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Experimental research of concrete floor blocks with crushed bricks and tiles aggregate

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HIGHLIGHTS

- Precast concrete floor blocks made with crushed bricks and tiles (CBT) aggregate.
- Increasing percentage of replacement of natural aggregate with CBT aggregate.
- Concrete floor blocks with high replacement percentage meet the requirements.

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ABSTRACT

The main objective of this paper is to demonstrate that it is possible to make precast concrete floor blocks with more than 50% replacement of natural aggregate with recycled aggregate made with crushed clay bricks and roof tiles. In first phase of the research, the physico-mechanical properties of concrete with recycled and with natural aggregate were tested. The second phase explored the properties of precast concrete floor blocks. Their geometrical, mechanical, thermal and acoustic properties were determined. Based on experimental research it can be stated that it is possible to make precast concrete floor blocks with recycled aggregate with the fulfilled thermal, cost and environmental requirements.

1. Introduction

Recycling of crushed clay brick and roof tile is an environmentally friendly means of disposing of them. During their production and transport, some bricks and roof tiles are broken in the factory and are immediately crushed in the factory. One way to reuse crushed bricks and roof tiles is by using them as recycled aggregate for concrete. Since the application of concrete with crushed clay bricks and roof tiles is not widespread, it is important to investigate the possibility of applying it in areas where such concrete shows better properties than concrete with natural aggregate.

Based on literature review, concrete with crushed clay bricks and roof tiles has better thermal properties and fire resistance than ordinary concrete with natural aggregate. The recycling of crushed clay bricks and roof tiles as a new raw material is not only economically viable but is also considered an environmentally friendly approach. Numerous studies have been conducted to establish the potential of using crushed clay bricks and roof tiles as aggregate. Hansen [1] reported that for a given strength, the modulus of elasticity, water absorption and sorptivity of crushed brick concrete increased for concrete containing crushed brick aggregates. Cachim [2] showed that crushed bricks can be used as natural aggregates substitutes in percentages up to 15% without any strength reduction. However, for a 30% natural aggregate substitution, there is up to a 20% reduction of concrete properties dependent on the brick type. Akhtaruzzaman and Hasnat [3] found that although the tensile strength of concrete containing coarse crushed brick was higher than that of normal concrete by about 11%, the modulus of elasticity was 30% less than that of normal concrete. Poon and Chan [4] observed that incorporation of 20% fine crushed

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brick aggregate decreased the compressive strength and modulus of elasticity of concrete by 18%. Debieb and Kenai [5] reported that compressive strength decreased by 30–40% when coarse, fine or both fine and coarse aggregate were substituted by crushed bricks. They recommend that the use of crushed bricks aggregates should be limited to low performance concrete such as pavement blocks and that if crushed brick is used in concrete the substitution percentage should be limited to 25% and 50% for coarse and fine aggregates, respectively. Sadek [6] examined the potential of using crushed brick as alternative aggregates in the production of innovative solid cement bricks and stated that the substitution level of natural aggregates should be limited to 50%.

The aim of this paper is to demonstrate that it is possible to enhance the replacement percentage of natural aggregate above 50% with crushed bricks and roof tiles as an aggregate in concrete for precast concrete floor blocks. The main objectives of this research were:

- To define the optimum composition and establish the properties of a mixture by experimental tests that met the requirement needed for the production of floor blocks.
- To determine the properties of concrete floor blocks with CBT aggregate at room temperature.

2. Material properties

The cement used was ordinary Portland cement, type CEM (I) 42.5. Its mechanical, chemical and physical properties are shown in Table 1.

Dolomite was used as a fine and coarse natural aggregate (NA). Crushed clay bricks (CB) and crushed clay roof tiles (CT), obtained as industrial waste product, were used as a recycled aggregate (referred to in this paper as crushed bricks and tiles (CBT)).

Roof tile industry of Croatia produces about 90 million of pieces per year. During the production a part of produced tiles is damaged. This part equals about 6–10% of total amount of produced tiles which results with approximately 21,600 tons of material that should be taken care of. Brick industry of Croatia produces about 900 million of pieces per year. This amount includes only waste that results from the production of clay bricks. This part of waste material equals about 2–5% of total amount of produced clay bricks which results with approximately 3,150,000 tons of material that should be taken care of. In production of brick and roof tiles, the damaged products cannot be placed on the market, and most of this waste produced by the construction industry is placed in landfills.

The CBT aggregate was produced from clay bricks and clay roof tiles through an immediate crushing process in the factory. The coarse CB, CT and NA were those passed from sieve No. 16 (16 mm) and retained in sieve No 4 (4.0 mm), whereas fine CB, CT and NA were those passed from sieve No. 4. To be able to use CBT as a replacement for NA aggregate, the geometrical properties, mechanical and physical properties, thermal and weathering properties and the chemical properties of CBT needed to meet the requirements set in HRN EN 12620 [8]. The aggregates' properties are shown in Table 2. The results showed that CBT had lower specific density than natural aggregate; water absorption of CBT was several times higher than that of natural aggregates, due to the porous characteristics of the clay brick and tile which was about 20%, as expected according to [1–6]. According to Table 2, it can be concluded that CB and CT can be used as a partial or full natural aggregate replacement for concrete.

Dolomite limestone powder was used as filler in concrete mixtures. Dolomite limestone helps to reduce water demand and segregates mixtures in order to increase their water-holding capacity, plasticity and the homogeneity of concrete, reduce shrinkage and improves the water and frost-resistance of the solution [9]. The superplasticizer used was high rang water reducer (HRWRA) and was used to improve the workability of the mix. The admixture used was produced by Sika under the commercial name Sika ViscoCrete-20Gold. The admixture is a brown liquid with a density of 1.06 Mg/m^3 at room temperature. The amount of superplasticizer used was 0.3% of the cement weight.

Table 1
Mechanical, chemical and physical properties of CEM I 42.5 N.

	CEM I 42.5 N	Limits of HRN EN 197-1:2012 [7]
Physical and mechanical properties		
Initial setting (min)	145	⩾60
Volume stability (mm)	0.50	⩽10
2 day compressive strength (MPa)	25.1	⩾10
28 day compressive strength (MPa)	54.8	⩾42.5 ⩽ 62.5
Chemical properties		
SO_3 (%)	2.73	⩽3.5
Cl (%)	0.06	⩽0.1

3. Methods

From ecological and economic point of view, concrete, floor blocks, solid concrete brick, etc. are designed to achieve the target compressive strength with minimum content of NA and maximum content of CBT. Thus, the main objective of experimental research is to produce precast concrete floor blocks that satisfy the requirements of national and international standards (i.e., EN, HRN), either for load-bearing or non-load-bearing units using CB and CT aggregates with as little NA content as possible. Concrete components were chosen based on previous experimental investigations of 62 different concrete mixtures [10]. The selection of two concrete mixtures was made according to experimental results and mathematical models. One control mixture was made only with NA aggregate. Optimal concrete compositions for precast concrete blocks, as part of a beam and blocks

Table 2
Properties of CB, CT and NA in accordance with HRN EN 12620 [8].

Aggregate type	CB		CT		NA	
	Fine	Coarse	Fine	Coarse	Fine	Coarse
Particle shape (%) Shape index	–	7 (SI_{15})	–	11 (SI_{15})	–	6 (SI_{15})
Particle size	G_F85	G_C90/15	G_F85	G_C90/15	G_F85	G_C90/15
Specific density SSD (Mg/m^3)	2.13	2.16	2.29	2.25	2.86	2.88
Cleanliness: fines quality	4.4% (f_{10})	0.4% ($f_{1,5}$)	3.6% (f_{10})	0.8% ($f_{1,5}$)	3.2% (f_{10})	0.8% ($f_{1,5}$)
Los Angeles (%)	–	40 (LA_{30})	–	37 (LA_{30})	–	24 (LA_{25})
Composition/content						
Chlorides (%)	0.001		0.001		0.0	
Acid soluble sulphates (%)	0.0		0.0		0.023	
Total sulphur (%)	0.0		0.0		0.0	
Water absorption (%)	19.05	16.71	11.50	9.25	2.29	0.50
Thermal and weathering properties: magnesium sulphate test (%)	–	3 (MS_{18})	–	4 (MS_{18})	–	10,7 (MS_{18})