Recycled aggregates for self-compacting concrete

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ABSTRACT

The protection of natural resources is becoming more and more necessary, at the same time, the demolition of concrete structures generates significant quantities of waste which could be crushed and then recycled in the form of aggregates. Until now, only a small fraction of this waste has been reused, mainly in road works. Improved characterization techniques for recycled concrete aggregates (GBR) and a better understanding of the properties of concretes manufactured with them would promote the use of GBR. This work aims to study the influence of the use of recycled concrete aggregates on the behavior in the fresh and hardening state of mortars for the formulation of self-placing concrete. The results show that the water absorption of recycled concrete aggregates (BGR) is greater than that of natural aggregates (GN). A first part of the work consisted in making the different concrete compositions while a second part is devoted to performance tests, allowing us to qualify the concretes obtained. The compactness of concrete directly influences its porosity, when the porosity increases, the compressive strength of the concrete decreases. However, the addition of limestone filler and superplasticizer gives the recycled aggregate concrete a maneuverability that can be described as self-compacting according to the results of spreading with Abrams cone.

Keyword: *Limestone filler, recycled aggregate, self-consolidating concrete, compressive strength*

1. INTRODUCTION

Reinforced concrete is a composite material made of concrete and steel which combines the compressive strength of concrete with the tensile strength of steel. It is used as a building material, especially for civil engineering.

However, for the coming years, a significant increase in the quantity of construction and demolition waste is expected, due to the large number of works arriving at the end of their life. Natural resources are more and more protected, the decrease in the volumes of quarries and other places of sampling is felt. The reuse of these recycled aggregates then constitutes a solution for many problems arising from this trend. But what would be the conditions? Do recycled aggregates fulfill the essential properties to guarantee the quality of these concretes?

Recycled aggregates are currently mainly used in road engineering or embankments requiring neither high mechanical performance nor particular characteristics. In this study we will focus on the use of recycled aggregates in the design of hydraulic concrete.

2. CHARACTERIZATION OF MATERIALS

2.1 Cement

In this study, CEMII / B-P 32.5N cement was used. It is a Portland cement which consists of 65% to 79% of clinker; from 21% to 35% natural pozzolan and 4.5% gypsum (setting regulator)

This cement is in compliance with standard NF 197-1, the presence of a small quantity of calcium sulphate ensures the regularity of the setting.

Table-1: Characteristic of cement

	Compressive strength in [MPa]		Chemical characteristics	
	Sort-term resistance	Current resistance	Sulfur trioxide content	Chloride content
32,5 N	7 days	28 days	< 3,5%	< 0,10%
32,5 N	> 16	> 32,5 et < 52,5		

2.2 Natural aggregates

The aggregates used come from the Ivondro quarry (east coast of Madagascar on the RN2 PK 338 + 200). This quarry has the ability to supply the region. These aggregates are marketed in different granular classes, including 0/3 sand and 5/8, 5/15 and 16/25 gravel.
The aggregates must be subjected to various characteristic tests which will make it possible to appreciate the quality of those ones so as to be in conformity with the standards. The quality of aggregates is important because it directly affects the physico-chemical and mechanical properties of concrete.

Table-2: Properties of aggregates

Properties of aggregates	Granular class			
	0/3	5/8	5/15	16/25
Apparent volumetric mass [kg/m3]	1427	1349	1423	1369
Absolute volumetric mass	2498	2584	2588	2566
Sand equivalent test [%]	63	-	-	-
Cleanness test [%]	-	1,92	1,3	0,73
Coefficient of finesse	2,94	-	-	-
Fine content [%]	17	-	-	-
Los Angeles test [%]	-	$\frac{4/6,3}{27}$	$\frac{6,3/10}{31}$	$\frac{10/14}{31}$
Micro Deval test [%]	-	$\frac{4/6,3}{15}$	$\frac{6,3/10}{11}$	$\frac{10/14}{8}$

2.3 Recycled aggregates

The recycled aggregates come from construction and demolition activities. Their composition varies according to the nature of the demolished structures (buildings, engineering structures, etc.) and their date of construction.

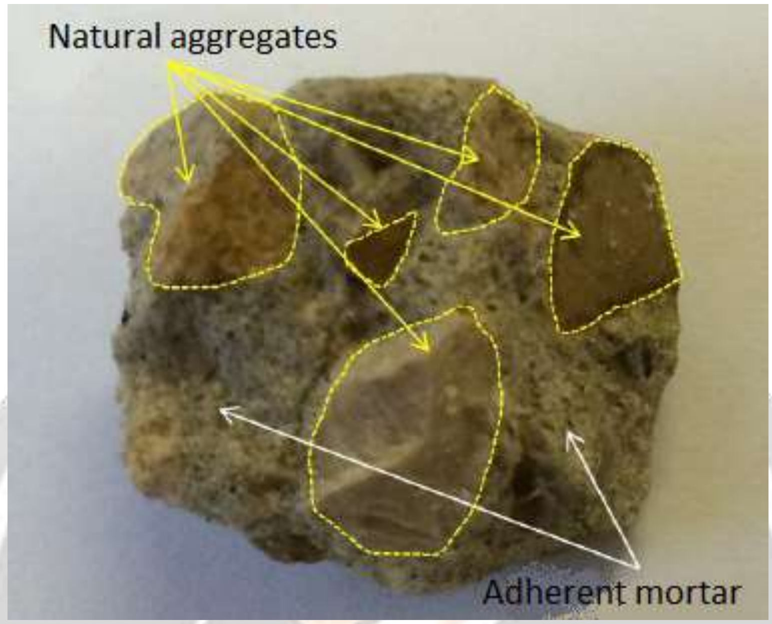

Figure-1: Example of recycled aggregate

The recycled concrete aggregates are mainly made up of partially crushed natural aggregates and crushed hydrated cement paste, which adhere to natural aggregates.

The original concrete and the crushing method significantly influence the properties of the recycled concrete aggregates. An original concrete of low resistance (Eeff / C = 0.63) produces aggregates of low density and with a high water absorption. Conversely, an original high performance concrete (Eeff / C = 0.35) produces recycled aggregates of higher density.

Eeff / C ratio of the original concrete	Level of crushing in the process	Particle size [mm]	Adhering mortar content [%]	Density [g / cm3]
0,35	1	5/20 mm	52,4	2,41
	3		29,7	2,5
0,45	1		54,7	2,43
	3		32,4	2,49
0,63	1		53,1	2,38
	3		32,2	2,49

Table-3: Property of recycled concrete

2.4 The limestone filler

To ensure sufficient maneuverability while limiting the risks of segregation and bleeding, self-compacting concretes contain a quantity of fines, here limestone filler, rated A, of the order of 100 kg / m3 (according to AFGC recommendations).

To take account, with regard to durability, of the additions associated with Portland CEM I cement, standard EN 206-1 introduces the concept of "equivalent binder L = C + k F". The coefficient k varies depending on the nature of the addition F.

The limestone filler is mainly composed of calcite (> 80%) produced from ball milling with a fineness of the order of 6000 cm² / g. The chemical and physical characteristics of limestone filler are collated in Table 4.

Table-4: Chemical composition [%] of limestone filler

CaO	SiO2	Al2O3	Fe2O3	SO3	MgO	Na2O	K2O	PAF
55,58	0,15	0,05	0,10	0,13	0,05	0,11	0,04	43,60

Table-5: Physical characteristics of limestone filler

Physical characteristics	Unit	Values
Apparent density	kg/m3	960
Absolute density	kg/m3	2620
Blaine Specific Surface	cm²/g	6285
Fines < 63 µm	%	87

2.5 Concrete admixture

The adjuvant used is a new generation plasticizer based on modified phosphonate, with a density of 1110 kg / m3; pH = 4 ± 0.5; chlorine ion content ≤ 0.1%; equivalent Na2O content ≤ 0.3% and the dry extract = 30 ± 1.5 (%). The recommended range of use varies from 0.3 to 3% of the weight of the binder.

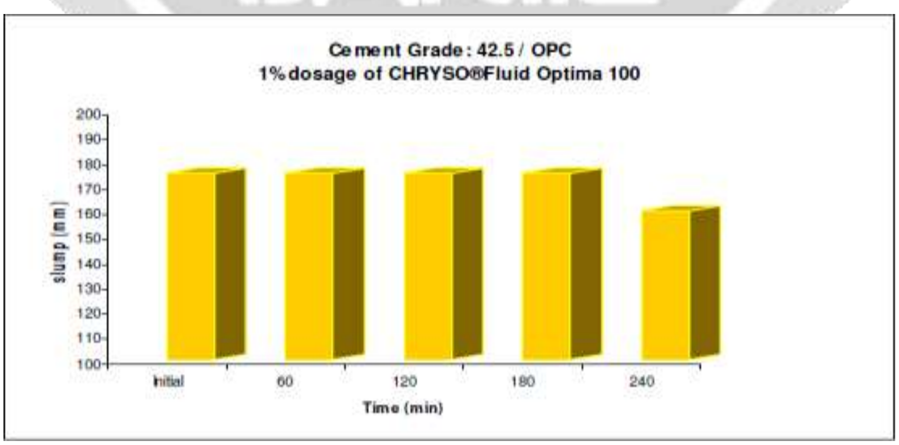

Figure-2: Characteristic of concrete admixture

3. EXPERIMENTAL PROTOCOLS

3.1 Concrete compositions

A CEMII / B-P 32.5N cement manufactured by Holcim was used for this study. The natural aggregates used are 0/3 sand and two crushed gravels (G1 5/8 and G2 5/15). The recycled aggregates were presented in a recycling platform in 3 cuts 0/4; 4/10 and 10 / 20mm. For all formulations, limestone filler and a superplasticizer (described above) were used.

Four concretes were formulated. The formulations include a reference concrete with natural aggregates and three concretes with recycled aggregates. Concrete must be of class S4, that is to say a slump of between 160 and 210 mm. The different formulations are given in the table below. The dosage of the constituents varies from one formulation to another. The cement dosage increases as the substitution rate increases in order to reach the target compressive strength.

Table-6: Concrete compositions

Constituents [kg / m3]	B0	BAP1	BAP2	BAP3
Addition water	188	246	230	301
Cement CEMII/B-P 32,5N	271	283	277	325
Limestone filler	46	31	31	49
Sand 0/3	776	809	500	
Recycled sand 0/4			218	671
Gravel	269		171	
Recycled gravel 4/10		162	141	302
Recycled gravel 10/20		701	107	442
Superplasticizer	1,31	1,4	1,08	1,18
Effective water	180	189	185	199
Dough volume	0,28	0,29	0,29	0,32
E/L	0,59	0,6	0,66	0,61

3.2 Abrams cone spreading test

The Abrams cone spreading test is used to determine the consistency of a concrete and therefore to qualify it if it can be self-compacting.

To carry out this test, a spreading table and an Abrams cone are used. The Abrams cone is a galvanized steel cone. It has an inside diameter at its base of 200 mm, a diameter at its top of 100 mm and a height of 300mm.

The test is carried out as follows:

- Abrams' cone is placed upside down and held on a steel plate with a hard, non-absorbent surface;
- the cone is filled with fresh concrete;
- the cone is leveled off with a rod;
- the cone is lifted immediately, vertically and gently by 4 cm by turning it a little to unmold it;

- the very fluid concrete collapses completely and spreads out in the form of a cake on the spreading table;
- the largest diameter is measured as well as the diameter which is perpendicular to it. The larger the spread, the more fluid the concrete is.

The spread is the average of these two diameters which must not be more than 5 cm apart.

The results of the tests on the different formulated concretes are given in the table below.

3.3 Water porosity by hydrostatic weighing

Concrete contains pores of different sizes. Some are so large (air occluded) that they have no capillary effect and cannot be completely filled with water by capillary action. With this process we will determine the total porosity of the samples.

The samples are cores with a diameter of 50 mm and a height of 50 mm. Following immersion and drying, the test bodies are flooded under vacuum. After which we calculate their respective porosities.

The total porosity in percentage will be given by the formula:

$$P = \frac{(P' - P)}{P \times 100}$$

With:

P Constant weight of test pieces in an oven at 70 ° C

P' New constant weight after wiping

The results are summarized in the table 6.

3.4 Compressive strength

16x32 cm cylinders were prepared to characterize the compressive strength. The test pieces were removed from the mold after 24 hours, kept in a room-temperature water basin for 28 days and then tested. The compression tests were carried out by imposing a loading speed of 0.5 MPa / s. Each characterization test was repeated 3 times and the results presented are the average values.

Table-6: Summary

	Substitution rate	Compressive strength [Mpa]	Porosity [%]	Spread [mm]
B0	0	33,8	10,3	660
BAP1	0,3	33,5	12,4	667
BAP2	0,5	32,5	12,7	660
BAP3	1	28,6	13	655

4. CONCLUSION

Self-compacting concrete (BAP) is defined as a very fluid concrete which is placed under the effect of its own weight, without internal or external vibration. BAP is characterized by the high volume of the dough, as well as the use of a superplasticizer adjuvant. The influence of recycled aggregates (GR) on the properties of BAP in the fresh state, by replacing 30%, 50% and 100% of natural aggregates (GN) by recycled aggregates, and by comparing with a reference self-compacting concrete (B0) based on 100% natural aggregates was analyzed. The BAP studied also include cement additions (limestone filler) at 20% by weight of cement. The results showed that the substitution of 100% and 50% of natural aggregates by recycled aggregates gives a BAP with a workability very comparable to that of the reference BAP. However, BAPs based on recycled aggregates are less stable with respect to PT. The added effect of limestone filler improves the workability of BAPs made from recycled aggregates.

Recycled aggregate concrete is very heterogeneous due to the diversity of formulations used in construction and deconstruction techniques. The presence of adherent cement paste leads to higher porosity and lower density than in the case of natural aggregates. It also leads to greater water absorption. Also after a comparison of the compressive strength of mortars containing recycled aggregates and natural aggregates of the same particle size, a fall in compressive strength at 28 days was observed by replacing the natural aggregates with recycled aggregates.

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