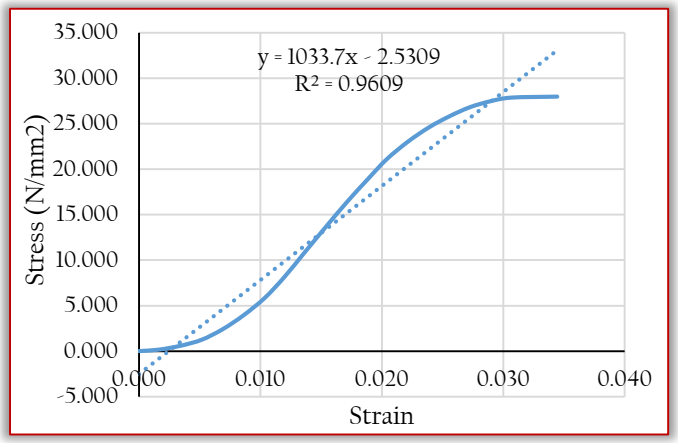

Figure 5: Typical Stress-strain curve for Eriri

Table 6 presents the relationship that exists between the timber species stress, strain, slenderness ratio and Young's Modulus. The stress at which a column buckles decreases as slenderness ratio increases and the mean length increases as well.

Table 6: Slenderness ratio, Stress @ Yield and Young's Modulus relationship for Akomu and Eriri

Mean Height (mm)	Mean Slenderness ratio, λ		Mean Stress @ Yield, σ (N/mm^2)		Young's Modulus (N/mm^2)	
	Akomu	Eriri	Akomu	Eriri	Akomu	Eriri
202.50	15.93	14.25	30.10	26.43	2045.71	1535.07
400.50	31.94	28.80	29.54	30.77	1465.74	1350.13
599.67	45.73	43.55	18.53	33.31	723.13	1091.83
803.00	58.31	57.77	15.43	26.37	418.43	918.17
Average			23.40	29.22	1163.25	1223.80

— Reliability Analysis results

The Tables 7, 8, 9 and 10 show the reliability analysis of Akomu and Eriri timber species using Constant Failure Rate model, while Figure 6 and 7 show the reliability index of the studied specimens.

The results of the reliability analysis show that the timber species Akomu and Eriri has reliability index of 0.68 and 0.63 respectively (which are both greater than 0.5, the minimum index for a reliable structure according to Abdulraheem (2016), Adedeji (2008) and Ajamu (2014), for a service life of 50 years, assuming other serviceability conditions are met.

Table 7: Strength Analysis of Akomu timber

Height (mm)	Average Strength (σ) (N/mm²)	Cumulative Strength (Q_i) (N/mm²)	Remaining Strength (R_i) (N/mm²)	Strength Rate (d_i)
200.00	30.104	30.104	63.508	0.4740
400.00	29.544	59.648	33.964	0.4652
600.00	18.530	78.178	15.434	0.5456
800.00	15.434	93.612	0	1.0000

Average Strength rate

$$d = \frac{0.4740 + 0.4652 + 0.5456 + 1.0000}{4} = 0.6212$$

Failure rate, $\lambda = \frac{1-d}{t}$, assuming a service life of 50 years and that other serviceability conditions are met, the reliability of the Akomu timber column is evaluated as shown below using Constant Failure Rate (CFR).

$$\lambda = \frac{1 - 0.6212}{50} = 0.007576/years$$

Table 8: Reliability of Akomu using CFR

Time (years)	λt	$e^{-\lambda t}$	Time (years)	λt	$e^{-\lambda t}$
0	0	1	140	1.061	0.3461
20	0.152	0.8590	160	1.212	0.2976
40	0.303	0.7386	180	1.364	0.2556
60	0.455	0.6345	200	1.515	0.2198
80	0.606	0.5455	220	1.667	0.1888
100	0.758	0.4686	240	1.818	0.1624
120	0.909	0.4029	260	1.970	0.1395

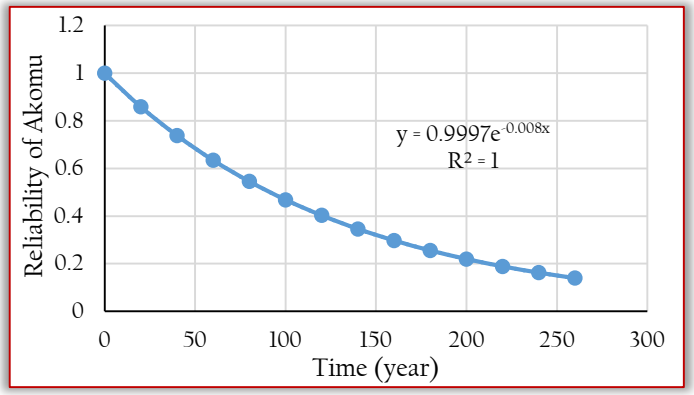

Figure 6: Reliability of Akomu Timber

Table 9: Strength Analysis of Eriri timber

Height (mm)	Average Strength (σ) (N/mm²)	Cumulative Strength (Q_i) (N/mm²)	Remaining Strength (R_i) (N/mm²)	Strength Rate (d_i)
200.00	26.429	26.429	90.450	0.2922
400.00	30.774	57.203	59.676	0.3402
600.00	33.311	90.514	26.365	0.5582
800.00	26.365	116.879	0	1.0000

Average Strength rate

$$d = \frac{0.2922 + 0.3402 + 0.5582 + 1.0000}{4} = 0.5477$$

Failure rate, $\lambda = \frac{1-d}{t}$, assuming a service life of 50 years and that other serviceability conditions are met, the reliability of the Eriri timber column is evaluated as shown below using Constant Failure Rate (CFR).

$$\lambda = \frac{1 - 0.5477}{50} = 0.009046/years$$

Table 10: Reliability of Eriri using CFR

Time (years)	λt	$e^{-\lambda t}$	Time (years)	λt	$e^{-\lambda t}$
0	0	1	140	1.266	0.2820
20	0.181	0.8344	160	1.447	0.2353
40	0.362	0.6963	180	1.628	0.1963
60	0.543	0.5810	200	1.809	0.1638
80	0.724	0.4848	220	1.990	0.1367
100	0.905	0.4045	240	2.171	0.1141
120	1.086	0.3376	260	2.352	0.0952

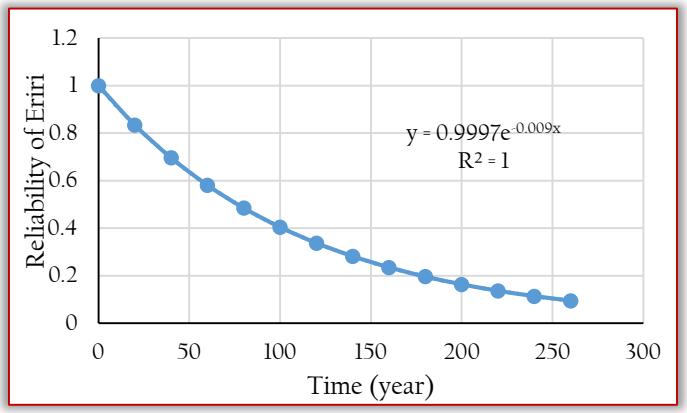

Figure 7: Reliability of Eriri Timber

CONCLUSIONS

The overall conclusions emerging from this study are:

- The result shows that Eriri has higher yield strength than Akomu and thus will be more suitable for Structural use. The result further illustrates the direct relationship that exists between physical properties such as moisture and density, and mechanical properties such as yield strength and elastic modulus.
- The maximum stress of Akomu and Eriri sections can be estimated using the equation: $y = 1097.8x - 2.9858$ and $y = 1033.7x - 2.5309$ respectively. The stress at which a column buckles decreases as slenderness ratio increases.
- A short column under the action of an axial load will generally fail by shear, but a long column will fail by buckling.
- With the results obtained and the associated equations derived, the strength of both timber species can be accurately predicted, thereby encouraging the use of these natural and sustainable construction materials.
- The result of the reliability analysis show that the timber species Akomu and Eriri has reliability index of 0.68 and 0.63 respectively for a service life of 50 years, assuming other serviceability conditions are met.
- However further research is required to determine other strength properties such as bending strength, tensile strength and the determination of these strength properties for different structural sizes should also be carried out. This will enable not only an effective design, but also a holistic design procedure to be developed for both Akomu and Eriri timbers.

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ISSN: 2067-3809

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WEATHER PREDICTION USING MULTIPLE IoT BASED WIRELESS SENSORS

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Abstract: Environmental monitoring is extremely important due to recent changes in climate, for ensuring a safe and wealthy life of both humans and artifacts. This field is based on remote sensing and wireless sensor networks for gathering data about the environment. Recent advancements, such as the vision of the internet of Things (IoT), the cloud computing model, and cyber-physical systems, give support for the transmission and management of huge amounts of data relating to the trends determined in environmental parameters. In this context, the paper presents three different IoT-based wireless sensors for weather prediction and environmental monitoring: one employing User Datagram Protocol (UDP)-based Wi-Fi communication, second communicating through Wi-Fi and Hypertext Transfer Protocol (HTTP), and third one using Bluetooth communication. The System consists of three different wireless sensor nodes based on Node MCU wifi module or Arduino microcontroller that is connected to the internet, and a firebase cloud server which provides information storage and delivery to remote clients. In addition, to view the result output in effective and user friendly manner MIT App Inventor is used to develop applications for Android phones using a web browser and either an associated phone or an on-screen phone person. The System conducts a look up table which contains the values of temperature, humidity, real time rain and level of carbon monoxide is used to predict the current environmental conditions by comparison of data.

Keywords: Wireless Sensor Network, IoT, weather predictions, cloud server, environmental Monitoring

INTRODUCTION

The environmental care has become one of the biggest concerns for almost every country in the last few years. The industrialization level has been increasing without any control in the last decades. So, there is a growing concern over environmental issues like global warming, energy conservation, efficient energy usage, radiation, etc; the current situation is clearly changing towards more environmentally friendly solutions.

Wireless Sensor Networks (WSN) has given a viable solution to these issues. This is the field where wireless sensor networks (WSNs) have been 1st used, their primary purpose consisting in the observation of the physical world and the recording of physical quantities of the atmosphere and organizing the collected info at a central location.

WSN consists of a large number of low-cost, low-power; small size and multifunctional wireless sensor nodes, with sensing, gathering and computation capabilities which can be communicated over a short distance via a wireless medium and collaborate to finish a standard task. WSN is generally deployed in unattended and harsh environments.

However, some constraints limit their application to some extent. These constraints include restricted amount of energy, limited communication range, low bandwidth, limited processing ability and storage in each node. Performance of a sensor node is highly dependent on the effective and efficient usage of these available limited resources that leads to maximum lifetime of the WSN.

One primary concern on wireless transmission is that the power consumption. WSNs measure environmental conditions like temperature, humidity, sound, pollution (such as CO, CO2, SOx) levels, wind pressure, rainfall, light intensity etc. These are similar to wireless ad hoc networks wireless ad hoc networks in the sense that they rely on wireless connectivity and spontaneous formation of networks so that sensor data can be transported wirelessly.

Water and air quality are essential thing to maintain the equilibrium between human development and a healthy environment. In this context, environmental monitoring represents a fundamental instrument for gathering relevant information about the ecosystem, leading to new knowledge and understanding, and for ultimately implementing adaptation and mitigation actions that address the degradation of the biosphere. Weather prediction is that the perform of science and technology to predict the conditions of the atmosphere for a given location and time. People have tried to predict the weather informally for millennia and formally since the nineteenth century. Weather forecasts are created by grouping quantitative information regarding the present state of the atmosphere at a given place and using meteorology to project how the atmosphere will change.

This paper presents the design details, the development, and the analysis of three different techniques that enable the achievement of Internet connected solutions for monitoring and prediction of environment at remote locations: one employing UDP-based Wi-Fi communication second based on the HTTP protocol, and third one consisting Bluetooth. Being provided with Internet connection capabilities, the developed techniques represent a part of the Internet of Things (IoT), the vision that "allows people and things to be connected Anytime, Anyplace, with something and anyone, ideally using Any path/network and Any service".

The Internet of things (IoT) is that the system of physical gadgets, vehicles, home apparatuses, and elective thing implanted with gadgets, programming, equipment, sensors, actuators and availability that these things to join, gather and trade data, making open doors for more straightforward combination of the physical world into PC based frameworks, bringing about effectiveness enhancements, monetary preferences, and diminished human exertions.

LITERATURE SURVEY

Several solutions for monitoring different environmental parameters which is based on wireless nodes have been proposed earlier. In this paper the solution described particular attention to the data storage and safety, even though conceived with a similar approach. The architecture proposed in [1] by Luca Lombardo et al., relies on a multiple-level data storage, which provides a strong data safety. In particular, it gives the possibility to retrieve the whole measurement history of the monitored site, avoiding any issue connected with cabling and network connection break. In paper named as "Wireless Sensor Network application for water quality monitoring in India" [2], aim of author Dr.Seema Verma and Prachi is to discuss requirement and suitability of WSN for water quality surveillance. Paper [3] presents the development of a real time wireless sensor network for any environmental data prediction using naïve prediction model. The developed system was imposed on intranet; Low forecast metric error result obtained shows the accuracy of the naïve model.

I.F. Akyildiz et al., describes the concept of sensor networks in their paper "Wireless sensor networks: a survey" [4] which has been made viable by the convergence of micro electro-mechanical systems technology, wireless communications and digital electronics. First, the sensing tasks and also the potential sensing element networks applications are explored, and a review of things influencing the planning of sensing element networks is provided. Then, the communication design for sensing element networks is made public, and also the algorithms and protocols developed for every layer within the literature are explored Open analysis problems for the conclusion of sensor networks are also discussed. Wireless small sensing element networks are known mutually of the foremost necessary technologies for the twenty first century. Paper [5] traces the history of study in the field of sensing networks over the past several decades, including two important programs of the Defence Advanced Research Projects Agency (DARPA) spanning this period: the Distributed sensor Networks (DSN) and the sensor info Technology (SensIT) programs. Technology trends that impact the event of sensing element networks area unit reviewed and new applications like infrastructure security, surroundings watching, and control area unit introduced. The technical challenges continue sensing element network development involve network discovery, management and routing, cooperative signal and knowledge process, tasking and querying, and security.

This paper presents the design details, the development, and the analysis of three different sensors that enables the achievement of Internet connected solutions for monitoring the environment or the ambient at remote locations: one employing UDP-based Wi-Fi communication [6], one based on the HTTP protocol, and one consisting in power harvesting Bluetooth Smart. Being provided with Internet connection capabilities, the developed sensors represent a part of the Internet of Things (IoT), the vision that "allows people and things to be connected Anytime, Anyplace, with Something and Anyone, ideally using Any path/network and Any service" [7]. Donno et al., [8] propose a solution where self-powered Radio-frequency identification tags, equipped with temperature, light, and acceleration sensors, are used. The device has the power to reap RF energy and its operation has been valid through two real-world experiments, within which the no inheritable knowledge area unit collected a number computer with the assistance of a reader antenna. The design achieved a transmission range of up to 10 and 20 m in fully passive and battery-assisted-passive modes, respectively.

The proposed system can be used for monitoring the ambient or outside weather parameters, and, if the host PC is provided with an Internet connection, can be part of an IoT-based solution. In [9] we reported the development of Wi-Fi sensors sending temperature and relative humidity measurements to a base station using UDP. A battery lifetime of two years with a twenty min measurement cycle was achieved. This encouraged the development of a device using HTTP, for investigating the power efficiency of this more reliable solution, from the communication point of view. J. Ramprabul describes a low cost and holistic approach to the water quality monitoring problem for drinking water distribution systems as well as for consumer sites in their paper [10]. Their approach is to develop sensing element nodes for real time and in-pipe watching, assessment of water quality on the fly and to calculate the number of water delivered.

Wireless sensor Networks (WSNs) are achieved widespread relevancy in water quality observance. However, existing WSN-based observance systems aren't adequate for Observance Lake and lake water, town water distribution and water reservoir. Moreover, these frameworks can't be reused in alternative observance applications since they use static and application specific detector nodes and aren't dynamic to the ever-changing needs. Thus, author of paper [11] introduce a reusable, self-configurable, and energy economical WSN-based water quality watching system that integrates a Web-based info portal and a sleep planning mechanism of sensing element nodes. The workplace and simulation results show that the framework will monitor the water quality in period and therefore the sleep programing mechanism will increase the network time period, severally. Finding patterns in giant, real, spatio/ temporal data continues to draw in high interest (e.g., sales of merchandise over house and time, patterns in mobile users; sensor networks aggregation operational info from vehicles or perhaps from humans with wearable computers). In paper [12], Anastassia Ailamaki et al., describe an interdisciplinary research effort to couple knowledge discovery in large environmental databases with biological and chemical sensor networks so as to revolutionize drink quality and security deciding. They describe a distribution and operation protocol for the placement and utilization of in place environmental sensors by combining (i) new algorithms for spatial temporal processing, (ii) new ways to represent water quality and security dynamics, and (iii) a classy decision-analysis framework.

The work planned in [13] by S. KaviPriya et al., is the event of low price fuzzy based mostly water quality watching system victimisation wireless sensing element networks that is capable of measurement physio chemical parameters of water quality like hydrogen ion concentration, temperature, conductivity, oxidation reduction potential and turbidity. Recent advancement in wireless communications and physical science has enabled the event of cheap detector networks. The detector networks will be used for

varied application areas (e.g., health, military, home). For different application areas, there are different technical problems that researchers are currently resolving. The current state of the art of detector networks is captured during this article, wherever solutions area unit mentioned underneath their connected protocol stack layer sections. The article presented in [14] also points out the open research issues and intends to spark new interests and developments in this field.

One of the immediate benefits brought by the acquisition of such physical proprieties, like soil moisture, temperature, and salinity, can be seen in agriculture, where significant water resource savings can be achieved [15]-[17]. Wireless sensing elements and sensor networks are with success utilized in the implementation of solutions happiness to numerous fields, together with environmental watching [18]–[19], natural disaster bar , current consumption watching in large buildings , monitoring systems for the dosimetry of radiology operators in healthcare applications [20]-[21].

PROBLEM STATEMENT & OBJECTIVE

- Environmental monitoring and prediction is extremely important due to recent changes in climate, for ensuring a safe and wealthy life of both humans and artifacts.
- The sudden change in climate impacts on environment in the form of pollution, temperature, humidity, rain, and heavy thunderstorm etc these are greatly affected to thousands of people, causes critical diseases and frowzled their life.
- In this context the proposed system having three IoT based solutions and providing environmental monitoring and weather prediction.
- The earlier system limits their monitoring region.
- This system is simpler and less costly as compared to earlier system.

OBJECTIVE

- To monitor environmental conditions like temperature, humidity, real time rainfall and level of carbon monoxide gas using three different IoT based wireless communication.
- To predict the weather conditions and update along with sensor value on the cloud server.

METHODOLOGY

The proposed system is simpler and uses advanced technology. It is based on sensor data collection and that uploaded to cloud server by three different technologies (UDP, HTTP and Bluetooth) and result is shown in mobile app taken from cloud server. The block diagram of the proposed system is shown below in figure 1.

The block diagram consists of three different nodes. Each node contains four sensors (such as Temperature, Humidity, Rain and CO sensors) and communicated to cloud server through three different protocols. Google Firebase is using as cloud server which stores the data collected by the sensors and displays in mobile app. For determining temperature and humidity of atmosphere we are using temperature and humidity sensor (DHT11) which will help in predicting environmental conditions. CO sensor (MQ-7) is used for determining level of Carbon Monoxide in environment, whereas rain sensor is used for detection of rain. The system is placed in 3 different locations and data from each location is collected by the server as shown in figure1.

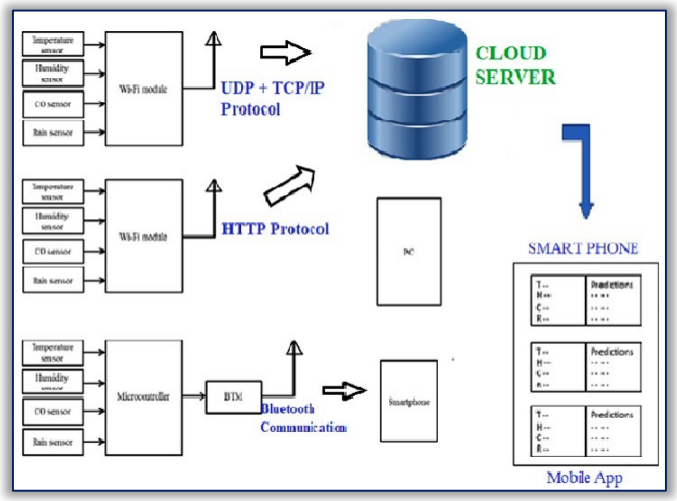

Figure 1. Block Diagram Of Proposed System

The server stores and displays the current values of all 4 parameters. A look up table is generated which contains the values of temperature and humidity and is used for predicting the current environmental conditions by comparing the data. These two data are only used because these are the basic and important constituents of environment, For example, if humidity is more and temperature is less then chances of rain is more, if humidity is less and temperature is more then chances of rain is less, if humidity is moderate and temperature is also moderate then weather is clear etc. Presence and absent of real time rain is determined by rain sensor.

System is placed at three different positions and each position uses different protocol for transmission of data. First place uses UDP+TCP/IP protocol to communicate with server. It transfers the data to mobile using the rules setup by TCP/IP protocols. The second place's system uses HTTP protocol to communicate with the webpage. The data is automatically updated in each 5sec. a webpage is developed to receive and transmit data using this protocol. The system placed at 3rd position uses Bluetooth module to transmit data on mobile. This system uses Bluetooth protocols and communicates with mobile app according to those protocols. Smartphone transfers data to webpage or mobile app using the mobile internet.

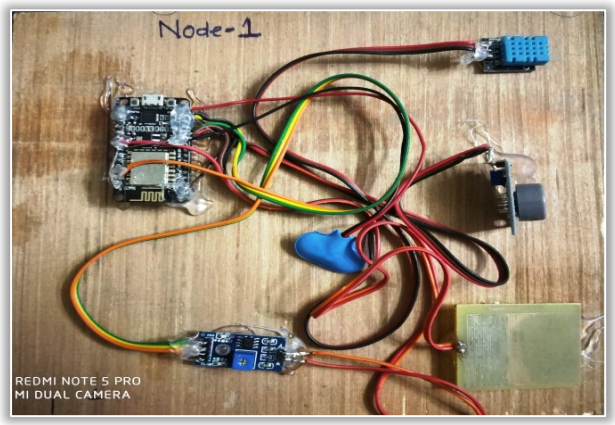

Figure 2. Node - 1 uses UDP+TCP/IP protocol

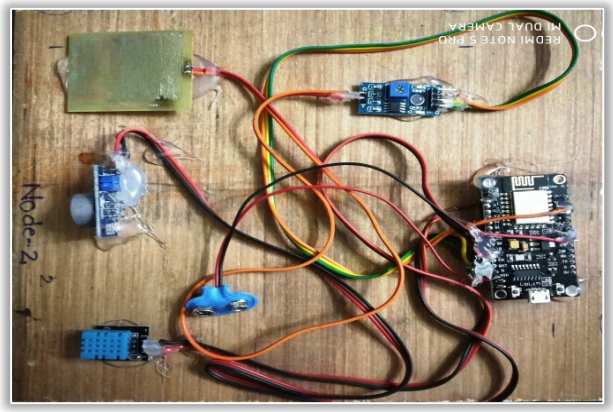

Figure 3. Node - 2 uses HTTP protocol

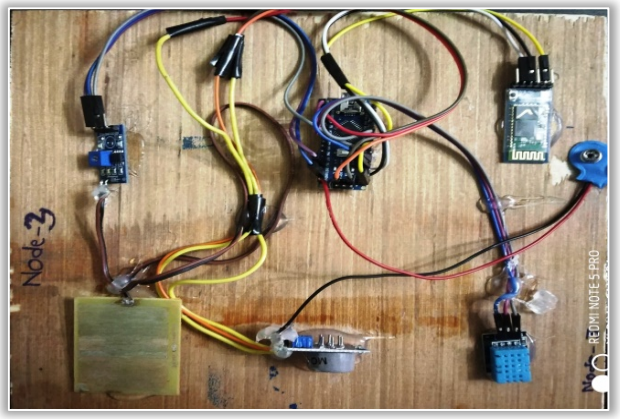

Figure 4. Node - 3 uses Bluetooth Communication

RESULTS AND DISCUSSIONS

Sensor data recorded on different days and their predicted value are presented in Table 1.

Table: 1. Output Result

Date	Temp (□C)	Relative Hum (%)	Conc. of CO	Rain status (Digital Value)	Prediction
10-Mar-19	32	54	115	0	sunny weather
11-Mar-19	32	57	116	0	sunny weather
18-Mar-19	33	43	109	0	sunny weather
19-Mar-19	33	43	108	0	sunny weather
27-Mar-19	27	95	115	1	It's Raining
28-Mar-19	32	65	116	0	clouded
29-Mar-19	33	70	135	0	clouded
31-Mar-19	32	42	112	0	sunny weather
4-Apr-19	31	43	109	0	sunny weather
5-Apr-19	31	78	108	0	clouded
10-Apr-19	30	43	105	0	sunny weather
11-Apr-19	32	34	106	0	sunny weather
12-Apr-19	32	78	138	0	clouded
13-Apr-19	31	43	128	0	sunny weather
14-Apr-19	31	43	116	0	sunny weather
15-Apr-19	31	45	143	0	clouded
16-Apr-19	30	48	121	0	clouded
17-Apr-19	30	43	117	0	sunny weather
18-Apr-19	30	60	110	0	Partly clouded
19-Apr-19	29	58	111	0	Partly clouded
22-Apr-19	11	96	108	1	It's Raining
26-Apr-19	30	60	109	0	Partly clouded

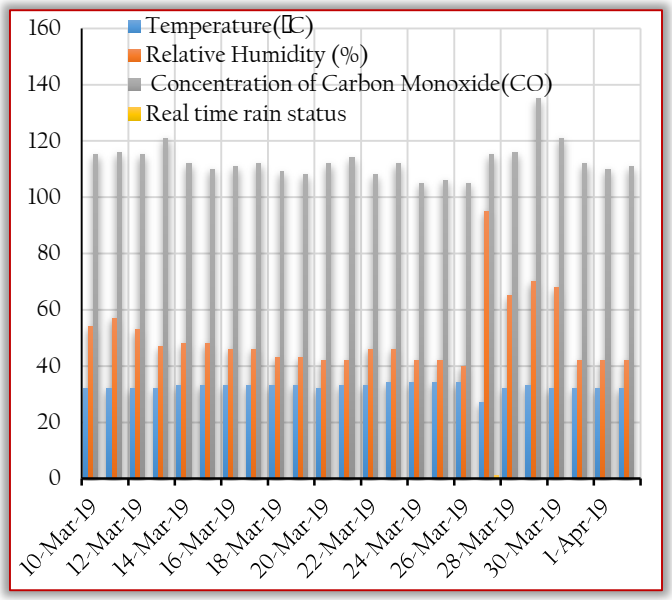

Figure 5. Graphical Representation of Output Result (sensor data on different days)

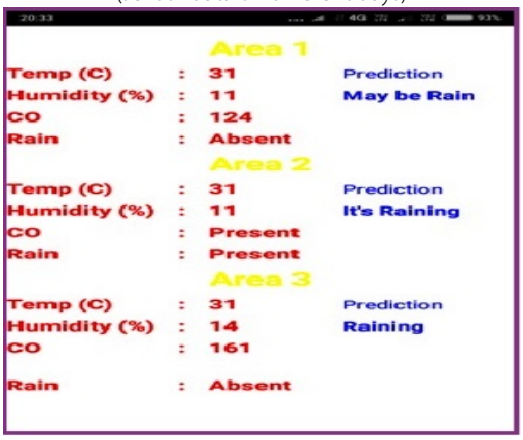

Figure 6. Result Displays in Mobile app

FUTURE SCOPE:

With some modifications in basic system, proposed system can be used in following areas:

- industrial sensing
- infrastructure security
- traffic control
- environment and habitat monitoring

CONCLUSIONS

This paper presents three different techniques for implementing IoT-based solutions for environmental monitoring and prediction: one employing User Datagram Protocol (UDP)-based Wi-Fi communication, second employing communicating through Wi-Fi and Hypertext Transfer Protocol (HTTP), and a third one using Bluetooth communication.

The system was designed, developed, and analysed and all of them were fabricated with discrete components and provide facile access to the Internet using a minimum of additional hardware and software resources. The analysis of the three implementations revealed the fact that all three technologies are suited for successfully environmental monitoring applications. The prediction done on the basis of sensor data collected, which experiments are done at Viman Nagar area in Pune on different environmental

conditions. The result shows in mobile application in form of data value and prediction. Employing this technology has been proved efficient and promising results which encourage for development of systems.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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SOLUTIONS AND TRENDS IN LOGISTICS 4.0

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Abstract: Logistics 4.0 means the application of Industry 4.0 in the logistics area. Therefor many new solutions are created and published which give a huge amount of single examples for realizing different logistics tasks. (Compare [1]) To find solutions in a systematic way it is necessary to create and use metaknowledge. The paper gives an overview about typical solution fields, the level of knowledge and application. It differs according the model "Smart Logistics Zone" into objects, processes, systems and the relevant infrastructure. The "Smart Logistics Zone" is defined as a scalable examination and action area for the analysis, evaluation, planning, control, regulation and (re-) configuration of logistics solutions [2]. The starting points are changed requirements and conditions according to Logistics 4.0. Logistics is a service that must meet customer requirements and protect the existence of companies. That means to do the right things in an efficient way, e.g. due to the possibilities of autonomously driving. They have the same idea to move, to handle and to transport without a driver/pilot. In addition, can be realized by all different means of transport. That can be Automated Guided Vehicles (AGV), autonomous material handling equipment e.g. mobile robots, bicycles, motor scooter, cars, trucks, busses, metro, train, robotic ships, unmanned area vehicles and so on. Typical tar-gets are to reduce personal costs and to rise the energy efficiency and the safety of transport activities as well as the performance. The majority of solutions of e.g. autonomous driving are on the level of prototypes and pilot projects.
Keywords: Logistics 4.0, smart objects, logistics processes, cyber-physical system, logistical infrastructure

INTRODUCTION

The term Logistics 4.0 brands the specific application of Industry 4.0 in the area of logistics. Industry 4.0 and Logistics 4.0 create a lot of new possibilities and new solutions by digitalization and networking. (Compare [1]) This is why there is also a growing need for an expanded theory of logistics that helps characterize existing solutions, systematically develop new ones, and bring them together effectively and efficiently. The objectives for science are to develop a new conceptual model, a framework model and a procedure model for current and future logistics solutions including Logistics 4.0. This is a big task. Models help to systemize logistical knowledge. The relevant knowledge areas are e.g. technologies and basics of Logistics 4.0, strategies and methods to improve processes and trends for the future.

METHODOLOGY

Years of scientific work and practical experiences in the area of logistics form the basis of the scientific work. This is extended by an evaluation of current scientific publications and own scientific projects on the area of Logistics 4.0. To enrich the theory of Logistics 4.0 the model "Smart Logistics Zone" is developed. It differs into logistical objects, logistical processes, logistical systems and the relevant logistical infrastructure. The "Smart Logistics Zone" is defined as a scalable examination and action area for the analysis, evaluation, planning, control, regulation and (re-) configuration of logistics solutions [2]. With this methodology, a knowledge basis about Logistics 4.0 solutions will be created and systematically applied.

SOLUTIONS OF LOGISTICS 4.0

Figure 1 gives an overview of some typical solutions of Logistics 4.0. Therefore, figure 1 is differed into the components of a "Smart Logistics Zone": objects, processes, systems and infrastructure (O, P, S, I).

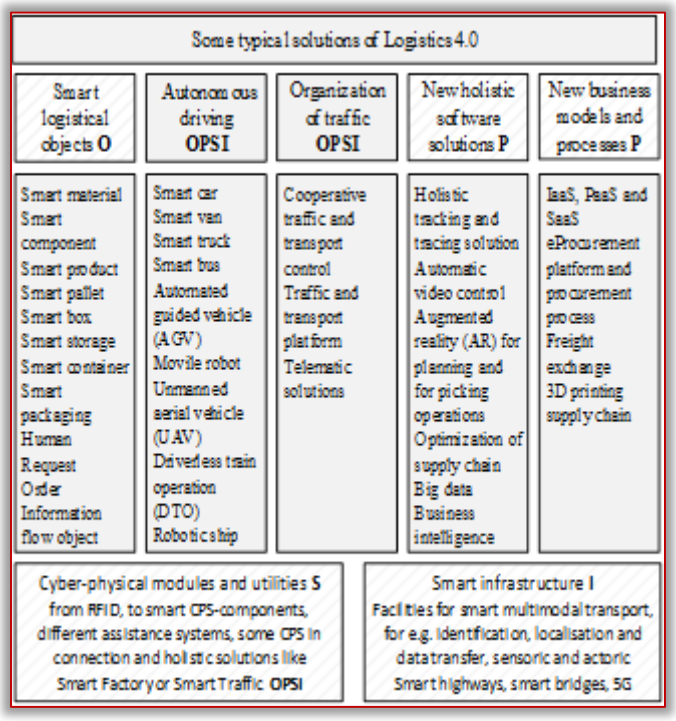

Figure 1. Some typical solutions of Logistics 4.0 (Compare [1] [3])

The first group contains smart, logistical objects. They include the use of embedded systems to collect data, communicate and make networking. They use identification (e.g. RFID) and sensor technologies. They create transparency about the identified logistical products or load carriers and their behavior. This information builds the basis for holistic tracking and tracing solutions and for process control. Processes are changed, where the logistic objects are involved.

The second group contains possibilities of autonomous driving and will be realized in combination of (O, P, S, I). They have different

technical solutions, but realize the same task to move, to handle and to transport without a driver or a pilot. There is a great potential to improve the energy efficiency and to increase the capacity of the transport mode and space. Smart vans, trucks and busses have sensors for direction, speed and safety distances. Cameras replace driving mirrors. GPS and WLAN give information about topological characteristics.

New models of Automated Guided Vehicles (AGVs) and mobile robots use more sensors to get more information, drive autonomously and communicate with each other. They navigate by themselves to places where they are needed. They support e.g. transportation and delivery processes, handling of tools and parts, assembly, quality control and maintenance. The newest solutions of Unmanned Aerial Vehicles (UAV) and the self-positioning of trains are also part of Logistics 4.0. (Compare [4]) Robotic ships will have robots, cameras, sensors, radar, sonar and GPS onboard. The navigation is autonomous, but could also be centrally controlled.

The third group of solutions (O, P, S, I) deals with the organization of traffic and transport by cooperative traffic and transport control. This is based on the recording of the current traffic situation and the adaption of traffic signs and signals, while the traffic platform interconnects the intermodal transport and the intermodal movement. Telematics solutions use technical data to optimize fleet management, vehicle management, driver management and cargo management.

The fourth group of solutions contains new holistic software solutions (with Cyber physical System (CPS) characteristic) allowing new processes. Tracking is useful for position fixing and for the delivery status of the objects. Tracing gives a holistic view on the value added chain. Video control is used for documentation, for security tasks and for control of logistics processes. The video sequences are automatically checked and give signals and/or actor activities as reaction to abnormal situations. Augmented Reality (AR) helps to increase the process quality by avoidance of logistical failures and by increasing the efficiency of staff by avoidance of unnecessary searching processes. Supply Chain Management (SCM) allows the identification of possible savings and the avoidance of effectivity losses in the framework of a holistic consideration. Big data are based on data analysis methods to discover patterns and other useful information. Business intelligence (BI) are "the processes, technologies, and tools needed to turn data into information, information into knowledge, and knowledge into plans that drive profitable business action. Business intelligence encompasses data warehousing, business analytic tools, and content/knowledge management." [5]

In addition, new business models and business processes are created. Examples are the realization of business-to-business or business-to-consumer or business-to-government purchase or the new 3D-printing process. New solutions of Logistics 4.0 realize the full process in the kind of a sensor triggered, software integrated, autonomously realized and optimized process. One more example is the freight exchange to conclude sub-contracts and to reduce empty runs. Integrated software helps to realize process mining, e.g. Business Activity Monitoring (BAM), Business Operations Management (BOM) and Business Process Intelligence (BPI).

Some typical Cyber-physical modules and utilities are smart shelf, shelfs with robots, modular cross-linked conveying systems, robot assistance, smart clothes, data glasses, data gloves. CPS should have the following functions: identification, object information and – storage (by CPS or by cloud), ability to communicate, localization, control/monitoring, to recognize and report problems, to make a decision and to realize actions.

Smart infrastructure gives the frame for smart processes and systems. Examples are e.g. smart docks, smart gates, smart ramps or urban test-fields for mobility. They allow different logistics processes and systems. As a result, it is to sum up that the majority of solution in fig. 1 will only change the fulfilment of existing processes, but some of them will also create new business processes.

PROCESSES OF LOGISTICS AND LOGISTICS 4.0

Logistics is a service fulfilling customer requirements and protecting the existence of companies. That means to do the right things in an efficient way. Logisticians are the masters of flows and processes. Therefore, process knowledge is very important for logisticians. The following Table 1 shows a new schema for systematization of the strategically process knowledge in the Logistics area.

Table 1. Schema for systematization of strategically process knowledge to improve logistical processes (created by the authors)

Aspect	Examples
General process models:	SCOR-model, material flow operations, information flow operations, financial flow operations, energy flow operations
General possibilities to improve processes:	
(a) Use typical processes (Application, adaptation / modification and combination)	JIT, JIS, KANBAN, CONWIP, Milkrun, Consignment warehouse processes, sourcing processes, VMI, Pick by vision
(b) Best practices, conveyance of solutions	Benchmarking, Analogy technique
(c) Total new processes	Business Process Reengineering, Process Reengineering, Logistics 4.0 processes
(d) Improvement of existing processes	KAIZEN
Tool set with special focus on:	
Define targets and trends	TOWS, SWOT, Scenario technique
Environmentally responsible behavior	Green Supply Chains, Sustainability
Value	Value stream mapping
Eliminate waste	Lean production, Lean techniques
Accept no failures	Six Sigma, TQM, FMEA
Classic automation	Logistics 3.0
Digitalization and networking	Logistics 4.0, Smart Logistics Zone
Identify potential	Potential analysis
Identify weaknesses in SC	Material flow analysis
Identify key aspects	ABC-, XYZ-, HML-, GMK-, FSN-, SDE-, SOS-, VED-, SKFO-, GOLF-Analysis (Compare [6] and [7])
Controlling	Balanced Scorecard, Key factors

Basics for the schema are process models for different types of flows. This can be business processes in supply chains as well as material, information, financial or energy flow operations. They can be used to define and describe elementary, complex or integrated logistics processes.

In general, there are four possibilities to improve processes: (a) use of typical, well-known, empirical strategies and processes (also modified and combined), (b) use of best practices, (c) define very new processes, e.g. Logistics 4.0 processes or (d) optimize existing processes.

For (a) there is a big group of generic strategies and typical processes to realize Logistics. They all have a main idea of solving logistics tasks. This is the group of proved and tested empirical knowledge. However, there is the danger that only basic technologies are used. These basic processes can be adapted, modified or combined. For (b) it is necessary to identify best practices if not known. This requires time for examination and evaluation. For (c) creativity is required. A new reference solution should be designed and realized. The Smart Logistics Zone supports this in a systematic way. For (d) the focus is on the improvement of existing processes. Typical aspects can be the aspects which the logistician wants and needs (compare Table 1) e.g. cost, time, quality and value. Material and information flows are as important as financial flows in Logistics. Financial key factors are to record in the logistics network and to be controlled. Important targets are profitability and liquidity of enterprises with logistics services. It is necessary to record cost and revenues as well as cash flows. Examples for energy operations are e.g.

energetic conversion, to increase, to reduce, to modify the direction, to conduct, to isolate, to collect, to share, to mix and to separate energy [8].

Typical for Logistics is the procedure to create variants of the processes and choose the best one. Therefore, the use of e.g. the Value benefit analysis and the evaluation with key factors are to be recommended. The evaluation by intelligence factors and levels is new in this field.

TRENDS AND RESEARCH AREAS OF LOGISTICS 4.0

The solutions of Logistics 4.0 will be enhanced in the next few years. New technologies and solutions will occur. There are common trends: progressive dispersion of modern information and communication technologies, rising globalization of the economic system, short life cycle of innovations and technologies, increasing individualization of customer requirements, demographic change, increasing importance of the efficiency of resources and energy, increasing requirements according reliability and safety. (Compare [9]) These trends have impacts on Logistics: globalization and individualization induce growing material flows with more and more single objects.

There is also mentioned an increasing cost pressure, an increasing networking and faster processes along the Supply chain. Modular systems will be more and more typical, fulfilling individual customer requirements. In addition, there are some trends, changing Logistics 4.0. Table 2 gives an overview about some of these trends. A short description characterized each identified trend. The trends are also scientific areas of operation and research for the future.

Table 2. Some trends and research areas of Logistics 4.0

Trends	Short description
Cloud software [10]	New offered services include infrastructure (IaaS), platforms (PaaS) and software (SaaS). Memory capacity, processing power and applications were provided by internet and do not installed local.
Edge Computing	Data streams were processed and compacting local. Resources are preserved and the data volume is reduced.
Artificial Intelligence [10][11][12]	Three group of methods are used and developed: Artificial neural networks, Fuzzy Logic and Evolutionary algorithm. It is possible to optimize f. e. logistical processes and systems (prescriptive analytics), prediction of failures and disturbances (predictive maintenance).
Trends	Short description
Pattern matching [13] and Big Data Analysis	Increasing data volume requires efficient methods of processing. It is necessary to evaluate situations and do forecast.
Blockchain technology	The accounting of logistics activities can be realized automatically by using block Chain technology (Smart contracts).
Decentral organization and self-organization (Compare [13])	Allows multiple interactions in the logistical zone between OPSI, have often a strong dynamical non-linearity.
Networking (Compare [14])	Internet of things (IoT) connect physical and virtual things by using information and communication technologies. The task is now to develop the Internet of services (IoS)
Autonomous driving	Solutions realize the same task to move, to handle and to transport without a driver or a pilot. Objectives are to improve the energy efficiency and to increase the capacity of the transport mode and space. They support e.g. transportation and delivery processes, handling of tools and parts, assembly, quality control and maintenance.
New professions and activities in logistics	E.g. data specialist, drone pilot, robot coordinator, digital transport manager, global supply chain manager
Infrastructure and smart infrastructure	Mobility infrastructure e.g. charging infrastructure for e-mobility and cargo bikes; 5G projects e.g. communication for mobility and communication for factories

CONCLUSIONS

The theory of logistics has to be further developed. Therefore, some new and improved systematics are presented in this paper: (1) solutions of Logistics 4.0, (2) strategies to improve logistical processes implementing Logistics 4.0 and (3) trends (as well as research fields) of Logistics 4.0. These systematics offer meta-knowledge in this field.

The use of the new theory of the Magdeburg Logistics Model ("Smart Logistics Zone") promises significant effects in the targeted, systematic, cross-functional, efficient, engineering-technical work as well as in the solution quality of Logistics 4.0 tasks that can be achieved in this way.

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ISSN: 2067-3809

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SHRINKAGE AND CREEP CHARACTERISTICS OF PALM KERNEL SHELL CONCRETE

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Abstract: This research work evaluates the shrinkage and creep characteristics of concrete containing Palm Kernel Shell (PKS) as partial replacement of natural coarse aggregate, for a period of 180days. Concrete was mixed at 0.55 water-cement ratio, mix proportion of 1:1:2 and percentage replacement of natural aggregate with PKS at 0%, 25% and 50%. For each concrete mix, nine 100mm x 100mm x 400mm short columns were made, six to evaluate its shrinkage behavior and three for creep characteristics, this makes a total of twenty-seven (27). Three concrete columns from each of the concrete mix were sealed while another set of three from each concrete mix were unsealed to measure the total, basic and drying shrinkage of the concrete. The creep results of Palm Kernel Shell Concrete (PKSC), increased as the percentage content of PKS increased in the concrete. The maximum creep strain observed for normal concrete, 25% and 50% PKS content were 0.00018mm/m, 0.00057mm/m and 0.00094mm/m respectively. The shrinkage results show that Palm Kernel Shell Concrete (PKSC) has a higher percentage of shrinkage (all types of shrinkage: basic, drying and total shrinkage) than normal concrete. The pattern of shrinkage development for both normal and PKS concrete was seen to be very similar. The maximum total shrinkage strain recorded for 0%, 25% and 50% PKS content was 0.00102mm/m, 0.00183mm/m and 0.00247mm/m respectively. Conclusively, the greater the PKS content, the higher the shrinkage strain. The creep results of Palm Kernel Shell Concrete (PKSC), increased as the percentage content of PKS increased in the concrete. The maximum creep strain observed for normal concrete, 25% and 50% PKS content were 0.00018mm/m, 0.00057mm/m and 0.00094mm/m respectively.
Keywords: Concrete, Palm Kernel Shell, Aggregates, Creep and Shrinkage

INTRODUCTION

The palm oil industry produces wastes such as palm kernel shells and palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. The use of palm kernel shell in concrete could resolve this challenge with some other advantages; reduction in the need to crush more rocks for natural coarse aggregate and reduced land areas used as dump sites. Shrinkage in concrete is defined as reduction in volume of concrete usually over a period of time. Concrete is subjected to changes in volume either autogenous or induced. Volume change is one of the most detrimental properties of concrete, which affects the long term strength and durability. Aggregate size and shape have been reported to be key factors affecting the shrinkage of hardened concrete. The study by Bisschop et al. (2002) indicated that the total length and the depth of micro cracking caused by shrinkage of concrete will increase with larger aggregate size. It has been reported that the elastic property of aggregate determines the degree of restraint to the cement matrix (Topcu et al. 2010). A normal natural aggregate is usually not subject to shrinkage. However, there exist rocks that can shrink up to the same magnitude as the shrinkage of concrete made with non-shrinking aggregate (Bairagi et al. 1993). For example, the shrinkage of a concrete made with steel aggregate will be lower than the one made with normal aggregate. Similarly, the shrinkage of a concrete made with expanded shale aggregate will be higher than the one made with a normal aggregate. In other words, If the skeleton of coarse aggregate in the concrete is stiffer, the shrinkage strain of concrete will be less. The elastic modulus of the aggregate determines the extent of restraining action to the shrinkage of concrete.

Studies by Kim et al. (2016) show that for a fixed mix proportion, there is a considerable variation in the shrinkage strain of the resulting concrete batched with coarse aggregate of different types. This phenomenon is very likely due to the difference in modulus of elasticity among aggregate of different types. Teo et al. (2007) carried out drying shrinkage test on PKSC and compared it with normal concrete on 7, 28, 56 and 90 days. They reported that the drying shrinkage of both the PKSC and normal concrete increased with age but PKSC showed higher increment. At the age of 28 and 90 days, PKSC showed 64 and 182 microstrain respectively. This was 6% and 14% higher than the drying shrinkage of normal concrete, for the ages indicated respectively.

Concrete creep is defined as deformation of structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending. Creep does not necessarily cause concrete to fail or break apart. Aggregate undergoes very little creep. It is really the paste which is responsible for the creep. However, the aggregate influences the creep of concrete through a restraining effect on the magnitude of creep. The paste which is creeping under load is restrained by the aggregate which do not creep.

The stronger the aggregate, the more the restraining effect and hence the less is the magnitude of creep. The modulus of elasticity of aggregate is one of the important factors influencing creep. It can easily be imagined that the higher the modulus of elasticity, the less the creep. Light weight aggregate shows substantially higher creep than normal weight aggregate. This is why it is of paramount interest to investigate the creep of palm kernel shell concrete.

The amount of paste content and its quality is one of the most important factors influencing creep. A poorer paste structure undergoes higher creep. In other words, it can also be said that creep is inversely proportional to the strength of concrete. Concrete

with PKS has been known to be less workable in some instances than normal concrete, because PKS absorbs more water than natural coarse aggregate. It is expected that this particular factor will have a significant influence on the creep of concrete made with PKS, since it has been reported by various researchers that palm kernel shell concrete usually has less strength compared to normal concrete at the same mix and water-cement ratio. (Ikponmwosa et al. 2018, Olanipekun et al. 2006, Shafigh et al. 2010).

Age at which a concrete member is loaded will have a predominant effect on the magnitude of creep. This can be easily understood from the fact that the quality of gel improves with time. Aged gel creeps less, whereas a younger gel under load being not as strong creeps more. Although moisture content of the concrete being different at different ages will also have a significant influence on the magnitude of creep. Over the years, there have been so many research works on the use of palm kernel shell in concrete, but little or nothing is known on the shrinkage and creep of palm kernel shell concrete, hence the significance of this work.

MATERIALS AND METHOD

The raw materials used in this investigation were locally available and these included ordinary Portland cement (OPC) as binder, river sand as fine aggregate, crushed granite and PKS as coarse aggregate. Potable water was used for mixing and curing throughout the entire investigation. PKS has comparatively high water absorption characteristics. As a result, to avoid water absorption during the mixing process, it was essential to mix PKS aggregate at saturated condition based on 24 h immersion in potable water.

Concrete was mixed at 0.55 water-cement ratio, mix proportion of 1:1:2 and percentage replacement of natural aggregate with PKS at 0%, 25% and 50%. For each concrete mix, nine 100mm x 100mm x 400mm short columns were made, six to evaluate its shrinkage behavior and three for creep characteristics; this makes a total of twenty-seven (27). The concrete specimens were demoulded 24hrs after casting. The specimens for shrinkage test were set up for observation while the specimens for creep test were cured for 13days.

For Shrinkage test, three concrete columns from each of the concrete mix were sealed (by covering the entire surface with paraffin wax, 3mm thick to prevent loss of moisture) while another set of three from each concrete mix were unsealed to measure the total, basic and drying shrinkage of the concrete. The concrete columns were set on measuring rigs for the shrinkage measurement after 24hrs of casting. The shrinkage deformations were measured by using loading and measuring rigs as recommended by Salau et al (2014). The rigs were designed and constructed to consist of a simple steel frame with an adjustable height beam, to hold the measuring gauge and a base plate on which the concrete specimen is placed. The arrangement of the adjustable height beam with the measuring gauge is then placed centrally on the concrete specimen. The measuring gauge is calibrated to read to the nearest 0.01mm. Measurements were taken every day in the first two weeks, and then three times a week up to 180 days. Figure 3 shows the set up for the shrinkage test.

The compressive strength of all specimens for creep test was predetermined. The specimens were loaded at 14days age for six months. The load applied was 40% of the compressive strength of the specimen at the time of loading. A helical spring which allows a constant load application was used. The pressure was applied at the center of the specimen.

Figure 1: Specimens under shrinkage test

Figure 2: Specimens under creep test

RESULTS AND DISCUSSION

— Physical Properties of Aggregates

Table 1: Physical Properties of Aggregates.

Properties	Palm Kernel Shell	Crushed granite
Maximum aggregate size (mm)	12.5	12.5
Shell thickness (mm)	3.5	-
Specific gravity	1.27	2.81
Bulk density (kg/m^3)	694	1440
Moisture Content (%)	6.1	-
Water Absorption (24hrs) (%)	19	0.5
Porosity (%)	22	-
Abrasion (%)	3.5	24
Aggregate Impact Value (%)	6.9	11.4
Aggregate Crushing Value (%)	5.2	6.4
Uniformity Coefficient (Cu)	2.0	1.5
Uniformity of gradation	1.39	1.04

Average bulk density of palm kernel shell was found to be 694kg/m^3, this falls within the specified limits for lightweight aggregate of 250-1000kg/m^3, (BS 3797). The specific gravity of PKS is 1.27. This is 2.2 times less than that of normal aggregate, given as 2.81. The specific gravity of a material is a reflection of its porosity; lower specific gravity is an indication of higher porosity. Aggregate porosity is an important factor that determines the durability of concrete. Moisture content, water absorption and porosity of PKS were found to be 6.1%, 19% and 22% respectively. This is relatively high and it is expected to impart on concrete strength by lowering it. The shrinkage and creep of PKS concrete may be higher than that of normal because the concrete matrix will permit easier loss of

moisture. The Aggregate Crushing Value (ACV) and the Aggregate Impact Value (AIV) were 5.2% and 6.92% respectively for palm kernel shell aggregates while that of normal aggregates were 6.4% and 11.4% . The low value of AIV and ACV indicate that palm kernel shell is a good energy absorbing material. When palm kernel shell is used as aggregate in concrete, the good energy absorbing capacity would be advantageous to structures which are likely to be exposed to dynamic or shock loading. Aggregate quality adds greater stiffness to the concrete. Aggregate work to arrest cracks when concrete is subjected to flexural loads, increasing aggregate strength increases the compressive and flexural strength of concrete, consequently reducing shrinkage and creep strain.

— Shrinkage Deformation of Palm Kernel Shell Concrete

The results of the shrinkage of normal and palm kernel shell concrete are presented in Figures 3,4,5,6,7 and 8. It was observed that shrinkage (all types of shrinkage: basic, drying and total shrinkage) increased as the percentage of PKS content increased in the concrete. The pattern of shrinkage development for both normal and PKS concrete was observed to be very similar. The pattern shows rapid shrinkage at early ages of the concrete (0-40days), then a steady rate at latter ages. The normal concrete curve achieved the steady rate of shrinkage at an earlier age than PKS concrete.

It was observed that the unsealed concrete prisms (for measuring total shrinkage), irrespective of PKS content, showed higher deformation than the sealed concrete prisms (measuring basic shrinkage). This could have occurred as a result of internal drying (moisture loss due to hydration) as well as external drying (effect of temperature and humidity) while the specimen under the sealed condition shrunk only because of internal drying.

⧉ Basic Shrinkage Deformation of Normal and Palm Kernel Shell Concrete

Basic shrinkage is the shrinkage deformation of a concrete that has been shielded from external factors that may affect and aid shrinkage deformation in the concrete. This is achieved by covering the concrete surface with paraffin wax to extinguish the effect of temperature and humidity on the specimen. The basic shrinkage curve of the normal concrete is shown in Figure 6, the curve rose rapidly at the early stage (0-10days of loading), and then followed almost a linear progression for the remaining days of loading. The basic shrinkage of normal concrete rose to a maximum value of 0.00036mm/m at 175days of loading and maintained this value over the five remaining days of loading. The basic shrinkage curve of the concrete with 25% PKS content as shown in Figure 6 showed a similar trend to that of normal concrete, where shrinkage increased significantly at the early age and slowed down to follow a more steady rate after 50days of loading. The basic shrinkage of concrete with 25% PKS content rose to a maximum value of 0.00054mm/m (a 50% increase from that of normal concrete) at 175days of loading and maintained this value over the five remaining days of loading. The basic shrinkage curve of the concrete with 50% PKS content, also shown in Figure 6, showed that shrinkage increased significantly throughout the days of loading, where no particular rapid rate is observed at the early age. The basic shrinkage of concrete with 50% PKS content rose to a maximum value of 0.00116mm/m (a 222% increase from that of normal concrete) at 170days of loading and maintained this value over the remaining ten days of loading.

Generally, it was observed that basic shrinkage increased as PKS content increased in concrete. Also, for both normal and PKS concrete (25% and 50% PKS content), basic shrinkage is less than both the drying and total shrinkage. This means that the shrinkage due to internal drying of concrete (moisture loss due to hydration) is less that shrinkage due to external drying (effect of temperature and humidity). The increased shrinkage obtained in the concrete containing PKS can be attributed to the compressibility or stiffness of the coarse aggregate which directly influenced the shrinkage of the concrete. Stiffer (harder) coarse aggregates are better at restraining shrinkage. The PKS with its lower aggregate impact value, aggregate crushing value and specific gravity is not as stiff as natural aggregate and can therefore provide less restrain to shrinkage than the natural aggregate. The quality of the aggregates ultimately determines the concrete specimen's potential for strength and resistance to shrinkage.

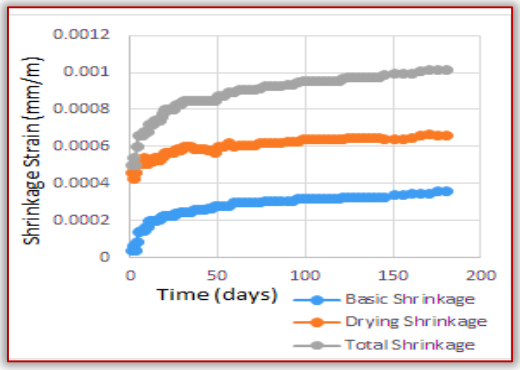

Figure 3: Shrinkage strain of normal concrete

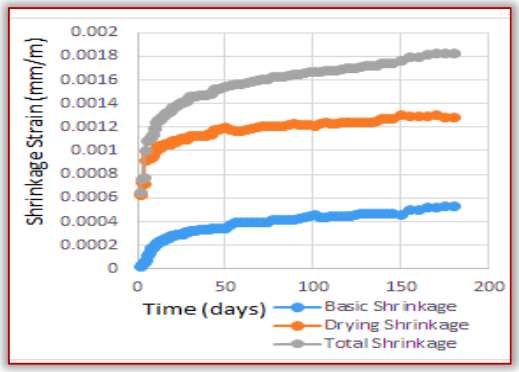

Figure 4: Shrinkage strain of 25% palm kernel shell concrete

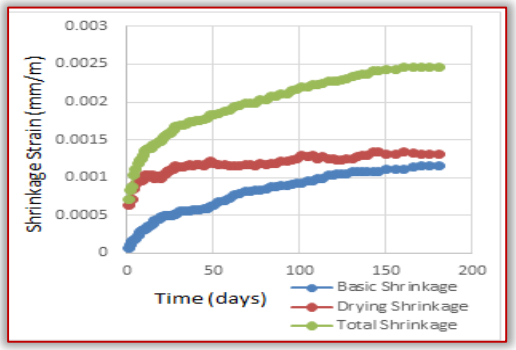

Figure 5: Shrinkage strain of 50% palm kernel shell concrete

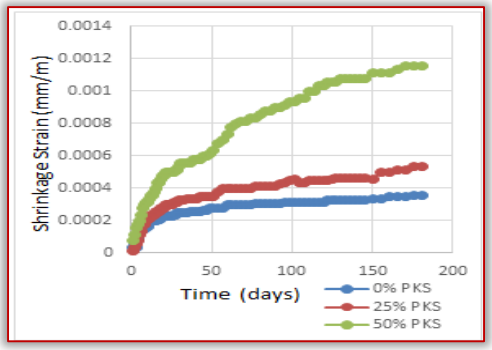

Figure 6: Basic shrinkage of palm kernel shell concrete

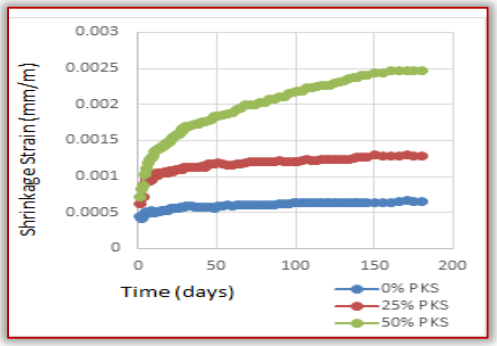

Figure 7: Drying shrinkage of palm kernel shell concrete

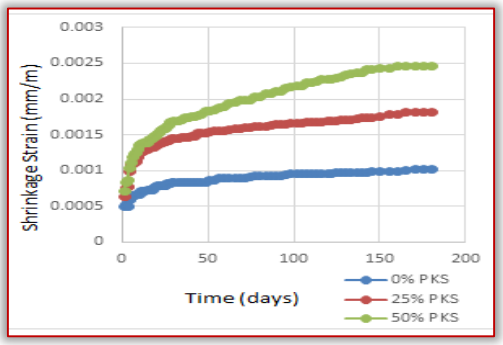

Figure 8: Total shrinkage of palm kernel shell concrete

Drying Shrinkage Of Normal and PKS Concrete

Drying shrinkage is the shrinkage deformation that occurs due to loss of free water from the concrete, due to the effects of temperature and humidity. It depends on variables such as water-cement ratio, cement composition, type of aggregate, degree of hydration, curing condition, temperature of curing, relative humidity, moisture content and the duration of drying.

The drying shrinkage curve of normal concrete is shown in Figure 7, the curve is almost a straight line. The maximum value of drying shrinkage of normal concrete is 0.00067mm/m at 170days. The drying shrinkage curve of concrete with 25% PKS content rose rapidly in the first 20days of loading as shown in Figure 7, it then followed a more linear progression afterwards, to appear similar to that of normal concrete. The maximum drying shrinkage of concrete with 25% PKS content was 0.00131mm/m (95% increase from that of normal concrete) at 150days. The drying shrinkage curve of concrete with 50% PKS content progressed throughout the 180days of loading (similar to its basic shrinkage), but a more steep trend was observed within the first 10days of loading. The curve is as shown in Figure 7. The maximum drying shrinkage of concrete with 50% PKS content is 0.00134mm/m (a 100% increase from that of normal concrete and only a 2% increase from the 25% PKS content) at 160days of loading.

Generally, drying shrinkage increased as the percentage of PKS increased in concrete, though only a 2% increase between the 25% and 50% PKS content in this investigation. At higher PKS content (50%), it increased throughout the period of loading. The increase in drying shrinkage observed in palm kernel shell concretes can be attributed to the content, interconnection and distribution of pore size of PKS.

Total Shrinkage Deformation of Normal and PKS concrete

Total shrinkage is the shrinkage deformation of a concrete subjected to all factors that may cause shrinkage. These factors may be categorized into internal factors, such as moisture loss due to hydration and external factors such as temperature and humidity. It is the shrinkage measured from the unsealed concrete specimen, which are affected by climatic conditions. It was observed that total shrinkage increased as the percentage of PKS increased. However, the trends of shrinkage development in both normal and PKS concrete (25% and 50% PKS content) were very similar. The trend shows rapid shrinkage at early ages of the concrete (0-40days) and a steady rate at latter ages. The total shrinkage curve of the normal concrete rose rapidly within the first 5days of measuring deformation. It continued to rise slowly and steadily, following almost a linear progression, over the remaining 175days of observation. The maximum total shrinkage recorded for normal concrete was 0.00102mm/m at 170days and this was constant till 180days.

Considering the palm kernel shell concrete with 25% PKS content, the total shrinkage curve rose rapidly within the first 20days and like the normal concrete, it followed almost a linear progression for the remaining days of observation. The maximum total shrinkage recorded for concrete with 25% PKS content was 0.00183mm/m at 170days and this was constant till 180days. This is 1.8 times more than that of normal concrete. The total shrinkage curve of concrete with 50% PKS content as shown in Figure 8 rose more rapidly over the first 40days of observation and continued to rise at a higher rate than was observed in the normal concrete and the 25% PKSC, though it followed a similar trend with them. The maximum total shrinkage measured was 0.00247mm/m at 160days and remained constant till 180days. This is 2.4 times more than that of normal concrete and 1.3times more than that of 25% PKSC.

The higher shrinkage deformation observed at the early ages of the PKSC can be attributed to the loss of water in the plastic concrete. The PKS was earlier reported in this research to contain higher porosity and water absorption properties than natural aggregate. This increases the loss of water in concrete and consequently lead to increased shrinkage. The irregular surface of the PKS and its concrete increases the porosity of the concrete and the irregular distribution of pore size within the concrete. This also promotes higher shrinkage strain in the concrete.

The purity of the employed palm kernel shell should be taken into account as a factor for the increase in shrinkage reported in the concrete containing PKS. The type and amount of contaminants that might be present in these aggregates is one of the causes for the differences in the shrinkage behavior of the concrete containing

PKS. In order to reduce the effect of contaminants in the palm kernel shell, it was washed thoroughly before being used in concrete.

Linear Regression Model of Total Shrinkage, Concrete Age and Palm Kernel Shell Content.

Linear regression model:

$$Y \sim 1 + X_1X_2 + X_1^2 + X_2^2.$$

where: Y = Total Shrinkage (mm/m); X_1 = Concrete Age (days); X_2 = Palm Kernel Shell Content (%)

Regression Statistics:

- Number of observations: 237
- Error degrees of freedom: 231
- Root Mean Squared Error: $9.17\mathbf{e^{-05}}$
- R-squared: 0.968
- Adjusted R-Squared: 0.967
- F-statistic vs. constant model: $1.4\mathbf{e^{-03}}$
- P-value: $1.57\mathbf{e^{-170}}$

Regression Table

	Coefficients	Standard Error	tStat	P-value
Intercept	0.00061509	$1.8255\mathbf{e^{-05}}$	33.695	$3.9651\mathbf{e^{-91}}$
X_1	$7.4053\mathbf{e^{-06}}$	$4.5401\mathbf{e^{-07}}$	16.311	$2.6154\mathbf{e^{-40}}$
X_2	$2.3859\mathbf{e^{-05}}$	$1.1152\mathbf{e^{-06}}$	21.395	$1.0215\mathbf{e^{-56}}$
X_1*X_2	$1.1603\mathbf{e^{-07}}$	$5.6083\mathbf{e^{-09}}$	20.69	$1.674\mathbf{e^{-54}}$
X_1^2	$-3.4943\mathbf{e^{-08}}$	$2.5875\mathbf{e^{-09}}$	-13.504	$5.0696\mathbf{e^{-31}}$
X_2^2	$-2.3494\mathbf{e^{-07}}$	$2.0218\mathbf{e^{-08}}$	-11.62	$6.9809\mathbf{e^{-25}}$

The regression model equation can be written as:

$$Y = 0.00061509 + 7.4053 \times 10^{-6} X_1 + 2.3859 \times 10^{-5} X_2 + 1.1603 \times 10^{-7} X_1*X_2 - 3.4943 \times 10^{-8} X_1^2 - 2.3494 \times 10^{-7} X_2^2.$$

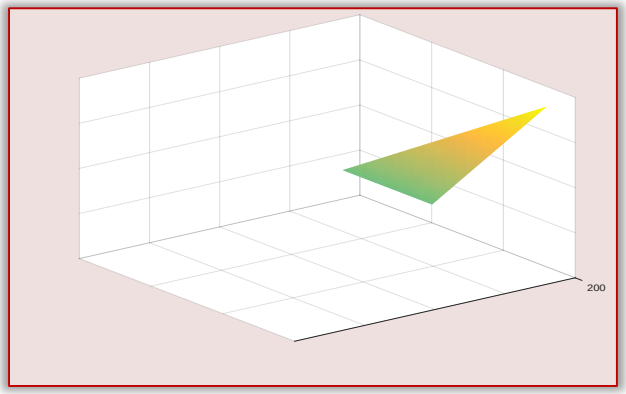

Figure 9 : Three-Dimensional Model of Total Shrinkage-Percentage PKS–Age of Concrete

Equation models the progress of total shrinkage with time (age of concrete) and the influence of PKS content on total shrinkage. It was observed that shrinkage increases with concrete age and increase in PKS content as shown in Figure 9. This model can be used to predict the expected shrinkage of palm kernel shell concrete at a certain age and a given PKS content from 0% to 50%.

— Creep Of Palm Kernel Shell Concrete

The results obtained from creep of normal and palm kernel shell concrete (25% and 50% content) are as shown in Figure 10. The trend of creep development in the 25% and 50% PKS concrete are more similar than that of the normal concrete. Creep in the normal concrete followed a more linear trend and can be seen to develop steadily throughout the 180days of observation. For palm kernel shell concrete (25% and 50%), the creep indices rose faster at the early stage (between 0 – 50 days of loading), after which it maintains a steady rise up to 180 days. The maximum value of creep measured for normal concrete, 25% and 50% palm kernel shell content are 0.00018mm/m, 0.00057mm/m and 0.00094mm/m respectively. It can be observed from Figure 10 that concrete creep increased as the percentage of palm kernels shell increased. The amount of paste content and its quality is one of the most important factors influencing creep. A poorer paste structure undergoes higher creep. The compressive strength results of PKSC has been found (Ikponmwosa et al. 2018) to be lower than that of normal concrete, and it decreases as the percentage of PKS increases in the concrete. This explains the increase in creep in PKS concrete than normal concrete and its increase as PKS content increases.

Age at which a concrete member is loaded will have a predominant effect on the magnitude of creep. Moisture content of the concrete being different at different ages will also have a significant influence on the magnitude of creep. The concrete specimens in this research were loaded on the 14th day after it was cast. This enabled the measurement of about the highest creep deformation possible in the concrete.

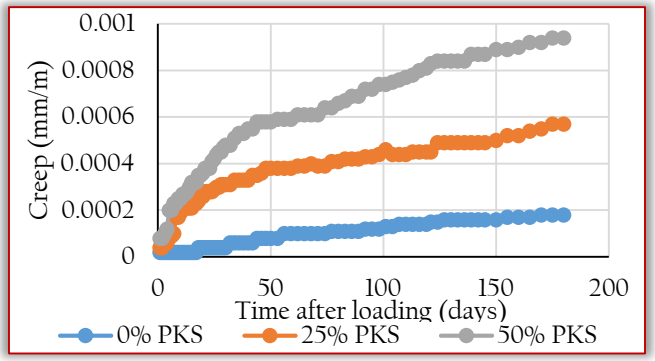

Figure 10: Creep of Palm Kernel Shell Concrete

Linear Regression Model of Creep, Curing Days and Palm Kernel Shell Content

Linear regression model:

$$Y \sim 1 + X_1X_2 + X_1^2 + X_2^2.$$

where: Y = Creep (mm/m); X_1 = Concrete Age (days); X_2 = Palm Kernel Shell Content (%)

Regression Statistics:

- Number of observations: 237
- Error degrees of freedom: 231
- Root Mean Squared Error: $4.09\boldsymbol{e^{-05}}$
- R-squared: 0.974
- Adjusted R-Squared: 0.974
- F-statistic vs. constant model: $1.76\boldsymbol{e^{\mp 03}}$
- P-value: $1.45\boldsymbol{e^{-181}}$

Regression Table

	Coefficients	Standard Error	tStat	P-value
Intercept	$-2.4893\boldsymbol{e^{-05}}$	$8.14\boldsymbol{e^{-06}}$	-3.0581	0.0024904
X_1	$3.2492\boldsymbol{e^{-06}}$	$2.0245\boldsymbol{e^{-07}}$	16.049	$1.9122\boldsymbol{e^{-39}}$
X_2	$6.9351\boldsymbol{e^{-06}}$	$4.9727\boldsymbol{e^{-07}}$	13.946	$1.766\boldsymbol{e^{-32}}$
X_1*X_2	$6.6807\boldsymbol{e^{-08}}$	$2.5008\boldsymbol{e^{-09}}$	26.714	$1.3633\boldsymbol{e^{-72}}$
X_1^2	$-1.4593\boldsymbol{e^{-08}}$	$1.1538\boldsymbol{e^{-09}}$	-12.648	$3.2806\boldsymbol{e^{-28}}$
X_2^2	$-3.6253\boldsymbol{e^{-08}}$	$9.0155\boldsymbol{e^{-09}}$	-4.0212	$7.843\boldsymbol{e^{-05}}$

The regression model equation can be written as:

$$Y = -2.4893 \times 10^{-5} + 3.2492 \times 10^{-6} X_1 + 6.9351 \times 10^{-6} X_2 + 6.6807 \times 10^{-8} X_1 * X_2 - 1.4593 \times 10^{-8} X_1^2 - 3.6253 \times 10^{-8} X_2^2$$

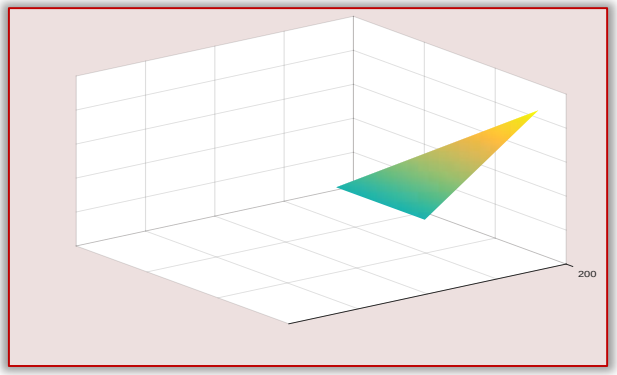

Figure 11: Three-Dimensional Model of Creep – Percentage PKS – Age of concrete

Equation 2 shows the dependence of creep of PKSC on age of concrete and percentage PKS content. The positive coefficients of CA and PKS shows that creep will increase as these variables increase while the negative constant of the equation means the rate at which the concrete creeps will reduce as the concrete ages. The inter-dependence of these three variables (creep, concrete age and percentage PKS content) is as shown in Figure 11.

— Temperature and Relative Humidity

It has been reported that the rate and magnitude of creep and shrinkage increases as the humidity of atmosphere decreases. The relation between relative humidity and creep/shrinkage is not linear as concrete under sustained load in air at 70% relative humidity will have a creep/shrinkage deformation about twice as large as concrete in air at 100% relative humidity.

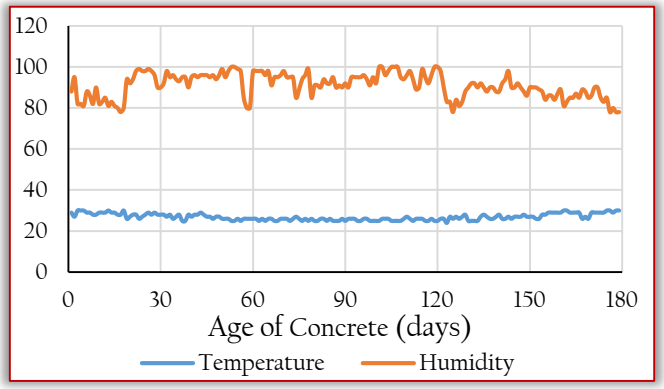

Figure 12: Temperature and Relative Humidity Result

The ultimate creep/shrinkage in air at 50% relative humidity will be about three times as large. (Bisschop 2002). The relative humidity recorded during the experiment varied between 78% and 100% while the temperature varied between 24^{0}C and 30^{0}C, [see Figure 12]. This range is believed to be close enough not to affect the shrinkage and creep results significantly.

CONCLUSIONS AND RECOMMENDATION

Average bulk density of palm kernel shell was found to be 694kg/m^3; this falls within the specified limits for lightweight aggregate of 250-1000kg/m^3, (BS 3739). The specific gravity of PKS is 1.27; this is 2.2 times less than that of normal aggregate, given as 2.81.

It was observed that shrinkage (all types of shrinkage: basic, drying and total shrinkage) increased as the percentage of PKS content increased in the concrete. The pattern of shrinkage development for both normal and PKS concrete was observed to be very similar.

The maximum total shrinkage strain recorded for 0%, 25% and 50% PKS content was 0.00102mm/m, 0.00183mm/m and 0.00247mm/m respectively. Conclusively, the greater the PKS content, the higher the shrinkage strain.

The creep results of Palm Kernel Shell Concrete (PKSC), increased as the percentage content of PKS increased in the concrete. The maximum creep strain observed for normal concrete, 25% and 50% PKS content were 0.00018mm/m, 0.00057mm/m and 0.00094mm/m respectively.

The elastic modulus of aggregate plays an important role in the shrinkage and creep of its concrete as it determines the extent of restraining action to the shrinkage of the concrete. Since PKS has lower modulus of elasticity compared to natural aggregates, this may be one of the reasons for higher shrinkage and creep values.

It is recommended that to avoid large shrinkage and creep strain in palm kernel shell concrete, PKS content should not exceed 25% in concrete.

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DESIGN INNOVATION IN STRUCTURAL ENGINEERING: AN OVERVIEW

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Abstract: This work examines how innovations could be factored into design of structural engineering systems to provide a deviation from the codified design approaches that grossly under-utilized engineering materials and lack of optimization and reliability considerations. The paper highlights some of the innovative approaches in design and innovative construction materials. The context in which innovation as a process or concept can be used effectively is dealt with in the paper. The use of innovative materials such as Fibre Reinforced Self Compacting Concrete could be beneficial for dry joint construction which provides solution to the construction in confined places such as congested city centers. In addition, the use of numerical analytical tools interfacing with optimization and reliability analysis such as Monte Carlo simulation is highlighted. This clearly leads to design optimization that leads to efficient system and reduction of construction cost.
Keywords: structural engineering, innovation, Fibre Reinforced Self Compacting Concrete

INTRODUCTION

It is important to understand the meaning of innovation before interpolating to the realm of structural engineering. Innovation is an improved way of doing old things such as processes and services with added values for the benefit of the consumers. It is clearly understood that traditional design is very conservative with the use of high safety measure with material usage in the elastic region. This leads to high construction cost and inefficient use of materials. In this respect, the present work examines some best practices that could be argued as new means of structural engineering with value addition of some sort for the benefit of the consumers.

The innovation is examined on the premises of new materials that provide better performance at reduced weight and cost. Also, the new construction methodologies such as dry joint that provides more span with reduced depth leading reduced cost. Application of Finite Element Method of analysis provides platform for the complex interaction of structural members. This could be coupled with the reliability analysis of the engineered structures using Monte Carlos simulation or any other stochastic approach linked with structural optimisation using Genetic Algorithm or Evolutionary Genetic Algorithm for multi objective functionalities. This definitely defines the failure probability of such structures using the optimal structures.

TRADITIONAL PRACTICE

The traditional codified design approach has been the practice of most engineers across the world and most especially in Nigeria. This approach is inherent with lack of intuition of experimenting with novel approach that can be beneficial to the consumers. Although the ultimate limit state design tends to lean on reliability approach for the determination of partial factors of safety and in most cases the stress resultants from the elastic analysis using factored loads are used in design. The reason is not far-fetched because at the planning stage project cost analysis are not the priorities of planning of the project and the life cycle cost is never in the mind of the designers. It is understood that resolution of constraints, code specifications and the client's need are usually the overriding considerations. The need for innovation is seldom considered at this stage. This leaves the gap for improvement unfilled and most times opportunities are missed to have a process for value addition for the design under consideration. Although, in certain cases, nonlinearity of material and geometry are taken into consideration in stability analysis but the ultimate design is based on the use elastic stress resultants. Even, the elastic perfectly plastic material idealisation is not an ultimate realisation of material capabilities in steel for example, the material ductility that takes the response of structural members to the strain hardening realm of stress-strain relationship is never exploited by the current codified design approach. This may be argued as charting the extreme utilisation of material but the factor of safety has discounted any excessive usage of material strength. This leaves a substantive material strength unused and on top of this is the huge factor of safety on both the materials and loadings. It is very evident that such a system of design based on codes is uneconomical despite the facts much is known of the capabilities of modern material. Although certain codes such Euro Codes provide for stability analysis that accounts for the material and geometric nonlinearities. In many countries in the world, particularly developing and underdeveloped worlds such as Nigeria, British Standards are adopted without customising the codes provision to the situation on ground. For example, blank adoption of foreign codes without adjustment for local materials available on ground can be a dangerous proposition.

Most of the research outputs from the country are of substandard and with little or no effort to explore numerical simulation that can assist greatly in coming up with innovative design concepts. Apart from the lack of adequate facilities, it is a strange concept to many practising engineers in the countries the use of numerical modelling to solving engineering problems. The engineering bodies are virtually doing little or nothing to advance the agenda of innovative design. This is evident in the research papers published in many of the conferences organised in the country. This could be said of many developing countries. In situations where researchers are interested in the pursuant of competitive research using state of the art computing facilities, hardly can you find adequate resources such as high powered computer software such as ANSYS [1] and ABAQUS [2] to mention but few. The laboratories in most Nigerian universities are scantly resourced with obsolete and non-

functioning equipment. Where modern equipment are available, they are either not put into use because of lack of knowledge of calibration or some components are missing. In an instance, a full tri-axial machine is lying fallow in a laboratory because the engineers could not operate it. These are just some of the inherent problems facing researchers in Nigeria today and thus innovation in structural design is not explored rigorously.

Strictly speaking, innovative design can be summarised as follows according to Yamakazi [3]:

- innovative material-based structural components and elements, that is reusable and recyclable as social infrastructure stocks.
- multi-functional, flexible, and long-life building systems that support to maintain and to improve urban functions.
- maintenance and revitalization technologies for urban functions that create a new urban building industry.

INNOVATIVE MATERIALS AND DRY JOINT CONSTRUCTION

It is imperative to exploit the huge capacities in the modern materials to reduce cost and add values in term of space and aesthetics for the benefits of mankind. Some innovative materials have been found to be of great asset. Such composite material is Fibre Reinforced Self Compacting Concrete. There are other composite concretes that are of great values in term of strength and improved shear resistance. Even, the use of ceramic wastes has proven to be of great benefit to the industry with the material strength improvement in excess of 30%.

Fibre Reinforced Polymer (FRP) is another innovative material for the repair of damaged concrete. This may be seen as post design and construction phases of engineering system but it requires innovative approach to accomplish the set goals. In the third world, engineering systems never perform to the end of designed life span before being degraded leading to sudden collapse. Using a product like FRP will rectify the anomalies built into the systems during design and construction phases with enhanced reliability. Ede [4] demonstrated the improved performance of strengthened cracked concrete beam using FRP that is externally bonded to the concrete surface.

The objectives of innovative structural design could be summarised into the followings:

- reduction of the structural weight by a sizeable proportion that is beneficial to founding medium and cost
- cost reduction of complex fabrication
- reduction of the design, engineering, build, test & qualification time cycle by a sizeable proportion.

These objectives could be realisable through system optimisation, efficient analytical tools, statistical reliability analysis, new material developments, construction methodologies and reduction of time cycle to a nominal window. In the current situation of climate change, new materials are currently being experimented using agricultural and industrial waste products. For example, composite concrete developed from coconut fibres and lathe steel wastes are proving to be of high strength and their potential use in the blast resistant construction is looking good. Although more work needs to be done to fully characterise these materials for blast resistance design and construction but reports already published are positive indicators. Galvanized steel also is of great values in the construction industry in the developed world today. In the Asian countries, bamboo stems have been used successfully to construct fascinating and aesthetically pleasing structures.

The use of many stabilising materials for soils has proven to be of great value adding approach. In Nigeria, Nigeria Building and Road Research Institute has developed a methodology of constructing stabilised roads in the rural country sides without the use of any fossil materials such as asphalt [5]. These roads are proving to be durable but statistics on their long time performance are non-existent. The innovative concept of design and construction is yet to be standardised. The institute has developed pozzolanic material that can be used as cement replacement for low cost building construction [5]. This material could also be of great benefit in stabilising weak founding medium for structures. Standardising the design and construction methods for such materials is necessary in order to permit the engineers to take advantage of these innovative materials.

The utilisation of new materials is linked to the innovative structural designs. Such materials are high performance steel and advanced complex functional materials that render the attainment of wider span and higher vertical dimension beyond what could be attained some years back a reality. This is made possible because of their light weight and high strength. These materials have excellent service performance, durability and low cost maintenance. The combination of these characteristics enables few connections for rapid assembly and disassembly of buildings which reduce wastes of structural materials and components.

The concept of dry joint construction is a fascinating one more so in a restricted city centre enclaves where multi storey buildings are needed for commercial purposes. The large operational space for in-situ construction can be a constraint to such an extent that surrounding buildings encroachment is a hindrance to the required haulage manoeuvring space for heavy duty cranes. The only solution is dry joint precast structural elements that could be assembled on site. This may not be limited to only beam and column framing but the entire building including the slab system. The use of post tensioning technology like Mac Alloy bars to hold the beam slabs together and the jointing of the beam and columns that can be an hybrid of post tensioning and in-situ construction. Although, traditional precast building construction is the moment resisting column base with a hinged connection between the beam and column.

The provision of the hybrid in-situ and post tensioning mechanism using un-bonded tendon can produce a ductile connection of significant moment capacity that is quite useful in a seismic event. A particular special beam-column joint was investigated by Meteli and Riva [6] whereby the joint is characterized by the use of high strength steel bars and of a fibre reinforced grout pad in the "Z" shaped beam-column interface, increasing the shear resistance of the connection.

The experimental results show a good performance of the joint, in term of resistance, ductility and energy dissipation, with little damage observed in the connected members. A pictorial view of such a joint is shown in figure 1.

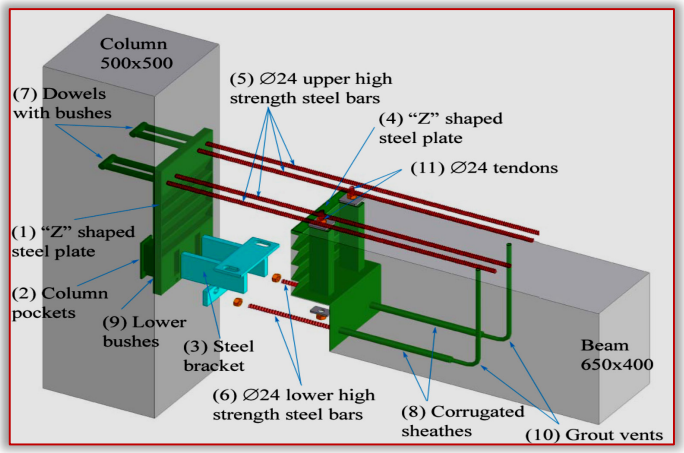

Figure 1: Details of the dry beam-column joint without rebar linkage

It is clear that the three encapsulating philosophies of innovative design can be developed to accommodate the break downs of each of the main captions. Some of these sub themes have been highlighted earlier but it is important to expatiate to broaden the scope of the current discourse. Innovative materials have been correctly identified for an innovative design. In the current culture of prevailing climate change and environmental degradation, researchers have embarked on the research programs with the emphasis on turning waste to wealth. Among such laudable investigation are the composite concrete made from lathe waste, coco nut fibre and so many as discussed earlier. These composite concretes are highly improved that their shear resistance is so high that fibre are suspected of providing more of the shear resistance. A self-compacting concrete used with these materials can lead to high strength and durable concrete that can improve dry joint capacity with great ductility.

The modern innovation of buildings must be anchored on reusability of structural members among other important factors. This calls for limited connections that would permit rapid disassembly and reassembly that ensures limited generation of waste materials. The second of its kind is the development of high strength light structural materials that will be capable of wide span members in ultimate limit state and the same time satisfying the serviceability limit state. Such materials must have high energy dissipation characteristics such that even in the event of seismic activities limited damage will be experienced and the building will be reusable with little retrofitting. It is important to note the current demand as a result of terrorism. The colossal loss of life and properties as a result of terrorist attacks across the globe calls for development of blast resisting materials.

In Africa where technological advancement is at slow pace, the double whamming consequence of terrorist attack is very visible. The effort has to be doubled with the help of international agencies to pay more attention to the development of blast resisting materials that will improve the performance index of buildings. Although, many researchers are very much keen to search for such materials but lack of adequate equipment and computing resources has plagued their initiatives. Some of the composite concretes investigated recently have shown promising signs of their blast resisting capabilities. However, more exhaustive works need must be done to fully characterize these products. It is unfortunate to note that despite the incessant terrorist attacks in Nigeria, the government has not come to the realization of employing engineering to fight terrorism. The effort is on humongous spending to acquire ammunitions. The emphasis on the development of high caliber materials is very elusive. The regulatory bodies for engineering in the country are in a deep slumber into the foreseeable future. They are the extensions of the political institutions in various shapes or forms. We hope they will heed the clarion calls to rise up to their original responsibilities.

APPLICATION OF NUMERICAL SIMULATION

It is important to focus on the use of technology to develop innovative design in structures and other engineering systems. The application of Finite Element Methods (FEM) is paramount to full realisation of the potential of innovative design. In fact, it is absolutely impossible to discount FEM out the equation of innovation in engineering. Ranging from inelastic analysis to the reliability analysis of engineering systems, FEM is positioned to help drive this agenda. There is no way we can rely on elastic analysis only in the drive to establish innovative design. The inelastic static and dynamic analysis (material and geometrical) could only be carried out with FEM and other versatile numerical computational approaches. For example, to effectively simulate the reliability of new design method using Monte Carlo approach, it may be required that the system has to be analyzed to its collapsed capacity for various configurations and sizes of members.

These physical analyses could only be achieved through the employment of powerful analytical tools like FEM. The outputs are fed into Monte Carlo simulation computer system. In many African tertiary institutions today, hardly can one find well equipped computing laboratory to accomplish such tasks. One has to praise the courage of our researchers who persistently continue to bite the finger nails to get things done. The administrators in those institutions are concerned with the immediate benefits for themselves leaving the primary reasons of having a job in the first instance to suffer. The dry joint construction could not be fully realized without the application of FEM to fully understand the true behavior of tensioned and non-tensioned joints. The friction surface where elements overlap cannot be fully studied without the representation of the slip surface elements in the FEM models. Ordinary classical analysis cannot avail the researchers the opportunity to fully investigate the dry slip plane interaction.

In order to engineer systems to resist fire for a desired period before catastrophic collapse, FEM is the only available tool to study the collapse behavior of various frame configurations. The likely culprit phenomenon, local buckling, in the progressive collapse of high rise steel buildings can effectively be studied using nonlinear FEM analysis. Even the business of soil-structure interaction can only be effectively investigated using FEM without recourse to extensive soil test that is time and resources consuming. It is apparent that powerful analytical tool like FEM cannot be overlooked in the drive to establish innovative design approaches for engineering systems. Finally, Value Engineering is a driver for innovation in design and construction. It is understood to be a means of analyzing alternatives to either drive the cost down with an improved performance or to improve performance without change in cost or performance remains unchanged but cost is driven down. Through

the process of Value Engineering, innovation becomes a vital aspect of sourcing for alternative solution that is optimum without increasing cost and the performance is enhanced.

CONCLUSION

It has been demonstrated that design innovation will resort to added value for the engineering systems and thus the consumers will benefit immensely. Light is shed on the use of innovative materials, dry joint construction and numerical analysis to predict structural responses. In addition, reliability analysis is an important of design tool to predict how reliable any design is before being built or constructed. In the 21st century, innovative material-based building structures are solutions to urban rejuvenation and development of new cities that will reduce pressure on the land utilization by utilizing the vertical space. Value Engineering is shown to be important in structural systems design because of it enable performance enhancement and cost reduction through innovation.

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ISSN: 2067-3809

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ECOLOGICAL AND EFFICIENT METHOD FOR THE RECOVERY OF NONFERROUS METALS FROM INDUSTRIAL WASTES BY PROCESSING IN MICROWAVE FIELD

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Abstract: The present paper presents an innovative ecological and efficient method to recover the useful metals from various types of industrial wastes by processing in a microwave field. Compared to the classical methods, microwave melting presents a series of major advantages, such as: i. simultaneous evolution of the heating gradient in the entire volume of material; ii. much higher heating rates that shorten the melting time by 70-85%, thus leading to energy savings and higher processing capacities; iii. superior quality of the obtained materials by reducing the melt impurification through oxidation; iv. remarkable versatility, as wastes with a wide range of shapes, chemical compositions and structures can be processed in the same installation; v. the possibility to neutralize the gaseous emissions also in microwave field. In the present work two types of wastes from the obtaining of aluminum-silicon and respectively antifriction antimony-tin-lead alloys, were melted in a microwave furnace. The values of the metal recovery efficiencies were of approximately 90%. Also, the treatment of the gaseous emissions in microwave field lead to the reduction of the hazardous substances' contents to values under the legal limits.

Keywords: novel materials and environmentally friendly technologies, microwave field, recycling, sustainable development

INTRODUCTION

The recycling of nonferrous metal wastes has a significant impact on the environment through the reduction of energy consumptions and of the emissions, thus contributing to the preservation of the natural resources and the sustainable development of human society.

In the European Union, the recovery of nonferrous metals is essential for the rentability of the metallurgical industry. The reintroduction of metallic materials in the economic circuit reduces the EU's dependence on the import of raw materials. Also, the production of metals using secondary sources requires a much lower amount of energy compared to the extraction of same metals from ores [1].

Pyrometallurgical processes are the most common methods used for processing nonferrous wastes. Current processing manages to convert the waste into metal or other raw materials (oxides, salts, etc.) which can be used in various industrial applications. Microwave melting is a novel technology which presents a series of major advantages compared to the classical pyrometallurgical processes, such as simultaneous evolution of the heating gradient in the entire volume of material, a much higher heating rates that shorten the melting time by 70-85% and allow energy savings and higher processing capacities and a superior quality of the obtained materials by reducing the melt impurification through oxidation. Also, this method exhibits a remarkable versatility, as wastes with a wide range of shapes, chemical compositions and structures can be processed in the same installation. Microwave melting also offers the possibility to neutralize the gaseous emissions in microwave field.

Microwaves (MW) are electromagnetic waves with a frequency between 300 MHz and 300 GHz and wavelengths in the range of 1 mm - 1 m, much larger than the size of the molecules (nm) or the metallic crystalline grains (μm). As a result, part of the energy of the electromagnetic field is transformed into thermal vibration energy and transferred to the molecules of the melted material.

This generates a heating effect of the dielectric material which is caused partly by the polarization of the charged particles from the material by the high frequency electric field (hysteresis losses), and partly by the Joule effect due to the conduction of the free loads under the action of the electric field [2-11].

In the present work two types of wastes from the obtaining of aluminum-silicon and respectively antifriction antimony-tin-lead alloys, were melted in a microwave furnace.

EXPERIMENTAL PART

The wastes come from the casting of Al-Si alloy parts and components and the production of antifriction Sb-Sn-Pb materials. The materials were milled and homogenized in a disc mill at a sized of maximum 3 mm. The 350 g charges were melted at temperatures up to 1000°C in graphite and silicon carbide (SiC) crucibles.

The influence of the crucible composition on the metal extraction yield from the molten waste was investigated. Table 1 shows the composition of the melting-protection flux used in the experimental work. The flux quantity used was of 5% of the charge mass.

Table 1. Chemical composition of the melting-protection flux [% wt]

Compound	NaCl	KCl	CaF_2
% gr.	35	35	5
Compound	NaF	Na_3AlF_6	$Na_2B_4O_7$
% gr.	5	10	10

The schematics of the experimental equipment for melting non-ferrous metal waste using microwaves is shown in Figure 1. The melting equipment consists of a cylindrical enclosure made of steel (1), in which are five rectangular windows for mounting the microwave magnetrons (6). The axes of the windows are positioned in different horizontal planes, the angle between the axes is 72°, thus radiating different areas of the susceptible material (3).

In order to reduce the heat loss, the interior of the enclosure is covered with a thermal insulation layer (2) made of super-alumina ceramic fibers with resistance to temperatures up to 1600°C. Coaxial, the melting crucible (4), made of graphite-clay mixture, approx. 2 litters, clothed in a microwave susceptible material (3) made of silicon carbide.

The batch heating is performed by five microwave generators (6) of 850 W maximum each. An inert atmosphere (N_2, Ar) at a pressure of about 0.5 bar can be made inside the furnace through a nozzle mounted on the furnace cover (7). The temperature is measured using a Pt / Pt-Rh thermocouple (8).

Melting gases and vapors are captured through the exhaust pipe (9), mounted on an adjustable speed blower. On this tube is placed the gas treatment filter (11). It consists of a steel cylinder in which windows are cut out for the installation of three magnetrons (13) of 850 W each.

A microwave transparent quartz cylinder is placed inside the steel cylinder and contains a microwave susceptible material SiC (12) in the form of 5-10 mm diameter granules. The temperature of the thermal filter is measured with a Pt / Pt-Rh thermocouple. Gas sampling is carried out through nozzles attached to the exhaust tube (9).

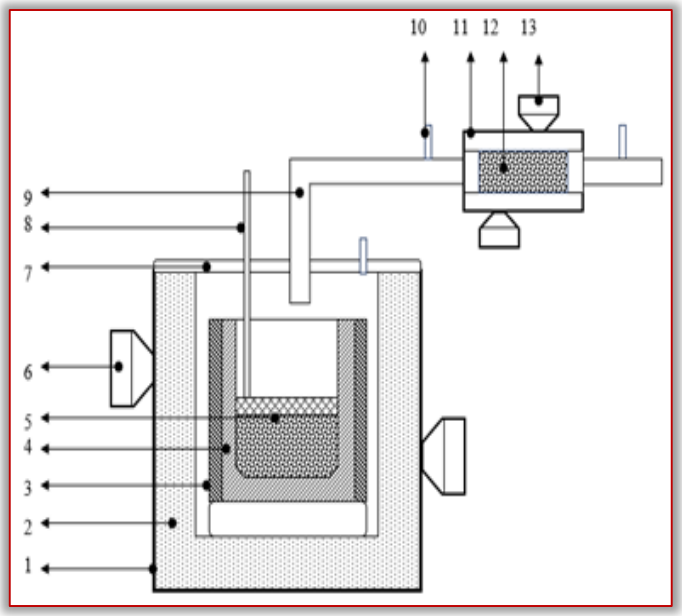

Figure 1. The experimental installation for the recovery of non-ferrous metals by melting in microwave field and resulting gas treatment:
1.Furnace body (steel); 2. Thermal insulation material;
3. microwave susceptible material (SiC); 4. Graphite/SiC crucible;
5. Charge; 6. Magnetron; 7. Furnace cover (steel);
8. Thermocouple (Pt / Pt-Rh type); 9. Outlet gas tube (steel);
10. Gas nozzle; 11. The resultant gas treatment heat exchanger;
12. Microwave susceptible material (SiC granules); 13. Magnetron.

The technological flow-chart of the metal-containing waste melting in microwave field is shown in Figure 2.

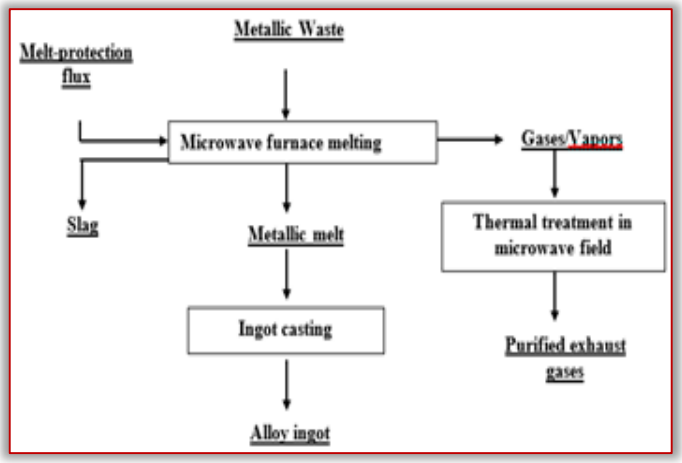

Figure 2. Technological flow-chart of the melting process and the microwave field treatment of resulted gases

At the end of the melting process, the crucible was removed from the furnace, the formed slag was removed, and the molten metal was poured into a metal shell.

RESULTS AND DISCUSSION

After complete cooling the obtained ingots were weighed for the determination of the metal recovery efficiencies and samples were taken for the chemical characterization of the resulting alloys. The chemical compositions are given in tables 2 and 3. Table IV presents the efficiencies of the recovery process, with very high values. For the antifriction alloy the efficiency was over 90%; for the aluminum alloy a maximum value of 82.3% was attained.

Table 2. Chemical composition of aluminum alloys

Element	Al	Si	Mg	Fe	Mn	Other* (sum)
wt%	base	12,35	2,82	0,48	0,82	< 1

*) Other: Cu, Zn, Ca, Na, Cr, Ni

Table 3. Chemical composition of antifriction alloys

Element	Sn	Pb	Sb	Cu
wt%	58,80	2,86	10,85	6,5

Table 4. Metal recovery efficiency

Waste	Crucible	Metal recovery efficiency
Antifriction alloy	Graphite	95.33
Antifriction alloy	SiC	87.66
Aluminum alloy	Graphite	82.3
Aluminum alloy	SiC	67

From the data presented in Table 4, it can be observed that the values of the recovery efficiency obtained when using the graphite crucible are higher than the ones determined in the case of melting in the silicon carbide crucible. These differences may be caused by the different values of the thermal conductivity for the two materials (120 W/mK for SiC, 8.7 W/mK for graphite) [12,13]. This characteristic may influence the capacity of the materials for

maintaining the working temperature in order to provide the latent heat for melting.

Also, the heating rate is faster for the graphite crucible because this material exhibits a stronger microwave susceptor character compared to SiC. Thus, for identical durations of the melting process, the use of a graphite crucible leads to the attaining of the melting temperature in a shorter time and its maintaining for a longer period.

Gas analyses have shown the presence in the melting gases of some particles/vapours of metals and HCl vapours (as a result of chlorine decomposition in the flux). Table 5 shows the content of HCl measured in the gases resulted from the waste melting.

Table 5. HCl content in gases resulted from melting

Temperature range, [°C]	50-400	700-750	Maximum legal limit
Contained HCl, [mg/Nm3]	5.5	1.5	5

The thermal treatment of the gases in a microwave heat filter lead to a significant reduction of their content, below the legal permissible limits.

CONCLUSIONS

The microwave field melting experiments for waste containing non-ferrous metals have shown that the method is feasible, ecological and economically efficient, with very high metal recovery yields. Two types of wastes from the obtaining of aluminum-silicon and respectively antifriction antimony-tin-lead alloys were processed, with recovery efficiencies of approximately 90%. The treatment of the gaseous emissions in the microwave heat filter reduced their concentration below the legal limits.

Acknowledgements

The researches presented in this article were funded through the project POC-A.1-A1.2.3-G-2015/ID: P_40_397 / Contract 17 / 01.09.2016, project co-financed by the European Regional Development Fund through the Competitiveness Operational Program 2014 -2020.

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ISSN: 2067-3809

Fascicule 4

[October – December]

tome XII

[2019]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

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INVITATION

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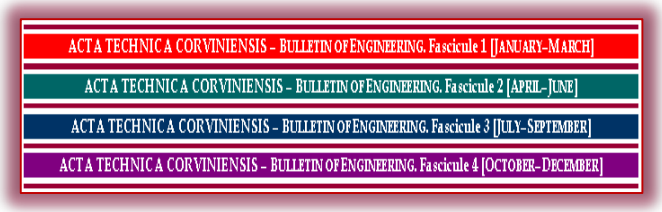

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On behalf of the Editorial Board and Scientific Committees of **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering**, we would like to thank the many people who helped make this journal successful. We thank all authors who submitted their work to **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering.**

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ISSN: 2067-3809