Mechanical performance of Recycled Aggregate from CDW at long term varying gypsum content.

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Keywords: Recycled aggregate, mechanical performance, long-term, feasibility.
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1. Introduction

One third of all waste generated in the European Union (Brito and Silva, 2016) corresponds to construction and demolition waste (CDW), it comes from total or partial demolition of buildings and civil infrastructure, mainly. Its recycling rate varies between 90 and 10% in the EU. Spain is one of the countries with the lowest rate (European Commission, 2011), 10-15%, very far from objective of 70% stablished by Directive on waste 2008/98/EC.

CDW is constituted by ceramic particles, mortar, concrete and natural aggregates, and to a lesser extent asphalt, gypsum, wood, metals, paper and plastics, this stream waste after being processed in CDW treatment plants, Recycled aggregates (RA) are obtained. Cardoso (2015) and Vieira (2016) have reviewed the RA applications highlighting the feasibility of its use in civil projects such as backfilling, to form base and sub-base layers on roads and pavement on unpaved roads. There are other applications of RA, such as cement-treated granular material (CTGM) or incorporated in concrete manufacturing.

The RA usually contains a higher sulphate content than natural aggregates due to the mortar adhered and the presence of gypsum. Due to the solubility, hardness and density of the gypsum, this has a negative effect on the quality of the aggregate. When applying RA with high sulphate content in CTGM, it is possible to cause dimensional instability and decrease in compressive strength, due to the formation of ettringite (Agrela et al. 2014). Because of this, restrictions in RA regarding to this matter are usually stablished severely in specifications to form road base layers. For instance, in Spain the maximum sulphur content expressed in S to 1%, and the acid-soluble sulphate content expressed in SO_3 to 0.8% for road construction (Ministry of Development, 2015). Barbudo et al. (2012) stablished good correlations between the percentage of gypsum in RA and acid-soluble sulphates content, and not with other parameters such as concrete and mortar and ceramic particles.

The aim of this research was to analyse the effect on mechanical properties at long term of gypsum content in RA. For this purpose, different RA samples were prepared by adding different percentages of gypsum (0%, 2% and 4%) previously hydrated and crushed. California bearing ratio (CBR) and compressive strength were conducted on the samples prepared without and with a 3% cement addition respectively at different ages, reaching one year of curing.

2. Materials and methods

The RA used was collected from a CDW treatment plant and mainly composed of produced by crushing concrete mainly, with a well-graded size range of 0–32 mm. The cement used was CEM II BL 32.5 N.

Hence, samples (Table 1) were produced in the laboratory in order to observe the effect of gypsum content on mechanical properties at long term to form a base layer for roads. The gypsum type C6 (EN 13279-1) added was previously hydrated and crushed to the samples without cement treatment (RA) and with cement treatment (CT-RA), the higher addition used was 4% due to Barbudo et al. (2012) concluded that a maximum of 4.4% of gypsum particles satisfy the leached sulphates limitations. The evolutions of mechanical characteristics of were studied over time using the CBR test and the compressive strength after 4, 34, 64, 94, 124, 154, 184, 214, 244, 274, 304, 334 and 364 days of curing in a chamber at constant temperature (20 °C ± 2 °C) and relative humidity above 95%.

Table 1. Composition of the samples and methods used.

Samples	Gypsum addition (%)	Cement addition (%)	Methods
RA+0%	0	0	CBR (UNE 103502:1995)
RA+2%	2	0	
RA+4%	4	0	
CT-RA+0%	0	3	Compressive strength (UNE-EN 13286-41:2003)
CT-RA+2%	2	3	
CT-RA+4%	4	3	

3. Results and discussion

Figure 1.a) shows the CBR evolution over time in RA mixes. RA+0% CBRA value is between 94% and 148%, which is considered by Federal Highway Administration (FHWA, 1997) the typical range for RA from concrete demolition CBR value. All CBR values obtained were over 30%, considered as an correct CBR value to apply in

unbound road base layer (Poon and Chan, 2006). The CBR gain of RA+0% between 4 days and 180 days was 86%, Garach et al. (2015) found similar values (133%), This may be the self-cementing effect caused by the remaining cement in the adhered mortar of the fine recycled concrete aggregates (Poon and Chan, 2006). Before the fifth month the values of the CBR index of the samples with gypsum addition were higher than those of RA+0%. This could be explained by the gypsum curing after being crushed, wetted and mixed with the RA. After nine months the CBR values of the three samples are similar.

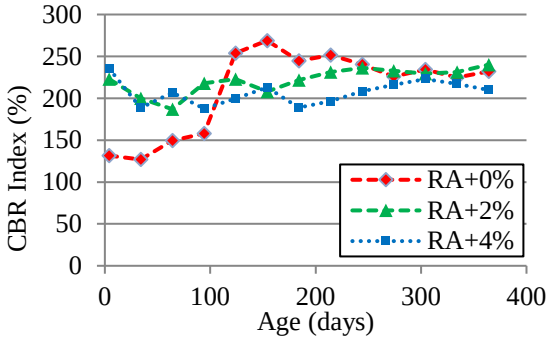

Figure 1.a) CBR evolution over time

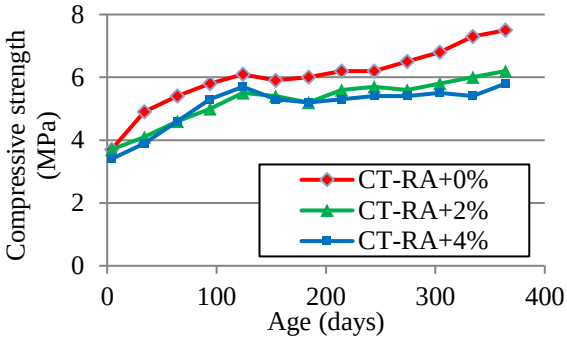

Figure 1.b) Compressive strength evolution over time

Figure 1.b) shows the compressive strength evolution over time in CT-RA mixes. The compressive strength values of the three CT samples at 4 days complied with the requirements stablished by the Spanish Code for basic materials on firm pavements (Ministry of Development, 2015). It can be seen that RA samples with gypsum addition were less than 1 MPa respect to that with gypsum addition up to 8 months, after that, the difference increased slightly.

4. Conclusions

In this study the mechanical performance at long term of RA from CDW according to the gypsum content has been assessed. Regarding to the CBR performance on RA with different gypsum content it can be concluded that; the values obtained has been above the limits to form a base layer in roads; samples with gypsum addition had a good performance at early ages, and at long term, no difference was found respect to sample without gypsum addition. In relation to the compressive strength performance of RA with 3% cement addition, it has been found that the gypsum presence slightly decrease the compressive strength values respect to that without gypsum addition. Hence, this research supports that new limits regarding to sulphate content could be reedited, in order to widen the use of RA to form base layers in roads.

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