Eco-efficient concrete in the circular economy of de precast Industry: An Example of sustainability

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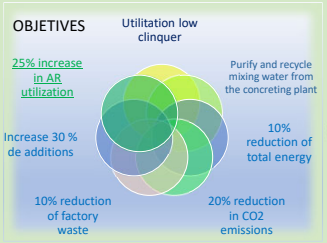
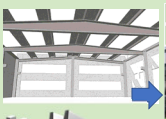
Abstract. The circular economy is an economic model of production and consumption that involves reusing, repairing, restoring, and recycling materials after their useful life. The use of waste as raw materials is one of the actions to establish this model in companies to achieve emissions at zero or neutral cost. The European prefabricated directives promote the implementation of a series of voluntary sustainability actions such as: the reduction of waste to be sent to landfill, the increase of additions to cement of at least 25%, an increase of 25% in the proportion of recycled aggregates to be used and reduction or recycling of water consumption, all for the benefit of reducing CO_2.This work exposes a real example of a company of prefabricated structural elements of construction applying the previous actions, incorporating a waste centre for its own and external use, where the waste materials are given a second life generating a new concrete. This new recycled concrete is designed with the substitution of natural aggregates for recycled aggregates in different proportions, even up to 100%, using recycled additions to the cement, using recycled water from the concreting plant itself in its process. The sustainable eco-concrete resulting from HR-30 and HR-45 resistance, self-compacting, is mechanically characterized and incorporated into the prefabricated elements tested also in prototypes against bending, shear and deformation stresses





MATERIAL PRODUCTS WITHOUT OUTPUT REMAINS MANUFACTURE

Healthy and resistant material between 30-50 MPa

To be able to produce the RCA, the precast plant must have the necessary equipment to crush these elements (e.g., jaw crusher) and the required space to collect both the RCA obtained and the rejected elements themselves, until their crushing. When this is not possible, an appropriate solution may be to treat this waste in a recycling plant, as long as it can be guaranteed that there will be no crossed contamination, and the lack of pollutants, inherent to this RCA from prefabricated elements, is preserved.

If RCA is produced and consumed in the same factory, two main benefits are then obtained: high sustainability of the final structural and nonstructural elements and also a careful control of the composition of the RCA generated.

Water recycling plant

For this, a technique is required that consists of using, when washing the machinery, a recycling equipment that will make it possible to dispose of the water used for cleaning on the one hand and the solid material such as sand, gravel and cement mud on the other.

Precast

Procces Recycled

New precast elements

Test laboratory-industrie

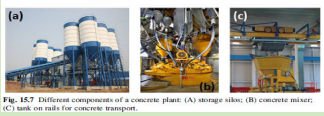


Fig. 15.7 Different components of a concrete plant: (A) storage silos; (B) concrete mixer; (C) tank on rails for concrete transport.

The concrete plants of the precast companies are fully automatic and can produce simultaneously between 1 and 5m3 of SCC in the same mixer machine. The facilities are huge, as can be seen in Fig. 15.7, unlike the concrete mixers traditionally used in construction sites, with a maximum capacity of 0.1–0.2m3

Property	Units	Standard	RAC-37.5			
			CC-37.5	20%	50%	100%
Viscosity by V-funnel test	s	UNE-83364	5 (VF1 class)	6 (VF1 class)	10 (VF2 class)	19 (VF2 class)
Passing ability L-box						
T20 s: H1/H2	-	EN-12350-9	0.88 (PA1 class)	0.87 (PA1 class)	0.85 (PA1 class)	0.80 (PA1 class)
T40 s: H1/H2	-		0.98 (PA1 class)	095 (PA1 class)	0.89 (PA1 class)	0.85 (PA1 class)

Fig. 15.8 SCC in-fresh tests: (A) Slump-flow test; (B) J-ring test; (C) V-funnel test; (D) L-box test.

Eco-concrete SCC test control

MIX-DESIGN: The traditional methods for determining the quantities of each aggregate fraction that should be added, such as the adjustment of the overall granulometric curve to the Fuller curve, are valid in general terms. However, the fines content of the traditional curve for vibrated concretes must be modified to get self-compacting (SCC). Moreover, if RCA I is used, its angular shape leads to a greater need of fines (EC-2, 1992; EHE-08, 2008). Furthermore, this procedure must always be conducted with volumetric correction of the different aggregates used.

Eco-concrete

SCC (self-compacting)

Mix- design

SCC

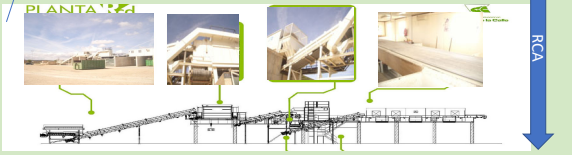
Mix-design Eco-concrete

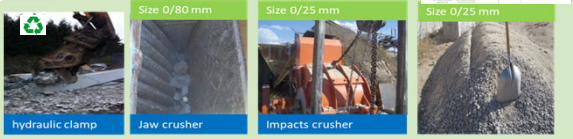
Mix-design Eco-concrete

MATERIAL	Ud	HR 30-0% (Control)	HR30-20%	HR30-50%	HR30-100%	HR-45-0% (Control)	HR45-20%	HR45-50%	HR45-100%
Coarse 0/2	kg	650	650	670	720	650	650	670	720
Gravel 2/12,5	kg	1150	920	540	0	1150	920	540	0
AR 4/12,5	kg	0	250	540	1040	0	250	540	1040
Limestone Filler	kg	320	320	320	320	280	280	280	280
Sika 20HE	kg	500	500	650	850	500	500	650	850
Sika 5920	g	1300	1300	1600	2000	1300	1300	1600	2000
Cement OPC I-52,5	g	250	250	250	250	250	250	250	250
Low-cement FRA	Kg	80	60	60	60	90	70	70	70

Materials

Recycling plant RCD



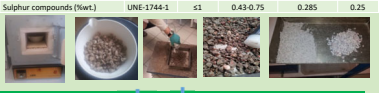


The use of recycled aggregates manages to capture 181% more carbon dioxide from the atmosphere compared to the use of natural aggregates

MATERIALS

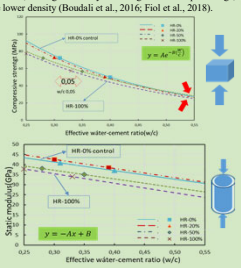
CHARACTERIZATION RECYCLED AGGREGATE

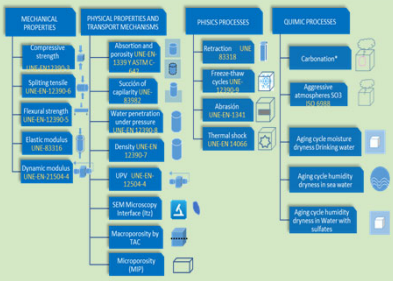
Properties	Standard	Spanish Standar limits	RA from common or in situ concrete	RA from precast concrete	Obtained values
Sieve modulus	-	-	6.2-7.6	6.78	6.68
Fines content (%wt.)	EN-933-2	≤1.5	0.27-1.14	0.27-1.14	0.41
Particles smaller than 4 mm (%wt.)	EN-933-1	≤10	0.5-2.0	1.38	1.10
Flakiness index (%wt.)	EN-933-3	≤35	7-22	10-12	7.9
Shape coefficient (%wt.)	EN-933-4	>0.2	1-15	11-12	2.25
Density (g/cm³)	EN-1097-6	2-3	2.1-2.4	2.48-2.6	2.41
Absorption coefficient (%wt.)	EN-1097-6	≤5	4-10	4.19-4.57	4.15
Los Angeles (%wt.)	EN-1097-2	≤40	25-45	31-33	37
Soft particles (%wt.)	EN-7134-58	≤5	20-60	16.68	21
Mortar adhered (%wt.)	Thermal shock	-	30-60	-	52
Crushing value (%wt.)	UNE-83112	-	-	30	35
Resistance to magnesium (%wt.)	EN-1367-2	≤18	0-20	2	11.51
Alkali reactivity(%lon)	UNE-EN-146509	≤0.4%	-	-	0.02
Light particles (%wt.)	EN-1733-1	≤1	0.5-5	0.023	0.01
Clay lumps (%wt.)	EN-7133	≤0.25	0.05-0.6	0.25	0.01
Water soluble chloride (%wt.)	UNE-1744-1	≤0.05	0.001-0.05	0.0015	0.005
Soluble sulphates in acid (%wt.)	UNE-1744-1	≤0.80	0.10-0.62	0.65	0.44
Sulphur compounds (%wt.)	UNE-1744-1	≤1	0.43-0.75	0.285	0.25



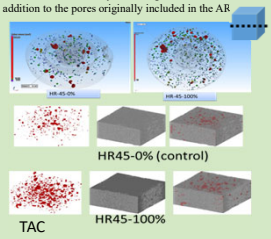
CHARACTERIZACION ECO-CONCRET LABORATORY TEST The experimental study of the new eco-concrete includes tests regarding mechanical behavior and durability we show the extract examples

The addition of RCA reduces the density of concrete, being this decrease proportional to the amount of RCA. The lower w/c ratio, the higher density and the greater RCA percentage, the lower density (Boudali et al., 2016; Fiol et al., 2018).

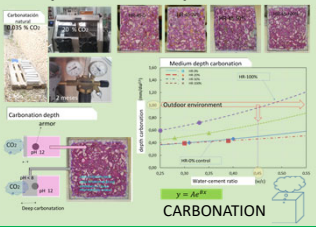




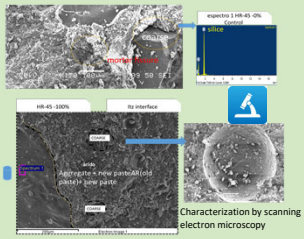
The macroporosity resulting from the study of the TAC, are adequate values for a new Eco-concret increasing for the concrete with 100% substitution due to the greater friction of the AR, they retain a greater amount of air, in addition to the pores originally included in the AR



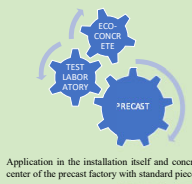
The simulation of the concretes studied against accelerated carbonation resulted in depths much lower than those obtained by other concretes with RA from other sources or with traditional vibrated concreting. The estimation of the useful life showed very favorable values and therefore in accordance with the quality to which the precast element should be required



A study of the microstructure of the concrete is carried out, by means of scanning electron microscopy (SEM) on two samples tested for compression, of the Eco-concretes HR-45-0% (Control) and HR-45-100%.

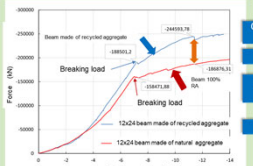


FULL-SCALE STRUCTURALS ELEMENTS An experimental campaign is reported that was conducted in collaboration with a precast concrete building-component manufacturer. The objective was to verify that Self-Compacting Eco- Concrete (SCC) containing maximum amounts of 100% coarse RA complied with the requirements of the precast-concrete manufacturer for structural building use. To do so, scaled beams (12x24x180 cm and 24x24x130 cm) produced with that SCC mix were subjected to bending, shear-bending, shear, and long-term-deflection



Application in the installation itself and concreting center of the precast factory with standard pieces

Flexural test



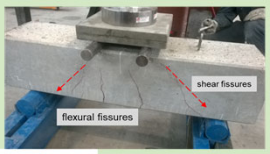
Cracking bending and shear connecting rods

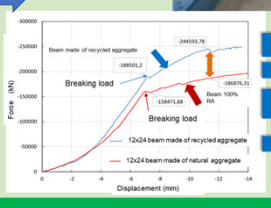
Natural aggregate beam > 26%

Beam plastic behavior aggregate recycled

Similar behavior

Bending and shear





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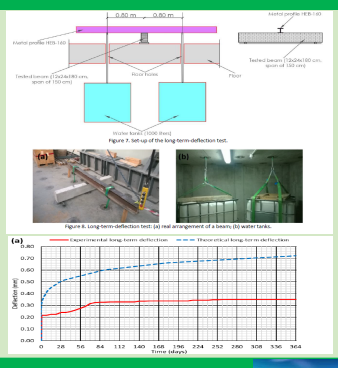
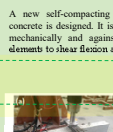


CONCLUSSIONS

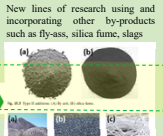
The circular economy is an economic model that helps businesses and consumers avoid wasting resources. In this model, products are designed with a useful life and are reused or recycled after the end of the life cycle.The importance of promoting the circular economy to reduce the extraction and processing of raw materials that impact the environment and increase energy consumption and CO2 emissions. And it is that 70% of greenhouse gas emissions are linked to the handling and use of materials

Circular economy applied to the company consisting of incorporating AR + recycled water + low-clinker with fine AR. The company makes an effort to recycle and incorporate disposable products, in addition to using low-cement, reducing the carbon footprint and CO2 emissions.

A new self-compacting high-performance eco-concrete is designed. It is tested in the laboratory mechanically and against durability, also with elements to shear flexion and deformation.



New lines of research using and incorporating other by-products such as fly-ass, silica fume, slags



Final result New elements executed with eco-concrete

Companies can increase their profit margins by designing with a life cycle in mind, from production to reuse or recycling. The life cycle would be divided into three stages: design, use and end of life. This model would also reduce waste by controlling input materials and designing products for natural resource efficiency.

An example of sustainability

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