FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 8, N° 2, 2010, pp. 155 - 162
DOI: 10.2298/FUACE1002155J

FROST RESISTANCE OF CONCRETE WITH CRUSHED BRICK AS AGGREGATE

UDC 691.322:691.4:620.251.1(045)=111

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Abstract. *The investigation included concrete made by using recycled brick as aggregate. Experimental work included several types of concrete made with the same cement content (385 kg/m3), and same consistency (slump about 1 cm). Recycled brick and combination of natural river aggregate and recycled brick were used as aggregates. The influence of percentage and grain size of crushed brick aggregate on concrete compressive strength, water absorption and frost resistance were observed. On the basis of the results obtained during experimental research, a general conclusion can be drawn that the application of recycled concrete as aggregate can lead to new composites with satisfactory physical-mechanical properties.*

Key words: *crushed brick, recycled aggregate, concrete, frost resistance*

1. INTRODUCTION

For environmental and other reasons the number of ready accessible disposal sites around major cities in the world have decreased in the recent years. Both disposal volume and maximum sizes of wastes have been restricted. The distance between demolition sites and disposal areas have become large and transport costs higher. At the same time critical shortages of good natural aggregate are developing in many urban areas, and distance between deposits of natural material and sites of new construction have grown larger, and transportation costs become correspondingly higher [5].

Fabrication of light-weight aggregate for concrete from industrial waste, helped transform waste material into raw material from which high quality aggregate is obtained. Due to its chemical composition and physical properties, every waste material can not be used as raw material for production of light-weight aggregate (produced aggregate must be chemically inert and harmless in concrete) [9]. Every production of light-weight aggregate on the basis of industrial waste material is not economical. During industrial

Received March, 2010

production of brick and tiles when the burning process is not adequately performed, waste can appear and it can successfully be used for production of concrete prefabricated elements of smaller sizes [3,4,11,12,13].
Concrete on the basis of crushed brick aggregate has satisfactory compressive and tensile strength and thermal insulating properties but shows weaker resistance to water and frost action and has greater shrinkage by 20-60% than ordinary concrete [1,6,7,8,14,15].

2. COMPONENT MATERIALS AND CONCRETE DESIGN

Concrete were made using pure Portland cement – CEM I 42.5 R Lafarge – BFC.

Natural river aggregate and crushed bricks aggregate were used. After demolition of masonry structure bricks were crushed and separated into fractions 0/4, 4/8 and 8/16 mm (see Figure 1).

Fig. 1 Crushed brick -fractions 0/4 and 4/8mm

Properties and chemical composition of recycled brick aggregate are given in the Tables 1 and 2.

Table 1 Chemical composition of recycled brick aggregate

Moisture at 105 °C (%)	1.06
Loss on ignition at 1000 °C (%)	6.41
SiO_2 (%)	50.91
Al_2O_3 (%)	15.29
Fe_2O_3 (%)	8.97
CaO (%)	12.70
MgO (%)	4.06
SO_3 (%)	0.20
S (%)	0.00
Na_2O (%)	0.83
K_2O (%)	0.76
CO_2 (%)	-

Table 2 Properties of recycled brick aggregate

Fraction	0/4	4/8	8/16
Particle density (kg/m^3)	1618	1758	1611
Compacted density (kg/m^3)	1216	1011	1010
Loose density (kg/m^3)	1017	907	850
Water absorption (%)	21.8	21.2	20.1
Water absorption after 30' (%)	17.7	17.1	17.4

One kind of concrete (P2) was made using recycled bricks as aggregate. Other kinds of concrete were made using combination of river aggregate and recycled bricks. Grain size distribution for mixtures with recycled bricks as aggregate are shown in figure 2 and for mixtures with combination of natural river sand and recycled bricks are shown in figure 3.

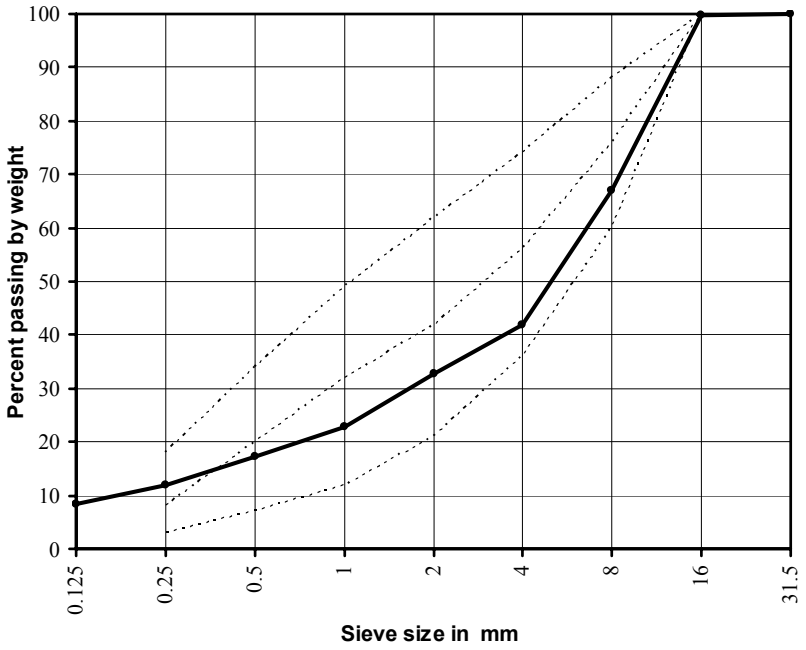

Fig. 2 Grain size distribution for concrete with recycled brick

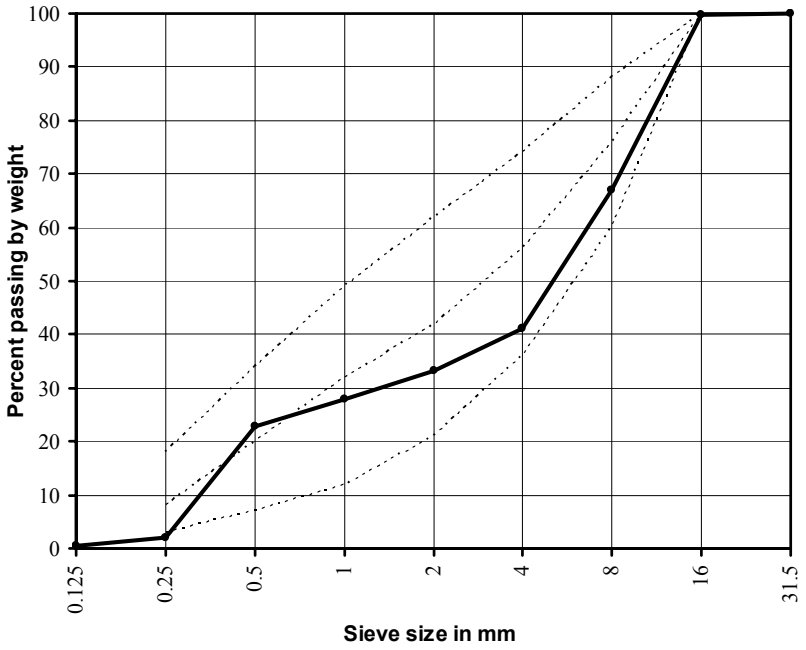

Fig. 3 Grain size distribution for concrete with combination of river sand and recycled brick

Concrete mixtures were made using superplasticizer "Dynamon SX", produced by "Mapei", Italy.

In this study a portion of natural river aggregate was replaced by crushed clay brick. The replacement levels by weight were 25% (P4), 50% (P5) and 100% (P2); one mixture was made with river sand and recycled brick aggregate (P3) and two mixtures were made with river aggregate fraction 8/16 mm and different percent of crushed brick (P6, P7). Informations about composition of concrete are shown in Table 3. One part of water providing the required consistency (slump about 1.0 cm) of the mixture (free water i.e. effective water). Quantity of absorbed water is equivalent average value of water absorbed by aggregate after 30' [2]. Due to large water absorption of crushed brick water to cement ratio was 0.48-0.95 (including free and absorbed water). It depends on percentage and fractions which were replaced by crushed clay brick. According to previous investigation for concrete with maximum gravel size of 32mm and 350kg/m^3 cement content [8] and expected compressive strength more than 30 N/mm^2, with maximum gravel size of 16 mm, the same cement content of 385 kg/m^3 for all kinds of concrete in this investigation was adopted.

Table 3 Quantities of component materials of concrete

Type of concrete		P2	P3	P4
Cement (kg/m^3)		385	385	385
Aggregate (kg/m^3)	river 0/4 mm		600 (40%)	512 (30%)
	crushed brick 0/4 mm	506 (40%)		170 (10%)
	river 4/8 mm			320 (18.75%)
	crushed brick 4/8 mm	316 (25%)	375 (25%)	107 (6.25%)
	river 8/16 mm			448 (26.25%)
	crushed brick 8/16 mm	443 (35%)	525 (35%)	149 (8.75%)
Water (kg/m^3)		365	285	205
Admixture (kg/m^3)		4.62	4.62	4.62
Type of concrete		P5	P6	P7
Cement (kg/m^3)		385	385	385
Aggregate (kg/m^3)	river 0/4 mm	313 (20%)		338 (20%)
	crushed brick 0/4 mm	313 (20%)	596 (40%)	338 (20%)
	river 4/8 mm	196 (12.5%)		211 (12.5%)
	crushed brick 4/8 mm	196 (12.5%)	372 (25%)	211 (12.5%)
	river 8/16 mm	274 (17.5%)	522 (35%)	592 (35%)
	crushed brick 8/16 mm	274 (17.5%)		
Water (kg/m^3)		265	265	185
Admixture (kg/m^3)		4.62	4.62	4.62

Mixing procedure was according to previous investigation [8]. Initially, aggregate and cement were mixed two minutes, 2/3 water was added and after mixing for 2 minutes 1/3 water and admixtures was added.

3. THE RESULTS OF INVESTIGATION

3.1. Density

The density of hardened concrete is given in the Table 4.

Table 4 Density of hardened concrete

Type of concrete	P2	P3	P 4	P 5	P 6	P 7
Density (kg/m^3)	2008	2160	2288	2205	2129	2254

3.2. Water absorption

The water absorption values were determined as a ratio of the mass of the absorbed water of an immersed specimen to the oven dried mass of the same specimen.

Table 5 Water absorption of concrete

Type of concrete	P2	P3	P 4	P 5	P 6	P 7
Water absorption(%)	20.4	13.1	8.6	11.7	13.5	8.4

3.3. Compressive strength

Compressive strength of concrete was established by testing the specimens of 10 cm cube edges. The obtained 28 days strengths of all kinds of concrete are shown in Table 6.

Table 6 Compressive strength of concrete in N/mm^2

Type of concrete	P2	P3	P 4	P 5	P 6	P 7
Compressive strength (N/mm^2)	40.9	46.7	60.6	46.7	42.2	60.8
Compressive strength, 20 cm cube (N/mm^2)	36.8	42.0	54.5	42.0	38.0	54.7

3.4. Frost resistance

According to Serbian standard frost resistance was tested on cylindrical specimens d/h = 5/5.6 cm by destructive method. Twenty four specimens of each kind of concrete were sampled (3 for every class of frost resistance and respective reference). After 50, 100, 150 and 200 freezing and thawing cycles decrease of compressive strength was tested.

Number of freezing and thawing cycles which satisfied decrease of compressive strength (maximum 25 %) is shown in Table 7.

Table 7 Number of freezing and thawing cycles

Type of concrete	P2	P3	P 4	P 5	P 6	P 7
Number of cycles	100	150	200	150	100	200

4. ANALYSIS OF RESULTS AND CONCLUSIONS

Comparing concrete with and without natural river aggregate it can be concluded that concrete with natural river aggregate has: greater compressive strength, greater bulk density and better frost resistance. Compressive strength was greater than expected. This type of concrete satisfied MB 35, 40 or 50 (C30/37, C 35/45 or C40/50) for 100%, 50% and 25% replacement of natural river aggregate. Crushed brick aggregate have lower density and that is reason why concrete density varied from 2008 kg/m^3 to 2254 kg/m^3 depending of percentage of recycled aggregate. Water absorption of crushed brick aggregate fraction was from 20.1% for fraction 8/16mm to 21.8% for fraction 0/4 mm. Water absorption of aggregate reflects to water absorption of concrete. That is reason why water absorption of concrete with 100% recycled brick aggregate was 20.4% and for concrete with 25% crushed brick as aggregate was only 8.6%. This property of concrete influence on frost resistance of concrete. This investigation was shown that there is of great correlation between density (i.e. percent of recycled brick aggregate), water absorption and frost resistance. This type of concrete satisfied M100, 150 or 200 for 100%, 50% and 25% replacement of natural river aggregate.

By modelling the structural characteristics of concrete, materials of various densities, mechanical and insulation properties can be provided. Comparing previous test results of concrete

paving blocks and tiles made of ordinary concrete and properties of concrete with recycled brick as aggregate it can be concluded that this kind of concrete can be used for production of elements for pedestrian areas and various non-structural elements.

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OTPORNOST PREMA DEJSTVU MRAZA BETONA SA AGREGATOM OD DROBLJENE OPEKE

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Predmet istraživanja su betoni spravljeni sa recikliranom opekom kao agregatom. Eksperimentalni rad je obuhvatio više vrsta betona spravljenih sa istom količinom cementa (385 kg/m^3) i istom konzistencijom (sleganje oko 1 cm). Kao agregat je korišćena reciklirana opeka i kombinacija reciklirane opeke i prirodnog rečnog agregata. Posmatran je uticaj upotrebljenih

frakcija drobljene opeke i njihovog procentualnog učešća na čvrstoću pri pritisku, upijanje vode i otpornost prema dejstvu mraza. Na osnovu rezultata eksperimentalnih istraživanja može se zaključiti da se primenom reciklirane opeke kao agregata dobija novi kompozitni material sa zadovoljavajućim fizičko – mehaničkim karakteristikama.

Ključne reči*: drobljena opeka, reciklirani agregat, beton, otpornost prema dejstvu mraza*