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Partial substitution of Cement in Concrete by Finely Ground Brick Body

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Summary

Brick chippings are the waste which can partially substitute the cement. Therefore this waste is utilized, in light of the environment, into the useful new product - the concrete. The finely ground brick body is characterized by certain pozzuolana activity which enables the partially substitution of the energetically demanding binder which is the cement. The paper indicates the observations concerning the tests of concrete in which the cement was substituted by 10% and 20% of finely ground brick bodies from the brick plants Kryry and Šlapanice.

KEYWORDS: brick body, concrete, additive to concrete, pozzuolana activity.

1. INTRODUCTION

The brick plants produce on the average 1 till 5 % of waste, which is recycled only in low range and utilized as opening material. The rest is stored in deposits. The price of this waste material rarely overreaches 5 till 10% of the cement price. It is true that for the utilization as substitute for cement it is necessary to prepare it (by grinding, separation etc.). However also after this preparation its price does not overreach 20% of cement production costs. The finely ground brick body shows pozzuolana activity so that we can hold it for the active pozzuolana admixture and we can substitute the part of binder in cement composite by this material.

By the addition of finely ground brick body we can achieve, with comparable concrete parameters, the decrease of production costs.

The reaction extent of the burned brick body with the hydrating cement is given on the one hand by the composition of raw materials and on the other hand by the burning conditions.

The brick products are on the present as a rule burned at the temperature 1000 – 1100°C. The brick body is formed by raw glass surrounded by other crystals and it can show variable pozzuolana activity in dependence on the used earth and on the burning temperature. The greatest portion in the resulting product forms as the rule the glassy phase with high content of silicon and of alkalis and it contents further

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also aluminum, different iron oxides, calcium and magnesium surrounded by crystals of mullite, silicon and sometimes also cristoballite. The brick products with high lime content can also contain considerably amounts of feldspars which support the increase of activity.

The reaction activity is highest mostly in the temperature range between 600 – 900°C. Higher temperature causes nucleation and crystallization of new phases in the body and the reaction activity rather decreases. The glassy phase excels during cooling and it is in dependence on the composition more or less active [4].

The following active admixtures were applied in practice:

- Finely ground brick body from the brick plant KRYRY
- Finely ground brick body from the brick plant ŠLAPANICE

The effect of the cement substitution in concrete by finely ground brick body, on its physico-mechanical characteristic, was tested in experimental work.

2. METHODS OF EXPERIMENTAL WORK AND THE COMPOSITION OF CONCRETE

The experimental work is based on the properties comparison of concrete made with different batch of finely ground brick body (substitution 10 % and 20 % of the cement weight) with the properties of reference concrete which was made without the use of brick body.

2.1. Input materials:

The following components were used for the production of concrete:

- cement CEM 42,5R from cement plant Mokrá
- sand fraction 0-4 mm from the locality Žabčice
- crushed aggregate fraction 4-8 mm from the locality Želešice
- crushed aggregate fraction 8-16 mm from the locality Želešice
- admixture: finely ground brick body from the brick plant KRYRY and ŠLAPANICE
- The volume weight of these brick bodies are 2750 kg/m^3
- Additive: poly-carboxyl-ether ACE 40, from the firm BASF which shows liquefying effects, increases the initial and the final strength of concrete
- batch water – it fulfils the demands of the EN 1008.

The basic parameters of the aggregate are in table 1.

Table 1: Basic parameters of the aggregate

Parameter	Unit	Žabčice 0/4 mm	Želešice 4/8 mm	Želešice 8/16 mm
Volume weight	[kg/m^3]	2630	2650	2730
Bulk weight in shed state	[kg/m^3]	1770	1670	1710
Porosity	[%]	32,7	37,0	37,4

2.2. Composition of concrete

The composition of concrete is in table 2.

Table 2. Composition of concrete in 1 m^3

Component	Reference concrete	Concrete with10% of brick body	Concrete with 20% of brick body
CEM I 42,5 R Hranice cement	400 kg	360 kg	320 kg
Finely ground brick body	0 kg	40 kg	80 kg
Sand 0 to 4 mm from the Žabčice Gravel Pit	745 kg	740 kg	739 kg
Aggregates 4 to 8 mm from the Želešice Gravel Pit	235 kg	230 kg	229 kg
Aggregates 8 to 16 mm from the Želešice Gravel Pit	980 kg	972 kg	971 kg
Plasticizer BASF ACE 40	4 kg	4 kg	4 kg
Mixing Water	151 kg	147 kg	141 kg
Water/Cement Ratio	0,38	0,37	0,35

2.3. Observed parameters

The following parameters were observed with tested concrete:

- fresh concrete - flow table test $\boldsymbol{F}$ (EN 12350-5 Standard)
- density of fresh concrete $\boldsymbol{D}$ (EN 12350-6 Standard)
- density of hardened concrete $\boldsymbol{D}$ (EN 12390-7 Standard)
- compression strength $\boldsymbol{f_{c,cu}}$ (EN 12390–3 Standard) in the age of concrete 1, 3, 7, and 28 days
- bending strength $\boldsymbol{f_{cf}}$ (EN 12390–6 Standard) in the concrete age 28 days
- depth of penetration of water under pressure $\boldsymbol{h_{tv}}$ (EN 12390–8 Standard)
- dynamic modulus of elasticity $\boldsymbol{E_{bu}}$ (CSN 731371 Standard) in the age of concrete 1, 3, 7, 14 a 28 days.

Marking of individual tested concrete:
REF - reference concrete (strength class C 55/67)

S10 - concrete with 10% substitution of cement by finely ground brick body from brick plant Šlapanice
S20 - concrete with 20% substitution of cement by finely ground brick body from brick plant Šlapanice
K10 - concrete with 10% substitution of cement by finely ground brick body from brick plant Kryry
K20 - concrete with 10% substitution of cement by finely ground brick body from brick plant Kryry

3. TEST RESULTS

The test results are in table 3 and for selected parameters they are represented graphically in figures:

- Fig.1: Effect of the finely ground brick body addition on the compression strength of concrete with different age

  Fig.2: Effect of the finely ground brick body addition on the bending strength of concrete and on the ingress of pressure water - age of concrete 28 days

- Fig.3: Effect of the finely ground brick body addition on the dynamical elasticity modulus – for different ages of concrete.

Table 3: Results of concrete tests

Properte	Age [days]	Unit	REF	S10	S20	K10	K20
			FRESH CONSCRETE				
F	--	[mm]	370	435	450	420	435
D	--	[kg/m^3]	2500	2480	2460	2470	2460
			HARDENED CONCRETE				
D	28	[kg/m^3]	2520	2490	2480	2490	2480
$f_{c,cu}$	1	[MPa]	39,8	30,2	20,8	28,6	20,4
	3		49,8	40,4	34,9	36,5	33,6
	7		59,6	54,6	43,1	52,6	44,1
	28		74,0	68,6	56,6	69	52,1
f_{cf}	28		7,8	6,5	5,5	6,6	5,5
h_{tv}	28	[mm]	11	8	6	10	7
E_{bu}	1	[GPa]	47,5	42,8	40,3	40,8	40,7
	3		52,2	46,5	44,5	44,6	44,5
	7		56,7	52,8	50,3	51,1	49,8
	14		57,1	53,0	51,7	52,2	51,5
	28		57,4	54,6	52,0	52,5	52,5

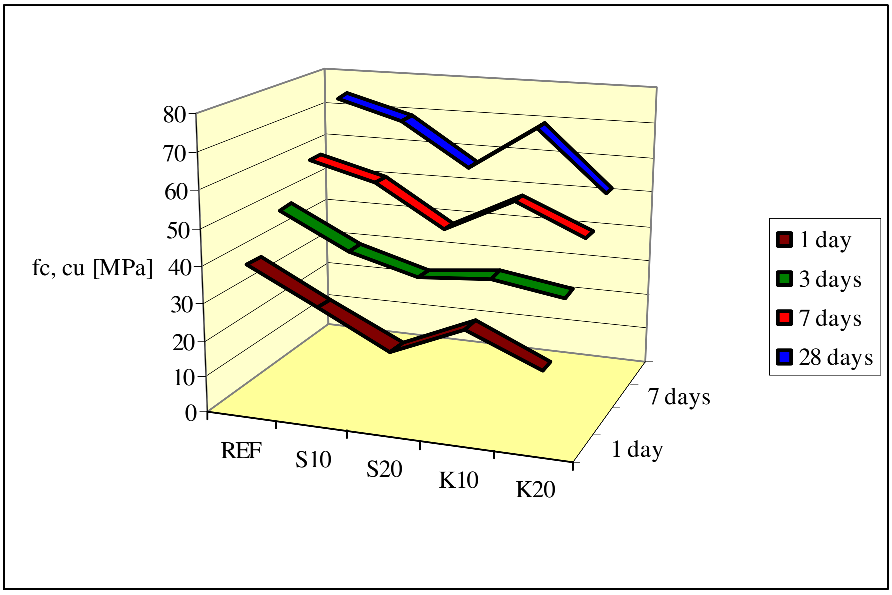

Figure 1.Compression strength in dependence on the quantity of added brick body and on the hardening time of concrete

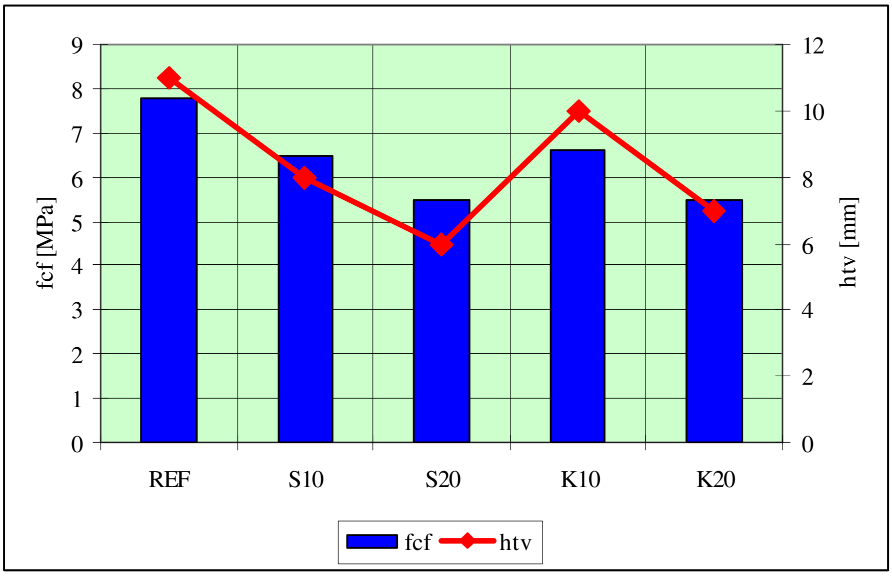

Figure 2.Effect of the quantity of added brick body on the bending strength and on the depth of the pressure water ingress

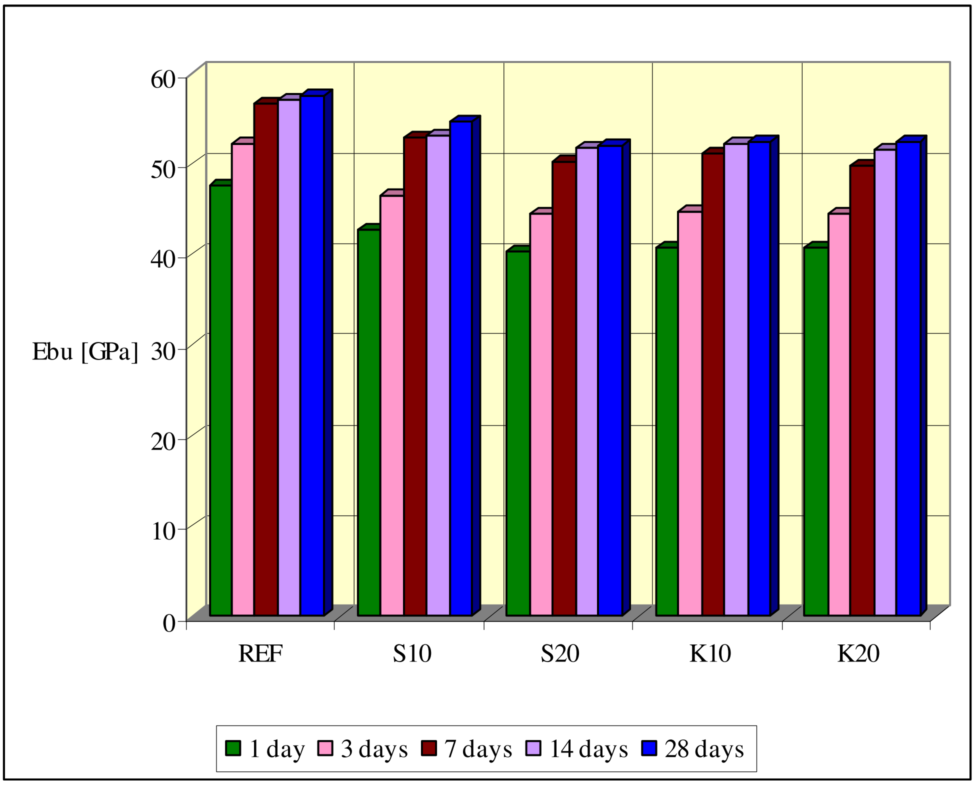

Figure 3.The dynamical elasticity modulus in dependence on the quantity of added brick body and on the hardening time of concrete.

4. CONCLUSION

Experimental works proved the usability of finely ground brick body as active admixture into concrete. The test results showed that the utilization of this active admixture is also adequate for the improvement of some special concrete properties.

a) Compression strength:

The concrete with the substitution of 10 % cement by finely ground brick body achieved after 28 days 92 - 93% of the reference concrete compression strength values.

The concrete with the substitution of 20 % of cement by finely ground brick body achieved after 28 days 71 – 73% of the reference concrete compression strength values.

b) Bending strength:

The bending strength decreases with the increasing content of the brick body. The highest strength had the reference concrete.

c) Depth of the pressure water ingress:

The depth values of pressure water ingress into the reference concrete were comparable with the water ingress into concrete with the addition of brick body and they are very favourable.

d) Dynamical modulus of elasticity:

The dynamical modulus of elasticity decreases with the increasing content of the brick body. The reference concrete had the highest value.

The results of experimental works show that better values of compression strength are achieved in the case of 10 % cement substitution by brick body – the concrete class corresponds with the concrete class of the reference concrete. Concrete with 20 % cement substitution by brick body achieves values which are by a class lower.

We can conclude that the utilization of finely ground brick body in concrete is useful from the ecological and also from the economical point of view.

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