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APPLICATION OF RECYCLED CONCRETE AGGREGATES CONTAINING WASTE GLASS POWDER/SUSPENSION AND BOTTOM ASH AS A CEMENT COMPONENT IN CONCRETE

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Abstract

The growing environmental concerns and the increasing scarcity of landfills encourage the recycling of industrial wastes and adopting environmentally friendly practices by rational usage of natural resources. The production of concrete with recycled aggregate and reduced cement volume is the most desirable form of achieving a closed life cycle as an ecological constructional material. This paper describes results of a study undertaken to examine the influence of recycled aggregates obtained from manually crushed concrete specimens (which already had Portland cement replacement of 30% by mass with waste glass powder/suspension and coal/wood bottom ashes) on the properties of the concrete with finely ground waste glass as Portland cement component.

Keywords: Recycled concrete aggregates, Waste glass, Wood/Coal bottom ash, Hydration temperature, Mechanical properties

1 Introduction

Concretes produced with recycled aggregates are the subject of several papers recently published in the technical literature (Dhir et al., 1998; Berndt, 2009; Fonseca et al., 2011; Nassar, 2012). Substitution of natural aggregates can be one of possibilities to take care of landfills, however according to the Umweltbundesamt report (2009) published data the use of concrete recycled aggregates is still far from being competitive as compared with natural aggregates, only 5%. In 2011 the world production of Portland cement was 3.4 billion tons (USGS Mineral Program Cement Report, 2012) and this number is increasing due to infrastructure development in China, India, Turkey and Brazil. Cement industry causes about 5% of global carbon dioxide emissions into the atmosphere and its reduction strategies by the cement industry mainly aim at reducing emissions per ton of cement product. One of the strategies is partial substitution of Portland cement with supplementary cementitious materials in the finished cement products and in concrete. For a material to undergo pozzolanic reactions effectively it must be finely ground, since a high surface area is required to ensure as adequate rate and degree of reaction. Glass cullet in finely ground form undergoes a pozzolanic reaction and has potential for use as a binder in combination with Portland cement and also has the effect of lessening expansion (Dyer and Dhir, 2001).

2 Materials and methods

An experimental study was carried out to investigate the mechanical, physical and thermal properties of concrete with waste glass and recycled concrete aggregates. Waste glass chippings were washed and ground for 30 min in laboratory planetary ball mill Retsch PM400 (with rotation speed 300 min-1). Waste glass powder was used as Portland cement replacement of 20% by mass with borosilicate glass and 30% by mass with glass cullets (flint, amber and green). The fineness of powders was obtained by automatic Blaine apparatus Zwick/Roell ToniPERM using rapid method without the need to prior measure density of the powder with pyknometer in accordance with BS EN 196-6 and ASTM C204. The bulk oxide analysis and a Blaine fineness of the glass powders and Portland cement are given in Table 1.

Table 1
Chemical composition and fineness of glass powders and Portland cement used in the study

Bulk oxide, %mass	Glass cullet			DRL	LB	PC
	Flint	Green	Amber			
CaO	11,300	10,930	8,890	1,320	5,110	69,01
Al_2O_3	1,340	1,530	1,420	2,600	1,220	5,260
SiO_2	69,610	67,800	69,260	71,140	65,520	18,74
K_2O	0,562	0,550	0,507	1,702	1,881	0,727
Na_2O	11,208	11,092	11,436	3,301	12,354	0,382
Fe_2O_3	0,080	0,360	0,430	0,170	0,110	2,030
MnO	0,008	0,018	0,018	0,006	0,011	0,059
MgO	0,462	1,584	3,078	0,615	2,946	1,812
TiO_2	0,028	0,062	0,052	0,006	0,027	0,261
Cl	0	0	0	0,038	0	0,179
SO_3	0,126	0,036	0,012	0	0,143	3,004
P_2O_5	0,021	0,023	0,026	0,023	0,038	0,151
ZrO_2	0,0134	0,0164	0,0159	0,0844	0,014	0,0078
Fineness, m^2/kg	502	463	542	608	542	388

Recycled concrete aggregates (RCA) were obtained by crushing old concrete specimens which were stored as waste after determination of their mechanical properties. The idea was to reduce accumulated concrete specimens' waste produced after laboratory experiments. The mix compositions of the crushed concrete specimens had cement replacement of 30% by mass with borosilicate glass (DRL, B_2O_3 = 16.63%) powder/suspension, or lead glass (LB, PbO=20.02%) powder/suspension, or wood/coal bottom ashes (Kara, 2012). The obtained RCA grains were separated into fractions (4/8mm and 8/11.2mm) and used as natural aggregate replacement at level of 50-100%. Ordinary Portland cement CEM I 42.5N was applied as binding agent. Sikament 56 polycarboxylat plasticizing agent and RW-Fuller silica fume were used for mix preparation. A total of 15 different concrete mixes were produced: 8 concrete mixes with DRL waste glass as cement component (20% by mass) and 7 SCC mixes with glass cullets as cement component (30% by mass). Mix compositions (kg/m^3): (Series I) Cement – 410, Sand 0.3/2.5mm – 650, Sand 0/1mm – 120, Gravel 4/11.2mm – 1000, Water - 180 and (Series II) Cement – 533, Sand 0.3/2.5mm – 602, Sand 0/1mm – 341, Gravel 4/8mm – 200, Gravel 8/11.2mm – 467, Water – 223, Silica fume – 40, Plasticizing agent – 9. The mixing procedure: first mixing dry ingredients for 120s and then adding 70% of the total water for 60s and after adding the rest of the water and mixing for 60s. As soon as the mixing was done, Abram slump and flow slump tests were carried out. Fresh concrete was placed in 150x150x150mm moulds and covered with polyethylene wrap. After 24 – 48 hours specimens were removed from moulds and cured in water (with temperature +20±2°C) for 28 days and then were placed in a curing chamber (with air temperature +20±2°C and relative humidity ≥95%) until the tests were carried out. Compressive strength of concrete specimens was determi-

Fig. 1 Equipment to measure hydration temperature inside of concrete mixes

ned at the age of 7, 28 and 90 days for concrete mixes in accotdance with LVS EN 206 standard. Splitting tensile strength was determined at the age of 28 days.
Equipment to measure hydration temperature inside of concrete mixes was designed (Fig. 1): concrete mixes were cast in demountable 150x150x150mm plywood moulds with a thermocouple (connected to a data transmitting device) located in the centre of one face of each mould. Four moulds were placed into a plywood box with 50mm insulation layer of polystyrene foam. The temperature in the centre of each concrete specimen was continuously monitored at least up to 144h after production in the ambient environment of 20±2°C.

The depth of penetration of water under pressure for concrete mixes was tested according to LVS EN 12390-8 standard. Specimens with dimensions 150x150x150mm at the age of 28 days were placed in apparatus and applied water pressure of 5Mpa for 72 hours. Afterwards, specimens were splitted in half in order to observe the water penetration depth.

3 Results and discussions

The tests results of compressive strength, hydration temperature, the depth of penetration and splitting tensile strength are summarized in Table 2. Each presented value is the average of three measurements.

Table 2
Mechanical, physical and thermal properties of concrete mixes with RCA and waste glass powder as a Portland cement component in concrete.

Series I Mix type	Used RCA	RCA, %	Glass type	Slump, mm	Compressive strength, MPa			Hydration tempera-ture, °C	The depth of penetration, mm
					7d	28d	90d		
1 (CTRL)	--	0	DRL, 20%	45	43.5	64.7	68.9	35.6	20
2	coal ash	100		5	39.3	61.0	66.0	35.6	25
3	wood ash	100		10	35.1	59.0	64.5	36.4	25
4	DRL powder	50		35	40.6	61.6	67.9	35.6	18
5	LB suspension and wood ash	100		3	42.2	60.5	65.4	35.9	22
6	DRL powder	100		7	43.5	71.0	74.0	35.8	19
7	LB powder	100		5	46.0	59.0	63.0	35.7	21
8	DRL suspension	100		40	44.0	59.0	72.0	35.8	20
Series II Mix type	**Used RCA**	**RCA, %**	**Glass type**	**Slump flow diameter, mm**	**Compressive strength, MPa**			**Hydration tempera-ture, °C**	**The depth of penetration, mm**
					7d	**28d**	**90d**		
9 (CTRL)	--	0	--	570	46.2	65.7	76.23	37.3	18
10	coal ash	100	Amber 30%	610	51.5	72.4	90.88	37.4	19
11	coal ash	100	Green 30%	670	41.9	64.5	87.25	37.4	19
12	wood ash	100	Amber 30%	670	36.7	69.8	91.87	38.1	20
13	wood ash	100	Green 30%	640	41.0	58.3	67.58	38.1	19
14	DRL powder	100	Amber 30%	640	44.0	69.9	96.37	37.5	18
15	DRL powder	100	Green 30%	640	41.0	61.4	84.22	37.5	18

The best performed mechanical properties in this study were for concrete mix compositions: (Series I) *concrete mix 6* - with Portland cement substitution at level of 20% with borosilicate glass and used RCA from concrete old specimens containing DRL glass powder as a Portland cement component; (Series II) *SCC concrete mix 14* - with Portland cement substitution at level of 30% with amber glass cullet and used RCA from concrete old specimens containing DRL glass powder as a Portland cement component. There was reasonable compressive strength increase for SCC concrete at the age of 90 days. Amber cullet glass as Portland cement component gave significant effect on mechanical properties. The best mix workability was performed for mixes 8 and 13, and especially for mix 13 with slump flow only 640mm. Hydration temperature was almost equal for all mixes in comparison to control mix. The best results of depth of penetration were for mixes with waste glass RCA and for SCC generally. The usual use of recycled aggregates in concrete is hindered by its higher water absorption, but in this study used RCA with waste glass powder/suspension as a Portland cement component showed lower water absorption and better workability.

4 Conclusions

This particular study showed that concrete with concrete recycled aggregates containing waste glass powder as Portland cement component in concrete can performe good mechanical properties but longterm-performance must be yet investigated. The application of waste glass recycled concrete aggregates could be an option for the next generation waste materials‘ application in recycled aggregate concrete in concern to reduce the amount of waste disposed and preserve natural resources, as also to reduce CO_2 into the atmosphere.

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