CONFERENCE PROCEEDINGS

3RD INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

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MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
AND ALEKSANDRA ĐUKIĆ

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PLACES AND TECHNOLOGIES 2016

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AN EXAMPLE OF USING RECYCLED CRUSHED CLAY BRICK AGGREGATE: A PREFABRICATED COMPOSITE FAÇADE PANEL WITH THE FACE OF STONE

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ABSTRACT

The contemporary trend of sustainability and waste management, among other principles of environmental preservation, promote recycling of building waste material. Building waste material may contain significant quantities of discarded bricks and concrete, which can be further used crushed, as aggregate. In line with the principle of recycling, the following research displays a possibility of using recycled crushed clay brick aggregate to form a prefabricated composite façade panel with a face of stone, which can be used within a ventilated façade system. The paper presents the production technology of a pilot element and design possibilities of the panel. The research contributes to the environmental preservation and sustainability concept by offering an example of using recycled building waste within a new building element.

Keywords: prefabrication, recycling of building waste, crushed clay brick aggregate, façade panel

INTRODUCTION

Sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, n.d.). In the context of sustainability, it is desirable that the whole life cycle of a building has as little as possible damaging impact on the environment. In line with aforementioned, the *4R* approach to waste management includes some of the key principles of sustainable development: *reduce*, *reuse*, *recycle* and *recover*. Recycling, addressed in this paper, involves melting or crushing of waste

[1] Corresponding author

materials, extracting component materials in the form of raw materials, which can re-enter the production process. If it is not possible to apply either one of the aforementioned principles, waste *disposal* at a landfill is the option. That is the worst option in terms of the environmental protection (Jevtić, Zakić i Savić, 2009; Kareem and Pandey, 2013)

According to Kim and Rigdon (1998), sustainable design in architecture, which is to be observed during the entire life cycle of a building is, among other methods, based on reuse of building elements, use of recycled materials and materials that are recyclable. The advantage of reuse and recycling is the conservation of energy which is embedded in building element - embodied energy[2], and would otherwise be lost. Reuse and recycling reduce the amount of waste material and the need for the landfill space which is scarce, as well as the consumption of new natural resources and the negative impact of their exploitation. Recycled aggregates from construction and demolition of buildings used at the building site contribute to reducing negative impacts of transport by reducing the emission of toxic gases (Kim and Rigdon, 1998).

The construction industry is a major consumer of natural resources and also a major producer of building construction and demolition waste (Cachim, 2009). Bricks and roof tiles could often be found as waste materials. If they cannot be cleaned and reused, recycled crushed aggregate can be profitably used for drainage, as a road base, concrete aggregate, etc. Reuse and recycling of brick products must be considered with care, as the consumption of energy during their production is relatively high. On the other hand, the consumption of energy needed to extract and clean used bricks could amount to only 0.5% of the energy needed for their production. These products could also be milled into pozzolanic powder and used as raw material (Berge, 2009).

Thanks to its wide application and composite nature, concrete is often perceived as suitable for the application of recycled aggregates, such as recycled bricks, tires, etc. Aggregate constitutes 60-80% of the total volume of concrete, and any reduction in natural aggregate consumption has a favourable effect on the environment (Cachim, 2009). Also, concrete could be further recycled and used as aggregate within a new cement composite mixture.

Constant efforts are being invested in research concerning the possibility of applying recycled waste in mortars and concretes, as well as within prefabricated elements as paving blocks (Poon and Chan, 2006), solid and hollow masonry blocks (Jevtić, Zakić, Markićević, Pavlović i Terzić, 2006), etc. The following paper presents a manufacturing technology and design options of a pilot element – a composite façade panel with the face of stone, which can be applied within a ventilated façade system.

CONSTITUENT MATERIALS

The proposed façade panel includes two distinct layers: a base and a face of stone. The base is composed of a lightweight aggregate fibre-reinforced cement composite (mortar) with the thickness of 2.5 cm. The face consists of stone tile mosaic with the thickness of 1.0 cm. The overall thickness of the pilot element with the designed area of 60 x 60 cm is 3.5 cm.

Portland-composite cement based on cement clinker with blended compounds of grinded slag and limestone *PC 20M (S-L) 42.5R (CEM II/A-M (S-L) 42.5R)*, manufacturer Lafarge from Beočin, was used for the formation of the base material. River sand aggregate (*Moravac*), fraction 0/2 mm, was also used as natural aggregate for the preparation of the base mortar mixture. As lightweight aggregate, recycled crushed clay brick aggregate, fraction 2/4 mm, was added (Figure 1a). The recycled aggregate participated with 25% in the overall weight of the aggregate used in the mixture (Figure 1b). For the purpose of the base fibre reinforcement, polypropylene monofilament fibres *Sika Fibers* with the length of 6 mm, manufacturer Sika, were applied. As

[2] Embodied energy is the amount of energy consumed during the product life cycle, i.e., it includes the energy necessary for production, transport and disposal of certain products (US Department of Energy, n.d.).

additives, polymer latex *Sika Latex* and super plasticiser *Sika Viscocrete Techno 20*, manufacturer Sika, were used. As rock material, granite *Šutica* from Arandjelovac, which was cut to dimensions of 10 x 10 x 1 cm, was applied.

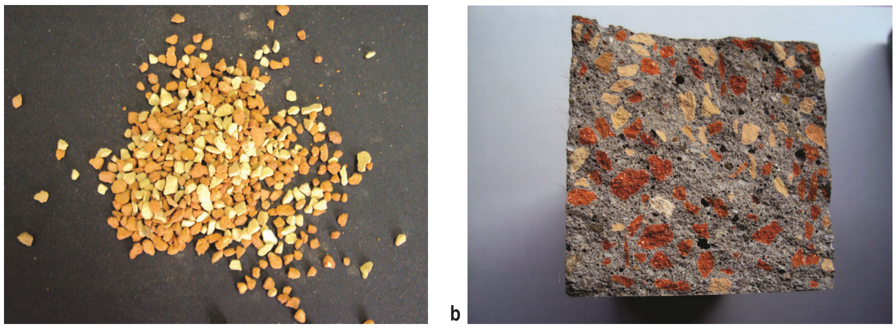

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Figure 1: Used recycled aggregate and a produced sample of the cement composite: a) recycled crushed brick aggregate 2/4 mm, b) section of the mortar sample with recycled crushed brick as aggregate

MANUFACTURING OF THE FAÇADE COMPOSITE PANEL

The development of the pilot element - façade composite panel measuring 60 x 60 x 3.5 cm, was performed in the Laboratory of Materials, Institute of Materials and Structures, Faculty of Civil Engineering, University of Belgrade. The proposed façade panel is a prefabricated product. It is characteristic by a direct contact of stone with the fresh cement composite mixture[3].

The manufacturing process started by placing the stone tiles (face down) on the bottom of the prepared mould (Figure 2a). The applied stone tiles were previously moistened, since the loss of water due to capillary absorption of stone might cause a decline of physico-mechanical properties of hardened mortar (Muravljov, 1983). They were immersed in tap water and placed surface dry just before the application of the mortar.

For the preparation of the mortar mixture, a mixer with fixed paddles was used. After homogenization of lightweight aggregate, cement and 2/3 amount of water, the last third of the water was added to the mixture. This method is proposed as the most favourable, since the lightweight porous aggregate absorbs considerable amounts of water during the mixing process (Pravilnik o tehničkim normativima, 1990). The lightweight aggregate was added dry to the mortar mixture. The fibres, superplasticizer, and polymer latex were added at the end of the mixing process according to the manufacturer's recommendations. The total duration of the mixing was extended to 4 minutes and 30 seconds for the purpose of evenly dispersing the fibres within the cement matrix.

[3] In the world market, there are already widely deployed façade systems with glued stone coatings (epoxy resin is often used) to the base of the façade panel, which is previously a formed element.

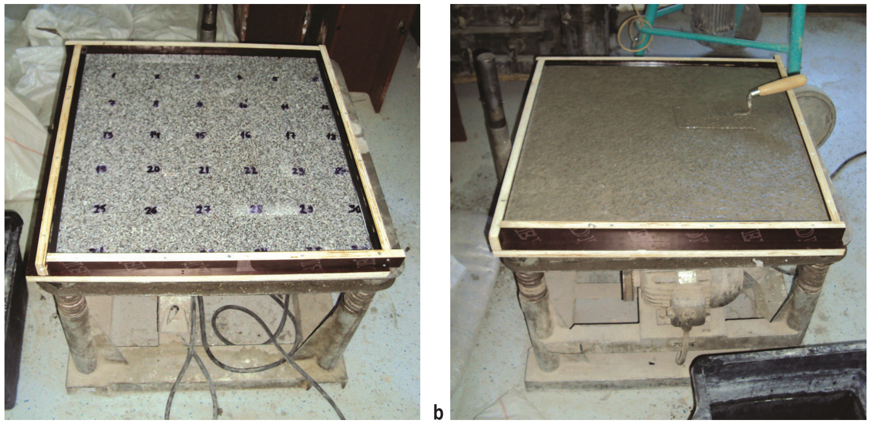
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Figure 2: Preparation of the pilot element: a) mould with placed stone tiles, b) embedding the mortar on a vibrating table

The fresh mortar mixture was poured into the mould, over the previously placed stone tiles, and compacted mechanically on a vibrating table (Figure 2b). This kind of a dynamic action achieves very good embedding and compaction, as globules of air get extracted out of the fresh mortar, and the mortar fills out the entire space of a mould (Muravljov, 2010). After preparing, the sample was protected from drying out too quickly, in order to ensure optimal hydration and prevent damage due to rapid shrinkage (Pravilnik o tehničkim normativima, 1990). Curing of mortars modified with polymers differs to a certain extent from curing of conventional mortars, as formation of the polymeric matrix requires dry (air) and cement hydration requires wet regimen of curing (water). For the purpose of achieving optimal properties, the pilot element was subjected to a mixed regimen of curing, which consisted of 7 days in a humid environment (temperature of 20 ± 2 ° C, relative humidity 95%) under damp jute cloth, and 21 days of curing in the air (temperature 20 ± 2 ° C, relative humidity 65%) (Radonjanin, Malešev i Folić, 1999). The mould was removed with care 24 h after embedding. Figures 3a and 3b show the formed panel (after 28 days) with installed anchors, manufacturer Tabaš. The anchor gaps were formed during the prefabrication process of the panel, by inserting metal strips into two opposite sides of the mould.

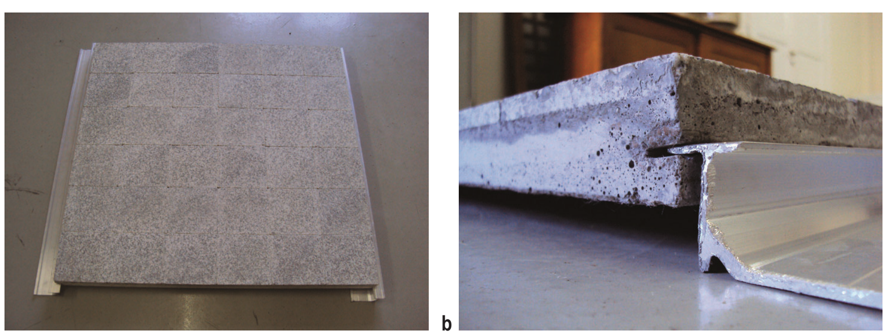
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Figure 3: A façade panel on anchors, manufacturer Tabaš: a) a pilot element with installed anchors, b) a detail

DESIGN OPTIONS

Bearing in mind the production technology of a composite panel with a face of stone, it is possible to propose basic classifications of such a façade cladding (Table 1). Along with the described manufacturing technology, it is also possible to propose other manufacturing options. Stone tiles with a relief face surface could be placed in a mould in a wet sand base - face down, or they could be pressed in a fresh mortar mixture - face up (Otović, 1995). Joints could be made by applying plastic stencils to properly separate the stone tiles and form suitable joints (Krstić, 2003), etc.

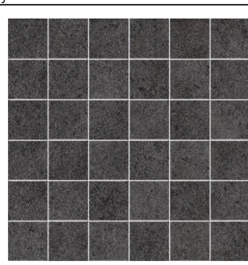
Design of a façade envelope contributes to its surroundings with an aesthetic appearance and creation of a distinctive ambient. It should also represent the time period and place in which the building was constructed. These requirements, considering the addressed panel, could be met by the possibilities of different stone surface finishing. The natural appearance of a stone surface can be altered in terms of greater or lesser highlighting of its colour and structure by various processing procedures. Treatment methods could also affect some physical properties of a stone surface. They could improve or worsen properties such as water absorption and resistance to weathering (Bilbija i Matović, 2009). The applied stone tiles are relatively thin. Impact treatments are not recommended, because they can damage the internal structure of the rock. The tiles may be applied with a natural stone surface which could be smooth or rough. A flat surface can be obtained by cutting in the process of the primary cutting of blocks on boards. Sanded surfaces have a fine rugged appearance. Honed or polished surfaces fully emphasize colour and structure of the stone. Silicate rocks can be thermally treated. Sudden heating of a stone surface causes the formation of fractures and separation of fine parts. The depth of the relief depends on the mineral composition and structure of the rock (Bilbija i Matović, 2009; Crnković i Šarić, 2012), etc.

Table 1: The basic design classifications of the panel

Classification according to the design pattern of the stone face		
Monolithic surface	Geometrical mosaic	Non-geometrical mosaic
		

Classification according to the finishing of the stone surface	
Recommended machine surface finishing	Natural surface finishing
	

Table 1- continued

Classification according to the variety of the applied rock	
One rock type applied	Various rock types applied
	
Classification according to the variety of the applied surface finishing	
One type of surface finishing applied	Various types of surface finishing applied
	
Classification according to the relief	
Two-dimensional (2D)	Relief (3D)
	
Classification according to the treatment of the joints	
With visible joints	With "no joints"
	

CONCLUSIONS

In line with sustainable development in architecture and contemporary trends of waste management, the research is promoting recycling of building waste material. The study shows a possibility of using an environmentally friendly material such as recycled aggregate – in the case of the study crushed clay brick aggregate, to form a new building element – a prefabricated façade panel with the face of stone. The proposed panel can be used within a ventilated façade system. The design possibilities of the façade panel depend on the various appearances of its stone face.

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