ROLLER COMPACTED CONCRETE MADE WITH RECYCLED CONCRETE AGGREGATE AND BIOMASS BOTTOM ASH

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1. Introduction

Households and businesses in the EU-28 in 2014 generated almost 2600 million of total waste tonnes, where construction and demolition waste (CDW) represented the 30% of the total waste (Eurostat, 2015). CDW was declared as priority waste stream in Directive 2008/98/CE, in order to reach the 70% in weight of this waste be reused, recycled, or recovered by 2020.

Moreover, in the EU-28, Directive 2009/28/EC set up a target of 20% final energy consumption from renewable sources by 2020. In this European Directive, biomass is one of these renewable sources that should be encouraged by the Member States, and it is defined as the biodegradable fraction of products, waste and residues from different biological origins such as vegetal substances. Spain has an important potential of biomass resources. Andalusia is the largest producer of biomass energy in Spain. By-products of biomass combustion are encouraged to be disposed in landfills due to the lack of regulatory frameworks.

The use of recycled aggregates (RA) from CDW in civil applications with cement has been studied by many authors (Perez *et al*, 2013, Agrela *et al*, 2012). Roller Compacted Concrete (RCC) is a mix that has the same basic constituents as plain concrete and is placed with compacting equipment. Its use is diverse, such as dams, heavy-duty parking and storage areas, and as a base for pavements. The use of by-products of biomass plants, such as Biomass Bottom Ash (BBA), which is defined as the portion of non-combustible residue found in the furnace or incinerator, as alternative construction material has been recently studied. Cabrera et *al* (2014) characterized 30 BBAs concluding that BBA was well graded and presented low density and high absorption. Regarding chemical properties, Hinojosa et *al* (2014) stablished that BBA may be used for granular materials with cement treatment and plain concrete but not to reinforced concrete. Aggregate and cement has been substituted by BBA in mortar manufacturing by Modolo et *al* (2013) and Carrasco *et al* (2014) respectively. Beltran et *al* (2014) found that BBA incorporation in concrete diminished the properties of the concrete, although small percentages of BBA incorporation were suggested in non-structural concretes.

The application of BBA in RCC can be a solution in rural roads where biomass energy plants are usually located. The aim of this study is to evaluate the use of RCA combined with BBA in the manufacture of RCC. Materials were characterised under standard laboratory tests. The effect of compaction in mixtures, and their physical, mechanical and durability properties were analysed.

2. Materials and methods

The materials used in this research were the following: two natural aggregates, sand (NS) and gravel (NG), Portland cement-type CEM II/A-L 42.5 R, and as incorporated aggregates, RCA, and BBA from a biomass power plant. Table 1 shows the main properties of the aggregates used.

Table 1. Main properties of the aggregates used, and composition of the mixtures.

		Results of aggregates properties			
Properties		RCA	BBA	NS	NG
Density-SSD (g/cm3)	0-4 mm	-	1.69	2.65	-
	4-31.5 mm	2.51	-	-	2.63
Water absorpt. (%)	0-4 mm	-	39.1	0.77	-
	4-31.5 mm	4.69	-	-	0.91
Acid-soluble sulphate content (%)		0.36	-	<0.01	<0.01
Los Angeles abrasion test		29.4	-	-	20.6
Size range (mm)		4-20	0-12.5	0-4	4-20

	Proportions (%)			
Mixtures	BBA	NS	NG	RCA
Mcontrol	5	42	42	0
MRCA50	5	41	21	22
MRCA100	5	40	0	44
Mcontrol-BBA	0	45	44	0
MRCA50 -BBA	22	0	45	0
MRCA50 -BBA	44	0	45	0

The composition of the six mixtures manufactured is shown in Table 1. To determine the dosage of each mixture, it was searched its maximum compactness through Fuller curve approximation. Three replacement levels (in volume) of NG by RCA (0%, 50% and 100%) were used. The BBA was substituted by 5% in weight, making it equally in fine and coarse fractions. The cement proportion in each mixture was 11% in weight. The amount of water needed was determined by Proctor Modified test. Samples manufacturing was carry out by a vibrating Kango hammer, in cylindrical specimens; and in prismatic specimens, it was developed a new method to cast them, by means of a vibrating table.

3. Results and discussion

Table 2 shows the results of the tests conducted. It can be seen that the properties studied as decreased as the replacement levels of the RCA increased and BBA incorporation took place. BBA affection in the mixtures was greater in flexural strength and modulus of elasticity than in compressive strength and indirect strength mechanical properties. Reduction in dry density and porosity comparing mixtures with and without BBA incorporation was 5.6% (±0.1%), and 8.1% (±0.7%) respectively. The greatest BBA affection in the studied properties was in drying shrinkage, it could be attributed to the high BBA absorption.

Table 2. Test results.

Mixtures	Dry Density 28 days (g/cm^3)	Porosity 28 days (%)	Compressive strength 28 days (MPa)	Modulus of elasticity 28 days (GPa)	Indirect strength 28 days (MPa)	Flexural strength 28 days (MPa)	Drying Shrinkage 90 days (µm/m)
Mcontrol	2.32	11.2	31.3	22.1	3.4	4.9	169
MRCA50	2.25	13.5	24.9	17.1	3.1	4.2	197
MRCA100	2.22	14.6	21.9	15.3	2.7	3.9	253
Mcontrol-BBA	2.20	12.1	27.7	17.4	2.9	4.0	189
MRCA50-BBA	2.13	14.7	22.1	13.9	2.6	3.0	334
MRCA100-BBA	2.10	16.0	20.4	11.5	2.3	2.5	376

4. Conclusions

In light of the obtained results, the use of RCC made with RCA and BBA could be recommended if low density is required, because of BBA and RCA low density. Despite the deterioration of all strength properties due to BBA and RCA incorporation, its application remains possible if it is compensated by cement addition. Asphalt irrigation or any other method used after placing is highly recommended in order to avoid water evaporation due to the high absorption of BBA. RCC with RCA and BBA incorporation could be applied in rural roads where biomass plants are located.

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