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CO_2 EMISSION ASSESSMENT OF CONSTRUCTION AND WASTE MATERIALS IN THE CONTEXT OF CIRCULAR ECONOMY: CASE STUDY OF PROJECT "CORRIDOR X"

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Abstract: Assessment of the environmental impact of construction materials and construction and demolition (C&D) waste is very important in the context of circular economy and sustainable development. This paper shows calculated CO2 emissions using data on the quantities of used construction materials and the amount of generated construction and demolition waste (mostly inert material), using the IPCC 2013 method in the case of "Corridor X" project. "Corridor X" project represents one of the capital projects in Serbia and in the Balkan region. This analysis covers mainly road infrastructure. In this paper, data related to all construction activities, construction materials and construction and demolition waste are used. This analysis which is related to the assessment of the impact concerning all construction activities on the project "Corridor X" in the form of CO2 emissions, thereby contributing with data and raising awareness of the principles of circular economy.
Keywords: Environment, construction and demolition waste, circular economy

INTRODUCTION

It is estimated that around 374 million tons of construction and demolition (C&D) waste is generated annually in the European Union (EU) (excavated soil is not included), representing 31% of the total amount of waste generated [1]. No specific directive on this type of waste has been published within the European Union, only the Waste Framework Directive 2008/98/EU mentions measures that correlate with C&D waste. According to this directive, it is foreseen that by 2020, the reuse, recycling and revitalization of materials (including excavation operations) should be increased to the at least 70% by weight, not including excavation materials.

GENERAL ASPECTS OF C&D WASTE

Materials that remain on site immediately after the completion of construction or demolition of construction or infrastructure facilities, may be considered as C&D waste.

Such materials (C&D waste), are more difficult to process in terms of their reuse in construction, which is imposed, among other factors, by higher costs. Thus, for instance, waste material generated when removing the asphalt road could be used to build another asphalt road. The only requirement for C&D waste that will be reused in that case, is to ensure its inertness from an environmental point of view.

Recycling of C&D waste in the form of obtaining reusable materials includes the sorting of waste, which can be done during the construction or demolition of the construction infrastructure itself, and then the treatment of each of the components, according to the properties and potential applications of such materials. The recycling methods for each of the C&D waste materials are at the forefront of all the factors that are essential for the treatment of C&D waste, both from the point of view of their practical feasibility and from the point of view of their economic justification. Thus, for example, among the companies involved in the recycling of C&D waste, wood is the most commonly sought after construction material, primarily due to its potential for use as an energy source. For some other materials, such as metals and its alloys, there is already an elaborate global market for products derived from recycled materials. On the other hand, processed concrete has both a limited market and a limited scope [2].

EXCAVATED MATERIALS AS A POTENTIAL RESOURCE

This material is formed during excavation processes in various construction activities and its composition can be extremely heterogeneous, with contents such as organic soil, loam, gravel, sand, old construction waste. Currently, the main purpose of this material is to cover the pits in the ground after excavation of sand, gravel or other construction materials. Excavated material that does not contain impurities that could actually or potentially contaminate soil or groundwater, can be used directly. This, in fact, contributes to the restoration of the site and the restoration of the environment to its original state. It is negligible that the excavated material used to cover the pits will ever be used again, but it is also considered that its use in soil revitalization and site restoration operations will close cycle of used construction material. The excavated material is almost always directly used, without the need for sorting.

CONSTRUCTION INDUSTRY AND THE ENVIRONMENT

The conventional construction sector is one of the largest consumers of raw materials. Globally, it is estimated that construction industry is consuming:

- 50% of all resources,
- 45% of energy for heating, cooling and lighting of buildings, and 5% during the construction,
- 40% of water for sanitary and other purposes,
- 60% of agricultural land,
- 70% of wooden products.

Many of the current construction materials used in the construction activities have been processed industrially (cement, steel, aluminum, sand, stone, clay, petroleum), which in many cases have negative effect to the environment and biodiversity.

Global annual carbon emissions as a result of construction activities reached its peak, at least temporarily, from around 9.5 gigatons of CO_2 ($GtCO_2$) in 2013, and then declined to 9 $GtCO_2$ in 2016. The energy intensity of the construction sector (in terms of energy consumption per m^2) continues to improve at an annual rate of about 1.5%. The Paris agreement marked a milestone in the form of calls for curbing global warming. The rapid implementation of energy-efficient and low-carbon solutions in the construction sector can improve sustainability in the construction sector.

The potential for energy savings and emissions in the construction sector remains largely untapped due to the continued use of less efficient technologies, with the lack of efficient policies and poor investment in sustainable infrastructure. Consumer choice and behavior also play a key role. However, energy-efficient, low-carbon products are already available in many markets [3].

AIM OF THIS WORK

The aim of this work is to show quantitative and comparative analysis of CO_2 emissions, consequently by using waste construction materials instead raw construction materials within the "Corridor X" project. In accordance with the principles of circular economy, one of the goals is to raise awareness of waste utilization (in the form of reuse or recycling) in order to reach the best possible solution that meets environmental aspects.

"CORRIDOR X" PROJECT

Corridor X is one of the most important Pan-European transport corridors that crosses Serbia and connects Austria, Hungary, Slovenia, Croatia, Serbia, Bulgaria, North Macedonia and Greece. With this project, the transport system of the Republic of Serbia becomes compatible with the transport system of the European Union, with a tendency for further modernization in order to enable the Republic of Serbia to comply with the European Union standards in the field of transport.

The implementation of this important project will lead to a general acceleration of traffic, improve the level of service, facilitate international trade flows and transport of passengers. The new highway will have a positive impact on commercial and trade activities in the region and will contribute to regional development and cohesion in the wider Balkans.

The "Corridor X" project is considered to be one of the capital projects in the Republic of Serbia. Corridor X includes the construction of 160 kilometers of highway south of Nis - Section E80 from Prosek to the Bulgarian border in Dimitrovgrad and E75 - from Grabovnica to Levosoje [4].

Assumption is that within the project "Corridor X", some of the construction materials with the highest inflows are:

- concrete,
- steel,
- asphalt.

METHODOLOGY

This research shows quantitative and comparative analysis of construction and waste materials within the "Corridor X" project and environmental impact in the form of CO_2 emissions. The data provided were used to calculate effects over a given time horizon resulting from the unit of mass emission related to the referent gas (GWP_{100a}), in this case the CO_2 emission was calculated using the IPCC 2013 method (Intergovernmental Panel on Climate Change). The functional unit in this case is 1 kg of construction materials and C&D waste. In this analysis, the *Ecoinvent 3.2* database was used to obtain benchmarks relating to the analyzed construction materials and C&D waste.

LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is an analytical instrument that sets the framework for analyzing the environmental impact of products. ISO 14040 and 14044 provide the principles, frameworks, requirements and instructions for conducting the life cycle assessment of products and/or services. The main objective of impact assessment is to identify and establish links between the life cycle of products and services and the potential environmental impacts [5,6].

The LCA examines environmental aspects and potential environmental impacts (example, resource utilization and environmental effects of pollutant components) over the lifetime of raw material extraction products, through production, use and end-of-life treatment, recycling and dispose.

LCA as a tool can help with:

- Identifications and impacts within activities (example, greenhouse gas emissions),
- Ensuring all aspects of the environment throughout the life cycle (example, equal consideration of emissions into the air, water and land during the construction, operation and decommissioning of plants),
- Identifying opportunities to improve the economic and environmental performance of different technologies, projects, products and services,
- More effective communication with various stakeholders interested in information on the potential consequences of projects and technological options (example, LCA development process requires the involvement of different stakeholders, establishing communication and providing information on the full impact and/or benefits of certain changes or new production processes).

Also, the LCA can help with:

- Identifying opportunities to improve the environmental protection of products at different stages of their life cycle,
- Informing the various target groups that make decisions in industry, government and non-governmental organizations (example, for strategic planning, prioritization, design or project modification for products or processes),

— Selection of appropriate environmental performance indicators (indicators), including procedures for measuring pollution.

RESULTS

In this chapter, the results of the analysis of concrete, steel and asphalt in the form of CO_2 emissions using the IPCC 2013 method are presented. Table 1 presents the unit of emission and CO_2 emissions of concrete, steel and asphalt used.

Table 1. Emission factors per unit for the analyzed materials and calculated kg CO_2 emissions related to the "Corridor X" project [7]

Material	Steel	Waste steel	Asphalt	Waste asphalt	Concrete	Waste concrete
IPPC 2013 (GWP 100a kg CO_2-eq)	2.346	0.0086	0.2897	0.02024	229.7	0.01329

According to the results from Table 1, it is visible that there is significant difference in the kg CO_2 between the products produced from raw materials and waste material.

Since steel, asphalt and concrete are in the most of it parts recyclable, following the principles of circular economy, Figures 1, 2 and 3 present environmental benefits by analyzing CO_2 emissions in the form of recycled construction materials as substitutes for construction materials obtained from primary production.

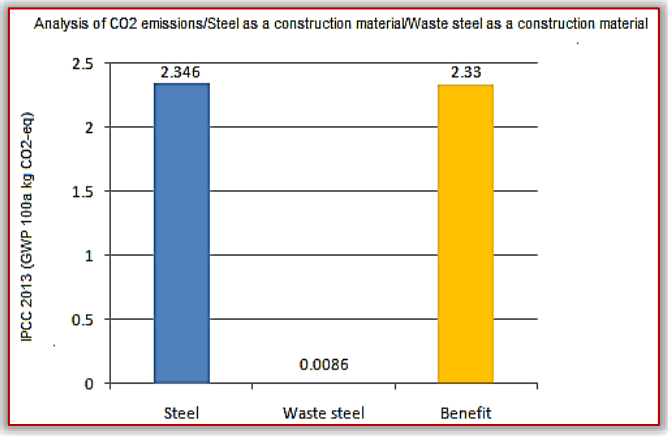

Figure 1. Analysis of kg CO_2 emissions using steel as construction materials and using waste steel in the construction processes [4]

Figure 1 shows the environmental benefit (orange color) as an example of using waste steel instead of steel produced by primary production (blue), which means that reduction in CO_2 emissions is 2.33 kg CO_2.

Figure 2 shows the environmental benefit in the context of reducing kg CO_2 if waste asphalt was used in the project of "Corridor X" project instead of asphalt from primary production, resulting with 0.27 per kg CO_2 in reduction.

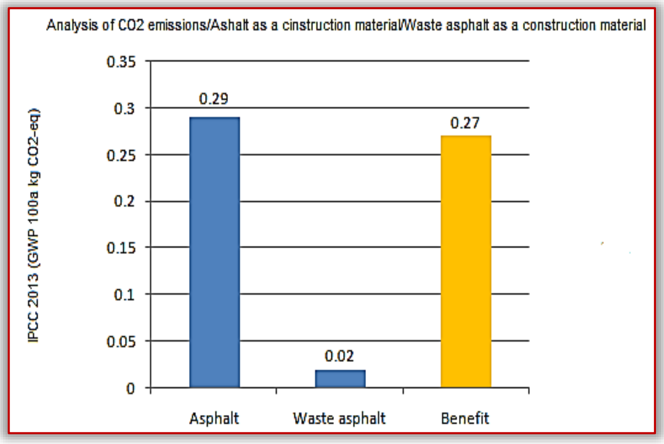

Figure 2. Analysis of kg CO_2 emissions using asphalt as construction materials and using waste asphalt in the construction processes [4]

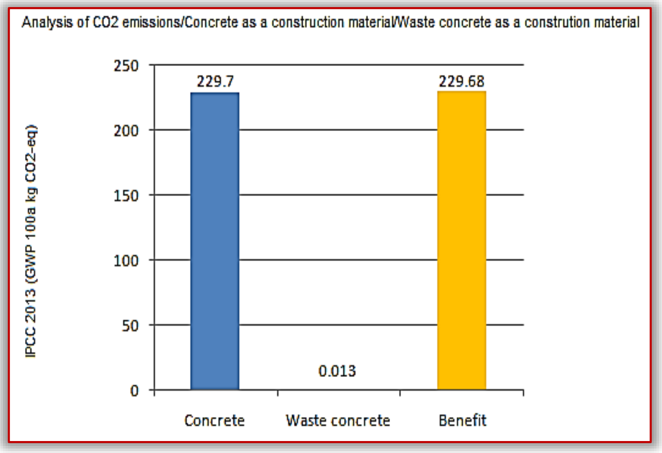

Figure 3. Analysis of kg CO_2 emissions using concrete as construction materials and using waste concrete in the construction processes [4]

Figure 3 shows an environmental benefit in the form of kg CO_2 reduction of waste concrete (aggregates). Concerning concrete, recycled concrete in the form of aggregates can be used in concrete production, although within concrete production itself, cement production industry is one of the largest environmental polluters. In this case, the analysis of kg CO_2 related to the concrete is presented empirically (assuming that the concrete obtained from primary production materials is completely replaced by recycled concrete). If recycled concrete (100%) is used on the "Corridor X" project, CO_2 emissions of CO_2 would be reduced by 229.68 kg.

CONCLUSION

This research considers quantitative and comparative analysis of construction and waste materials, from which it can be concluded that the use of recycled construction materials is an environmental benefit, both in terms of reducing CO2 emissions and conserving the natural resources. In order to justify the benefits of EU waste legislation, a much deeper analysis of the environmental impact of C&D waste should be made. Considering the principles of circular economy, replacing raw materials from primary production with recycled ones, would be a more desirable option, as demonstrated in this analysis. In order to stimulate the use or recycling of C&D waste, there is a need for end markets. There is also a lack of information and data indicating flows and stocks of C&D waste in Serbia. This analysis is an initial step for further research related to construction materials and C&D waste within infrastructure projects.

Note:

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