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DEVELOPMENT OF INNOVATIVE BIO-CONCRETES BASED ON MISCANTHUS GIGANTEUS WITHIN GREEN INNOVATION VOUCHER PROGRAM

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Abstract: "Green construction" is in a great expansion, hence there is a need for innovative building materials which production and application requires a minimum CO₂ emission. As a result of a joint research, conducted by the company "TRANSKOP" and Faculty of technical sciences, within Green Innovation Voucher Program financed by the European Bank for Reconstruction and Development, the new segment of "low carbon materials" for the concept of "green construction" has been developed. The concept is based on the use of the lignocellulose fast-growing plant *Miscanthus giganteus* for the production of bio-concrete by the substitution of conventional aggregates. The realization of the project aims to contribute to the goals set out in the De-carbonization Roadmap for the cement and concrete sector in Serbia. The results of the initial experimental research are briefly described in the paper.

Key Words: low carbon materials, bio-concrete, green innovation voucher, *Miscanthus giganteus*

1. INTRODUCTION

The construction industry is one of the greatest CO₂ emitters and the production of concrete - as the most widely used construction material on Earth (over 4.7 tons per person per year) - is responsible for 8-9% of global anthropogenic greenhouse gas emissions. The majority of traditional building materials in infrastructures are made out of the cement-based materials (such as concrete). Concrete is the second most consumed material in the world (after water) and the most used man-made material at all. The major component of concrete (up to 70% of its volume) is natural aggregate, such as sand, gravel or crushed stone. Aggregate is the world's number-one nonfuel mineral commodity in terms of both volume and value. Its worldwide demand is estimated to be rising by 4.7% annually. The excessive extractions of rocks and aggregates result in the depletion of natural resources and lead to secondary effects such as erosion, deforestation, and damage to river ecosystems. The growing environmental awareness and need for reducing both the raw material consumption and CO₂ emission of the construction industry are recently strongly anchored in various European directives. This research is focusing toward seeking for replacement of natural aggregates, as the dominant concrete component in concrete, with an alternative locally available cost-effective material.

The company "TRANSKOP" doo has established its constant growth and is constantly committed to developing and expanding the offer of products and services. Thanks to the dynamic team, the importance and perspectives of the green economy are recognized. "TRANSKOP" doo intends to make a breakthrough by extending the existing assortment of conventional products to the new segment of "low carbon materials" for the concept of "green construction".

By the research team of the FTN Novi Sad a comprehensive research activities has been already conducted on the use of recycled aggregate as a natural aggregate replacement, as well as sustainable utilization of various waste cementitious materials, as cement substitutes in cement-based materials. The expertise and the accumulated know-how is an important an valuable basis for starting of the proposed joint research cooperation.

The business concept is based on the use of the lignocellulose fast-growing plant *Miscanthus giganteus* for the production of bio-concrete by the substitution of conventional aggregates. The second segment includes the replacement of conventional Portland cement with hydraulic lime. This concept is in line with the principles of green low carbon economy and resource sustainability.

The project will contribute, at the national level, to strengthening the capacity of fulfilling the obligations that Serbia accepted by signing the Paris Agreement, such as those arising from the process of harmonization with EU regulations related to the achievement of the goals of the "EUROPE 2020 Strategy" [1]. The realization of the project will contribute to the goals set out in the De-carbonization Roadmap for the cement and concrete sector [2].

A planned business model that involves opening new jobs, developing cooperant relationships with *Miscanthus* producers, creating new value chains of products, provides the opportunity to diversify conventional agriculture and economic empowerment of local communities, thus contributing to the achievement of the Global Sustainable Development Goals. This production fully meets the principles of circular economy, as we have a closed circle from growing raw materials to the possibility of reusing bio-concrete due to its recyclable properties.

From the aspect of risk, the advantage of the possible competition from imports is the fact that we can provide lower costs of production of the basic input (*Miscanthus*), since in Serbia there is a lower cost of working staff, as

well as a lower price and availability of unprocessed agricultural land. A great advantage is the fact that one of the primary principles of sustainable green construction is the minimal distance of the location of building materials production from the construction site, which also reduces the possibility of importing these products.

2. COMPOSITION AND PROPERTIES OF BIO-CONCRETE

2.1 Composition of bio-concretes

Five different mixtures were designed for the initial experimental research. The composition of bio-concretes is given in Table 1.

Table 1 – Composition of bio-concretes

	Miscanthus giganteus chips	Binder phase	Water (kg)	Note
Sample 1	1kg	700g hydrated lime 700g metakaolin 100g gypsum	1,5	/
Sample 2	3dm ³	300g Portland cement 150g hydrated lime 30g gypsum	0,75	/
Sample 3	2dm ³	400g hydrated lime 200g metakaolina 200g gypsum	0,75	/
Sample 4	1kg	700g hydrated lime 700g metakaolin 100g gypsum	1,5	Additional compression in the mould
Sample 5	670g	400g portland cement	0,57	Due to the lack of mineralization of chips, adequate binding was not achieved

2.2 Visual inspection of hardened concrete samples

The appearance of hardened bio-concrete samples is shown in Figures 1-5. A detailed visual inspection of the samples revealed the following:

- Samples 1, 2 are not compact. Under the fingers and at higher pressure the material is friable and falls off. A lack of a binder component is observed.
- Sample 3 is partially more compact than samples 1 and 2, which is the result of a larger amount of binder phase. The tendency of the material toward crumbling and falling off under pressure was registered, as well.
- Sample 4 is characterized by satisfactory compactness, as a result of the increased amount of binder component. When preparing this type of bio-concrete, finer particles of *Miscanthus giganteus* were used, and additional compaction of concrete in the mould was applied, which resulted in greater compactness. Minor crumbling of the sample in the corners was observed.
- Sample 5: Adequate binding of miscanthus with the binding component was not achieved, which resulted in intensive crumbling and disintegration of the samples and reduction of its dimensions. This sample was excluded from further testing.



Figure 1. Appearance of bio-concrete sample 1



Figure 2. Appearance of bio-concrete sample 2



Figure 3. Appearance of bio-concrete sample 3



Figure 4. Appearance of bio-concrete sample 4



Figure 5. Appearance of bio-concrete sample 5

2.3 Bulk density and water absorption of bio-concrete

Testing of the bulk density of bio-concrete was performed in accordance with the standard EN 12390-7 [4]. All types of bio-concrete are characterized by relatively small bulk densities, as a result of lightweight aggregate application – Figure 6. Sample 4 is characterized by a higher bulk density, compared to sample 1, as a result of better packing of smaller particles of *Miscanthus* in the production of this type of bio-concrete. The increase in bulk density was also influenced by the additional compaction of bio-concrete 4 in the mould.

From the aspect of the obtained bulk densities of samples 2 and 3, it can be concluded that the bulk density increases with increasing share of the binder component in the process of designing the composition of bio-concrete.

Based on the concrete classification according to bulk density, given in SRPS EN 206 [3], all bio-concretes belong to lightweight concretes. According to this standard, the lowest defined class of bulk density of lightweight concrete is D1.0 (bulk density between 800 and 1000 kg/m³), hence all tested bio-concretes have a lower bulk density than the lowest declared value. If the bulk densities of bio-concretes are compared with the bulk densities of other types of lightweight concretes with organic filler, such as sawdust-based concrete ("Durisol"), it can be concluded that bio-concretes have a bulk density in the similar range (400-800 kg/m³).

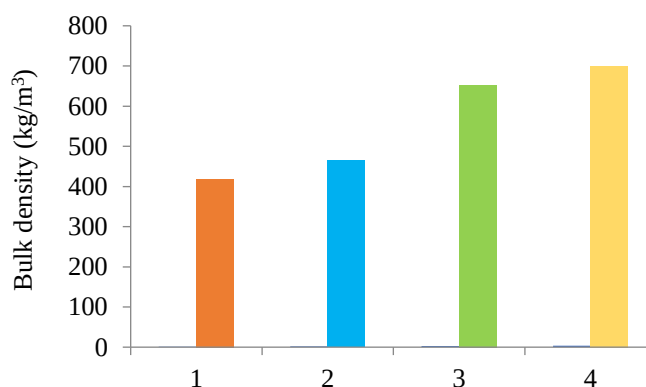


Figure 6. Bulk density of bio-concretes

The water absorption of bio-concrete samples was tested by the method of gradual immersion, in accordance with the procedure given in the standard SRPS B.D8.011 [6][5]. Absorption kinetics is illustrated in Figure 8.



Figure 7. The water absorption of bio-concrete testing

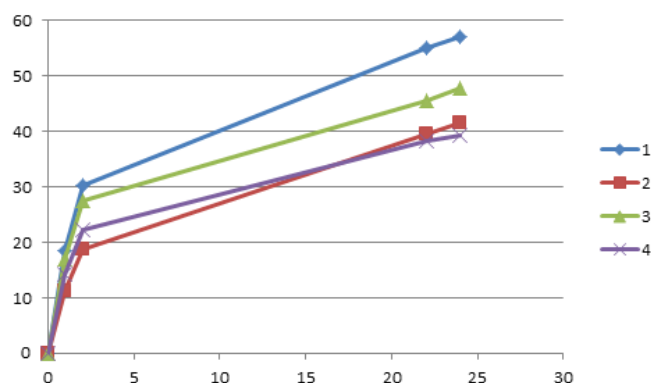


Figure 8. Kinetics of water absorption by the method of gradual immersion

All bio-concretes are characterized by high absorption values ranging from 10%, when immersing samples to ¼

of sample height, up to 57%, when completely immersed. The change in granulometric composition and additional compacting of the material in the mould had a positive effect on the absorption of bio-concrete, hence sample 4 is characterized by lower absorption value compared to sample 1. The differences in the absorption of samples 2 and 3 are not significant. All types of bio-concrete have a more pronounced trend of water absorption in the initial period, up to 2 hours, after which the increase in absorption decreases. It can be noticed that bio-concrete 2 and bio-concrete 4 have approximately the same values and kinetics of water absorption, which is the result of the denser structure of these types of bio-concrete.

2.4 Compressive strength of bio-concrete

Compressive strength was tested on bio-concrete samples at the age of 14 days. The compressive strength test was performed in accordance with standard EN 12390-3 [6] on a hydraulic press with a capacity of 3000kN.

As a result of reducing the size of *Miscanthus* particles and increased compactness by additional compression, sample 4 has higher compressive strength in relation to sample 1.

On the other hand, sample 3 has higher compressive strength compared to sample 2, which can be attributed to the increase in the share of the binder component in the composition of this type of bio-concrete. The obtained compressive strength value is in the same range as the strength of Durisol concrete, from 1.0 to 2.7 MPa. The results are graphically shown in Figure 9.

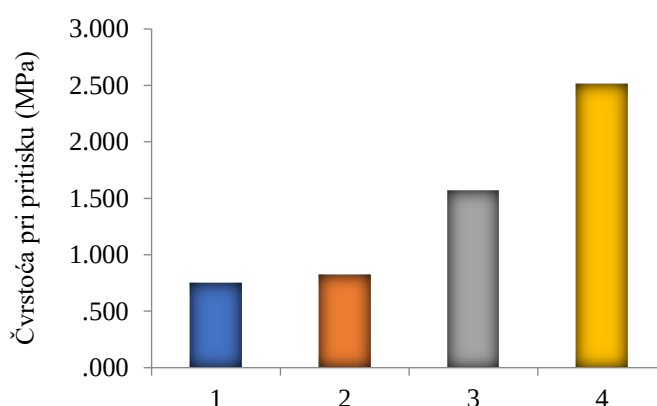


Figure 9. Compressive strength of bio-concrete

3. CONCLUSIONS

Based on the results of testing the properties of bio-concrete with *Miscanthus*, the following conclusions can be drawn:

- type of binder, proportion of binder component, degree of fragmentation of material and method of compaction in mould have an impact on the tested properties of bio-concrete,
- bio-concrete 4 is characterized by the highest bulk density, the lowest water absorption and the highest compressive strength, as the result of a densified structure - the effect of packing smaller particles of *Miscanthus* and additional compaction of concrete in the mould,
- values of tested properties: bulk density and compressive strength of bio-concrete are in the range of properties of commercially used types of lightweight concrete – Durisol, which justifies the possibility of application of these innovative eco-friendly products in the construction sector.

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