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IMPACT OF USING RECYCLED AGGREGATES ON COMPRESSIVE STRENGTH OF CONCRETE

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Abstract: Recycled aggregate concrete is considered the next generation in the field of construction: it respects the environment, solves the problem of debris management and is economically profitable. In order to better adapt its use, technical studies, experimental studies and simulations are carried out in all research centers around the world in order to define its field of application. Our study falls within this framework. It is concerned with the study of the mechanical characteristics of recycled aggregate concrete essentially the compression test for various percentages of replacement. The purpose of this study is to confirm the results of studies by other researchers and to find techniques that will maximize the replacement of natural aggregates with recycled aggregates. The concrete chosen for these tests is an old building in the region of Rabat, Morocco which has been built more than 40 years and demolished in the year of 2017.
The tests carried out showed a decrease in the compressive resistance noted when the replacement rates exceed 50% rate. The first improvement methods were put in place and being tested: the partial replacement of cement with pozzolan (20% rate) known by his improving of the compressive strength for ordinary concrete, the partial replacement of the large proportion [12.5-31.5] only in recycled concrete and work with natural gravels. Other improvements will be proposed as the studies progress.

Keywords: Recycled aggregates (RA), compressive strength, recycled aggregates concrete (RCA), Laboratory tests, Replacement percentage

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INTRODUCTION

The use of recycled aggregates is not new but rather goes back to the 1990s of the previous decade. The most common examples are in the field of roads or superstructures. This is due to a poor knowledge of the results of the use of recycled aggregates concrete in terms of mechanical, physical and chemical characteristics. Recycled aggregates are based on crushing old concrete (usually with unknown characteristics). Thus it is natural aggregates surrounded by cement paste that why we can't predict the result of its interaction with the components of the new concrete, mainly water and cement.

In the domain of the recycled aggregates concrete, many studies have been done to determinate the effect of using RA instead of NA in the concrete's properties. The results of these studies are aleatory, he majority of these have proven, based on experimental studies, that the compressive strength is lower for concrete made with RCA but some ones declare the contrary (Poon *et al.,* 2004; Gesoglu *et al.,* 2015). In Silva *et al.* (2014) even went from experimental studies to analytical studies and performed statistical analysis based on the collected data from literature and reported that it is possible to develop a model to predict the strength decrease in concrete containing RCA for different replacement level.

TEST PROCEDURE AND RESULTS

Materials used

Two types of aggregates are used: (a) Natural aggregates with the following dimensions: [5–12.5] and [12.5–31.5], and (b) Crushed aggregates obtained during the demolition of a building in Rabat, Morocco built in the 80s. After demolition, the concrete was sorted and cleaned and crushed in a jaw crusher.

The proportions chosen are similar to those of the natural aggregates namely [5–12.5] and [12.5–31.5]. The sand used is a natural with a fineness of 2.66 and a sand equivalent of 95%. The cement used is CPJ 45 cement, produced by Asment Temara (Portuguese group Cimpor) and available in Rabat, Morocco; the water used is tap water.

Properties of aggregates

Before testing on recycled aggregate concrete, a characterization of recycled aggregates is required. In this sense, a study of the physical characteristics: density, water content, water absorption capacity, granulometric curve ... was made in the laboratory.

Particle size analysis

The granulometric curve of the two aggregates is as follows:

Table 1. Result of particle size analysis

Sieve size	% passing			
mm	GN1: natural gravel size [5-12.5]	GN2: natural gravel size [12.5-31.5]	GR1: recycled gravel size [5-12.5]	GR2: recycled gravel size [12.5-31.5]
0.08			0.00	0.00
5	0.00	0.00	2.78	0.60
6.3	6.23		16.15	1.23
8	17.67			
10	50.89		67.90	2.54
12.5	100.00	3.77	97.33	6.64
16		5.76		35.10
20		21.81		70.35
25		70.87		91.41
31.5		100.00		99.13

Our study is based on a replacement of natural gravels by recycled gravel so a comparison between the two must be made. The first criterion of comparison is the granular squelette, this is due to its importance in the filling of the voids and the compactness of the concrete.

The following tables summarize the results of the passage of our various samples in the columns of the test of particle size analysis.

In order to compare the granular shape of the various aggregates, the design of the granular curves is essential. The interpretation of the granular curves show that:

- The shape of GR1 and GN1 is almost identical, at the 10 mm opening, for example, the percentage of the cumulative sieve of GN1 is almost 50% and the GR1 is 60%.

- The distribution of the various sizes of GR2 and GN2 aggregates is different; This distribution is favorable for GR2 ca allows to have less vacuum and pore in our concrete and to compensate for the defects of the recycled aggregates.

Absolute Density for the recycled aggregates: It is the quotient of the dry mass of the specimen by the volume of the solid matter of it (excluding pores). There are several ways to determine these densities according to the desired accuracy and the nature of the aggregate; in our case we use the method of the graduated test tube The test specimen used has a diameter of 1.6 cm so the $V = \Pi \times (1.6)\ 2 \times h$ [cm³]. The test was carried out on three samples.

Water content (w %)

The water content is equal to the ratio of the mass of water contained in the sample by its dry mass. It is determined according to the standard "NF P 18-554".

$$\eta = 100 * (M - Ms')/Ms$$

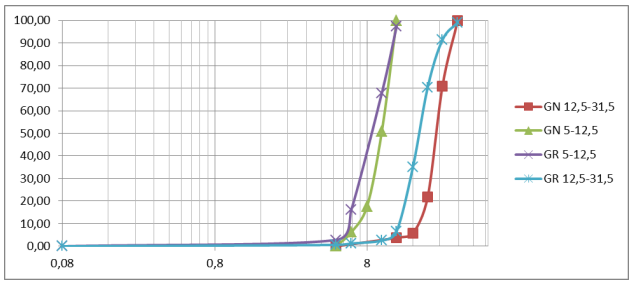

Fig. 1 Granometric curve for natural and recycled aggregates used in experimental study

Table 2. Summarize of the absolute density test results

	Specimens		
	1	2	3
Weight of the sample (g)	300	300	300
Difference in height after and befor addition of gravel (cm)	14.65	15.59	15.04
Volume of the gravel (cm³)	117.85	125.34	120.97
Absolute Density (g/cm³)	2.54	2.4	2.48
Calculated average absolute density (g/cm³)	2.48, We consider 2.5		
Chosen absolute density (kg/m³)	2500		

Table 3. Summarize of the water content test results

GR1			GR2		
M	M's	Ms	M	M's	Ms
2000	1976	1975.2	2000	1915	1963.8
	H			H	
	1.49%			4.32%	

with: M = the mass of the sample, M's = the mass of the sample dried in an oven at 105 °C to constant mass without prior washing, and Ms = the mass of the sample washed on the 4 mm sieve and dried in an oven at 105 °C until constant mass.

Water absorption rate (ab%)

The water absorption by definition is the quotient of the mass of a sample immersed in water for 24 hours at 20 ° C and at atmospheric pressure, by its dry mass. It is determined according to standard standards "NF P 18-554, 18-555, EN 1097-3, EN 1097-6".

$$Ab=100(Ma - Ms)/Ms \quad (1)$$

with: Ms = the mass of the sample washed on the 4 mm sieve and dried in an oven at 105 °C until constant mass, and Ma = the mass of the sample immersed in water for 24 h at 20 °C at atmospheric pressure and sponged thoroughly with an absorbent cloth.

Table 4. Summarize of the water absorption test results

GR1		GR2	
Ms	Ma	Ms	Ma
1975.32	2194.8	1963.8	2148.4
	Ab		
11.11%		9.4%	

Concrete formulation

The concrete chosen to study is an ordinary concrete with an fc28 (compressive strength at 28days) of 25 MPA, and an average slump of 7 cm. The chosen quantities using the Dreux Gorisse method is thus (for 1 m³ of concrete).

In order to compare the replacement effect of natural aggregates with recycled aggregates, several replacement ratios were studied: 0%–20% –50% –75% –100%.

Test results

The results of the compressive strength test for standardized 16×32 test specimens which have been removed at 24 hours and left in wet cure until they are fouled are as follows (in average value):

METHODS OF IMPROVING TEST RESULTS

In introduction, the modification of some parameters (w/c, cleaning condition, initial moisture,) has shown their effect in increasing the compressive strength of the RCA, but this improvement remains limited. Thus the researchers have worked out more sophisticated methods to improve the performance of recycled aggregates. Some of these methods are detailed below.

Improvement of mechanical properties of recycled aggregate concrete basing on a new combination method between recycled aggregate and natural aggregate (Bui *et al.,* 2017).

The traditional method of replacement of natural aggregates by recycled one is based on the replacement of the entire of coarse aggregate including all the particle sizes. The proposed new method is to replace

Table 5. Summarize of the concrete formulation

Component		Quantity for 1 m³
Cement		350 kg
Water		193L
Sand		473 kg
Aggregates	Gravillon 5-12.5	402 kg
	Gravier 12.5-31.5	512 kg

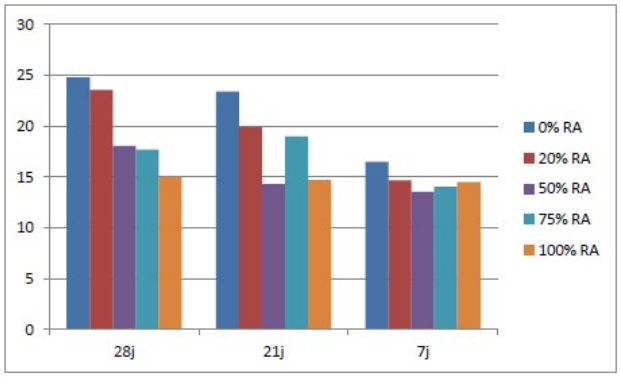

Fig. 2 Results compressive strength at 7j, 21jet 28j for recycled aggregates proportions of 0%, 20% 50%, 75% and 100% (MPa)

Table 6. Tests results

	0% NAC – 100% RAC	30% NAC	50% NAC	70% NAC	100% NAC
%of amelioration of the FC28	0%	15.2%	22.7%	11.4%	0%

only the large size of natural aggregates by recycled ones. In our case, we should always maintain the 5-12.5 mm aggregates and replace the 12.5–31.5 natural aggregates by recycled with different percentage.

This proposed method is because of the fact that fine aggregates has an important role of filling the volume of void with the cement, thus, it is necessary to guarantee their quality, porosity and water absorption which will improve the quality of the concrete. The study than by Bui *et al.* (2017) with this approach is summarized is the table below that shows the result of compressive strength test in 28 days for four replacement proportions of RA which are 0%, 30%, 50%, and 100% respectively. Thus this solution is conceivable to improve the quality of the mixture.

Performance of concrete based on a new combination of cement and pozzollan

Many studies done based on the replacement of a percentage of cement by the pozzollan have proved that choosing the right percentage gives the concrete many benefits specially thermic ones and the compressive one. 20% of replacement improves the compressive strength witch gives me the idea to combine the replacement of cement by pozzollan and the aggregates by recycled one.

CONCLUSION AND PERSPECTIVES

The purpose of the study is to characterize the strength recycled aggregate concrete mechanically especially compressive strength in order to propose improvement methods in case laboratory tests confirm the results of various previous studies. : 28-day compression decreases with increasing proportion of recycled aggregates in concrete.

The concrete thus chosen for these tests is an old building in the region of Rabat, Morocco which has been built more than 40 years and demolished in the year of 2017. This concrete was sorted from the rest of the debris and was crushed in a jaw crusher and at the end separated in two proportions [5-12.5 mm] and [12.5-31.5 mm].

The tests carried out showed a decrease in the compressive resistance noted when the replacement rates exceed 50%. Percentage of decrease is 25% for 50% replacement, 30% for 75% and 40% for 100% replacement rate.

Knowing its environmental value, its economic value and the growing need for its use, improving the quality of recycled aggregates concrete is essential. Several studies have been done in this direction, some of it was detailed above.

The prospects for this work are to experiment with some of the methods found in the literature, to propose new ones and to combine them in order to increase the compressive strength for concrete based on recycled aggregates proportions of 50% and more. In the first place, the ameliorations tested will be:

- The partial replacement of cement with pozzolan (20% rate) known by his improving of the compressive strength for ordinary concrete.

- The partial replacement of the large proportion [12.5–31.5] only in recycled concrete and work with natural [5–12.5] gravels. Other improvements will be proposed as the studies progress.

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