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Extended Abstract

Catalogue of Pavements with Recycled Aggregates from Construction and Demolition Waste †

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Abstract: Construction and Demolition Waste come from debris generated during construction, renovation and demolition of buildings, roads, and bridges. Recycling and reuse are essential in terms of sustainability, mainly from an environmental point of view. Although the recommendation of the use of these recycled aggregates is currently included in some technical specifications, its use is still not widespread due mainly to the lack of knowledge on their technical application. This work is a compilation of the recommendations proposed in the "Catalogue of road pavements with recycled aggregates", supported by the construction of experimental stretches. It proposes different structural sections for road pavements by using recycled aggregates.

Keywords: construction and demolition waste; recycled aggregates; catalogue; pavements

1. Introduction

Construction and Demolition Waste (CDW) is a priority waste stream in the European Union. Currently, the production of CDW in Spain is around 20 million tons (430 kg/habitant·year). The Waste Framework Directive requires Member States to recycle 70% of CDW before 2020. Recycled aggregates (RA) which are obtained from the CDW conveniently treated in recycling plants, can be used in civil engineering and building works. The recycling rate in Spain is approximately 40%, very far from recycling rates in other countries such as the Netherlands, Denmark and Germany that exceed the recycling rate of 80%.

The RA have different physical-mechanical and chemical properties from natural aggregates (NA). These have a lower density, a higher water absorption, a lower resistance to fragmentation and a higher content of sulfur compounds and soluble salts [1–3]. However, these properties should not limit its use while the infrastructure in which they use has adequate functional and structural characteristics.

Habitually, RA are rejected because they do not meet the technical specifications required for NA in regulations such as the Spanish General Technical Specifications for Road Construction (PG-3) [4] or the Structural Concrete Instruction (EHE-08) [5]. It should be noted that the PG-3 is applicable to the Road Network of the Spanish State and that the EHE-08 constitutes the framework in which the requirements considered in the design and manufacturing of concrete structures are established. However, there are other uses with lower requirements, such as roads with low traffic intensity [6,7], bike lines [8], urban and pedestrian roads, unpaved rural roads [9–11] where RA provide similar functional and structural characteristics to the of NA.

Hence, to increase the recycling rate, it is necessary to develop a specific technical regulation and new uses for RA. In this sense, the University of Córdoba (Construction Engineering Area), together

with the Regional Ministry of Public Works and Housing of the Regional Government of Andalusia, recycling companies (AGRECA) and companies in the construction sector (CEMOSA) have developed a "Catalogue of road pavements with recycled aggregates (CRA-2017)" [12]. This technical document proposes constructive solutions designed with RA and supported by the construction of experimental sections. The CRA-2017 is the first document of these characteristics in Spain.

2. Area of Application

The scope of application of this Catalogue are the pavements sections, where RA is currently used, but without a specific technical regulation for it, such as:

- Pavements roadworks with traffic intensity lower than T2 (<800 heavy vehicles/day).
- Pavements of rural roads.
- Steel and pedestrian routes.
- Pavements of cyclist's routes.
- Drainage works and ditches.

This paper presents the technical requirements of the materials, the project criteria and constructive solutions with RA proposed for road and rural roads.

3. Characteristics Required of Materials to Pavements

Figure 1 shows the types of pavement structural sections recommended for using RA (their use on rigid pavements has not been considered, nor on roads with traffic levels greater than T2). The recycled materials for the pavement can be classified as well-graded recycled concrete aggregate (ZARHor), well-graded mixed recycled aggregate (ZARM I and ZARM II), recycled cement-soil (SCR) and the roller compacted recycled concrete (HCR). Table 1 shows the classification of recycled well-graded granular materials according to their composition.

Figure 1. Types of structural sections recommended in the catalogue. * MB = Bituminous mixture.

Table 1. Classification of recycled well-graded granular materials according to composition test.

		ZARHor	ZARM I	ZARM II
Composition EN 933-11	Rc + Ru + Ra	-	≥70%	≥70%
	Rc + Ru	≥90%	≥55%	≥55%
	Rc	-	-	-
	Ra	-	-	-
	Rb	-	-	-
	X	<1%		<2%
	FL	<1 cm^3/kg		<2 cm^3/kg

Footnote: Rc = concrete particles; Ru = aggregates not bonded with cement; Ra = asphalt particles; Rb = ceramic particles; X = impurities (woods, plastics, plasters, glass, etc.); FL: floating particles.

In order to analyze the failure of the pavement layers, it has been considered as critical parameters the following:

- The maximum tensile stress (σr) in cement-treated materials.
- The unitary vertical deformation in the upper face (εz) in the subgrades.

Each material has been considered separately by selecting the stress or critical deformation given by the response model, which is introduced in the fatigue law, which provides the admissible number of load applications (N). The lower value of N among those obtained for all the layers of the firm will represent the number of load applications that could cause the structure to collapse the pavement by fatigue. Table 2 shows the characteristics of the materials and fatigue laws used for each material.

Table 2. Characteristics of the materials and fatigue laws.

Recycled Material—Pavements	Modulus	Poisson's Coefficient	Fatigue
ZARHor	500 MPa	0.35	
ZARM I	400 MPa	0.35	$\varepsilon z = 2.16 \cdot 10^{-2} \cdot N^{-0.28}$
ZARM II	300 MPa	0.35	
SCR-3	8000 MPa	0.25	$\sigma r = 0.43(1 - 0.065 \log N)$
SCR-4			$\sigma r = 0.72(1 - 0.065 \log N)$
HCR	13,000 MPa	0.25	$\sigma r = 1.03(1 - 0.065 \log N)$

4. Typical Sections on Roads Pavements

The catalogue shows solutions for the different categories of subgrade (E1: low category subgrade, E2: medium category subgrade and E3: high category subgrade) (Table 3) and different T2 traffic categories (≥200 and <800 heavy vehicles/day); T3A (≥100 and <200 heavy vehicles/day), T3B (≥50 and <100 heavy vehicles/day), T4A (≥25 and <50 heavy vehicles/day), T4B (<25 heavy vehicles/day).

Table 3. Categories of the subgrade.

Category of the Subgrade	Equivalent Module, E_e (MPa)	Valid Categories of Project Traffic
Low	≥60	T4
Medium	≥100	T3 and T4
High	≥160	T00 to T2

For the calculation of the pavement structure layers, the multilayer elastic response model developed by Burmister has been used to obtain the response in stresses and deformations in the layers of the road subject to stresses.

5. Conclusions

This work is extracted from "Catalogue of pavements with recycled CDW aggregates (CRA)", redacted with the aim of promoting the use of recycled materials in roads in the framework of a sustainable perspective and immersed in the future policies of the European Union.

Author Contributions: All authors have actively worked on the project and developed as co-authors a "CRA-2017" which this communication is extracted. J.R.J. and A.B. have worked in the preparation of the communication and write the full paper, J.A. have reviewed this work and A.P.G. reviewed the language.

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