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Recycling of Aggregates from Construction Demolition Wastes in Concrete: Study of Physical and Mechanical Properties

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***Abstract*—**This work is focused on the study of valuation of recycled concrete aggregates, by measuring certain properties of concrete in the fresh and hardened state. In this study, rheological tests and physic-mechanical characterization on concretes and mortars were conducted with recycled concrete whose geometric properties were identified aggregates. Mortars were elaborated with recycled fine aggregate (0/5mm) and concretes were manufactured using recycled coarse aggregates (5/12.5 mm and 12.5/20 mm). First, a study of the mortars was conducted to determine the effectiveness of polycarboxylate superplasticizer on the workability of these and their action deflocculating of the recycled sand. The rheological behavior of mortars based on fine aggregate recycled was characterized. The results confirm that the mortars composed of different fractions of recycled sand (0 /5) have a better mechanical properties (compressive and flexural strength) compared to normal mortar. Also, the mechanical strengths of concretes made with recycled aggregates (5/12.5 mm and 12.5/20 mm), are comparable to those of conventional concrete with conventional aggregates, provided that the implementation can be improved by the addition of a superplasticizer.

***Keywords*—**Demolition wastes, recycled coarse aggregate, concrete, workability, mechanical strength, porosity/water absorption.

I. Introduction

FACED with the growing needs of material resources and the requirements and conditions of preservation of the environment in a vision of sustainable development, it has become necessary and relevant to prospect and explore all the possibilities and opportunities for reuse and recycling of waste and in particular in the industrial area of public works products [1]. Portland cement concrete will always be the building material most commonly used in the future. As in the case of other industries, the universal need to conserve resources, protect the environment and make good use of energy must necessarily be felt in the field of concrete technology. Therefore, emphasis on the use of waste and by-products for the manufacture of cement and concrete will be given much.

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Deposits of natural sand, gravel and stones, especially those located near large urban centers, will run down or lead to very high operating costs due to transport costs and restrictions on the protection of the environment. The production of recycled developed in the early 80 aggregates, it addresses the need for another source of aggregates and reducing the volume of waste [2]. The use of recycled aggregates in concrete has many advantages both in human and economic environmental and technological interests that increasingly industrial. The main purpose of this research study is to contribute to the reuse of waste concrete in the manufacture of hydraulic concrete and this allows [3]:

- From waste by which environmental recycling;
- Help solve problems related to lack of aggregates and in particular the use of alluvial aggregates.

This study presented here focuses on the analysis of the characteristics and reuse of recycled concrete aggregates [4]. Indeed, aggregates from recycling are mainly used in the road sector as a serious treated or untreated with hydraulic binders or as backfill. Despite several research studies for possible use with hydraulic binders for the construction of structures or buildings, recycled aggregates found little application in France as concrete aggregate. Nevertheless neighboring countries like Switzerland or Denmark have adopted standards for the production of recycled aggregate concrete [5]-[7].

Therefore, the recycling and reuse inert construction waste represent interesting solutions and integrate the concept of sustainable development [8]-[13]. More recent studies have focused on the implementation of recycled aggregate concrete and the influence of the use of superplasticizer on the handling of these. In particular, the systematic use of the removal of fines (fines) can be avoided by the addition of superplasticizer and allow to keep these fines which have a beneficial effect on the mechanical properties [14]-[19].

In our study, we are interested in the reuse and recycling of recycled concrete aggregates. For this testing is performed on mortars and concretes them. Our work has three main parts:

- The first part is in the preparation and characterization of different fractions of recycled aggregates (fillers, fine sand, coarse sand, whole sand, gravel 5 / 12.5, gravel 12.5 / 20);
- The second part consists in the incorporation of these fractions in the formulation of mortars (with and without superplasticizer) with a percentage of 60% by weight of cement mortars and characterization of this fresh and cured condition;

- The third part is devoted to the comparative study of the characteristics of the concretes.

II. Experimental Study

A. Materials for Mortars

Cement: The cement used is a Portland cement (CEMII 42.5) CEMII 42.5.Sand (0/5): The sand used in this work is: filler (0.08/1, 25 mm), the sablon (1, 25/3, 15 mm), coarse sand (3, 15/5 mm) and whole sand (0.08/5 mm).Adjuvant: is a Superplasticizer used for concrete.

B. Mortar Mixtures

The study is performed with a fixed W/ C of 0.5 and a fixed proportion of recycled sand 270 g (60% of the cement weight). In tests for the study of mortars, the specimens used are prismatic dimension of 4x4x16 cm according to NF EN 197-1 [1]-[4].The study was conducted with: weight is fixed of cement; the water/cement ratio (W/C) is fixed at0.37 and for all amounts of recycled sand is fixed at 60% by weight of cement. The superplasticizer is dosed at 1% by weight of cement.

In this analysis, we seek to define the efficacy of the adjuvant on the cement paste. The analysis therefore focuses on the positive gain in terms of handling and fluidity. To characterize the immediate effectiveness of the adjuvant on the sand 0/5, gains in workability and fluidity are determined according to the relationship:

$$\%\,\boldsymbol{GainX} = \frac{\boldsymbol{X_i - X_{ref}}}{\boldsymbol{X_{ref}}} * \mathbf{100}$$

X: is a measure slump or spreading; X_{ref} the reference composition (0/5 sand mortar without adjuvant) and $X_i$is a slump of sand mortar with adjuvant.

TABLE I
Details of Mortar Mixtures

	With normal sand	with filler 0.08/1.25	Fine sand 1.25/3.15	Coarse sand 3.15/5	Whole Sand 0.08/5
Cement (g)	450	450	450	450	450
Water (g)	225	225	225	225	225
Normal sand (g)	1350	1080	1080	1080	1080
Recycled sand (g)	0	270	270	270	270

C. Concrete Mixtures

This section is devoted to the comparative study of the characteristics of the concretes developed based waste (recycled concrete and mixed concrete) compared to a witness concrete made with natural aggregates (conventional concrete). Search results are presented of an experimental design, which aims to generate a set of information to enable the user to connect the compositions of concrete with their performance [20]-[23].

Three types of concrete of different compositions were prepared by the method of Dreux Gorisse(conventional concrete, recycled concrete, and mixed) in which, is fixed and the mass of cement W / C for all blends.

TABLE II
Details of Concrete Mixtures

	Traditional Concrete (TC)				Mixed concrete (MC)				Recycled Concrete (RC)			
	Nat. sand		Nat. gravel		Nat. sand		Recy gravel		Recy Sand		Recy gravel	
	0/1	0/5	8/15	15/25	0/1	0/5	5/12.5	12.5/20	0/1	0/5	5/12.5	12.5/20
Aggregates (%)	25.03	14.96	30	30	30.82	11.18	12	46	28.62	10.37	14	47
Mass (Kg)	458.8	276.6	554.8	558.96	560.1	204.7	198.9	769.17	436.7	172.20	232.15	785.9
Cement (Kg)	400				400				400			
effective water (l/m3)	With adjuvant W=217.4				217.4				217.4			
	Without adjuvant W=192				192				192			
SP (kg)	adjuvanted 1% of the cement weight (M=4kg)											

III. Results and Discussions

A. Effect of Recycled Fines Aggregates on the Mortars Properties

1. Workability of Studied Mortars

This study shows the influence of recycled on the workability of mortar sand. Indeed, for any fraction of recycled sand used (whole sand, coarse sand, fine sand or fillers), a stiffening of the mortar paste is observed.

Compared to normal mortar sand, there was a slump loss of 30.55% and 19.16% for spreading of the mixture consisting of sand 0/5 full. This confirms the strong absorption of water by the fine sand recycled [17], [18].

In addition, this study also asserts that the fine parts of recycled aggregates contribute significantly a reduction of the mortar workability. Indeed, the mortar workability of the fillers is lower than the other fractions of sand thus the absorption is greater than the other fraction fillers. This result is consistent with previous studies on the problem of water absorption by fine recycled concrete aggregates. This will highlight the negative effects of the recycled sand, including its strongest absorption.

On all compositions, a spread and slump measurement is performed immediately after the 4 minutes of mixing. These tests; therefore possible to conclude on the immediate effectiveness of superplasticizer. Various superplasticizers are known for their action on the cement particles. The following tests are used to characterize the influence of the superplasticizer on the stiffening provided by the recycled sand.

These results (Figs. 1 and 2) show significantly adjuvant action on the spread of superplasticizer mortars, the latter acts on the thin portion with a spreading gain of 0/1 for the 32.5% sand. The spreading of the mixture is improved by the addition of superplasticizer, without increasing sag mixture by a significant percentage of this additive (1% by mass of cement), and on the contrary the other fractions [15], [16].

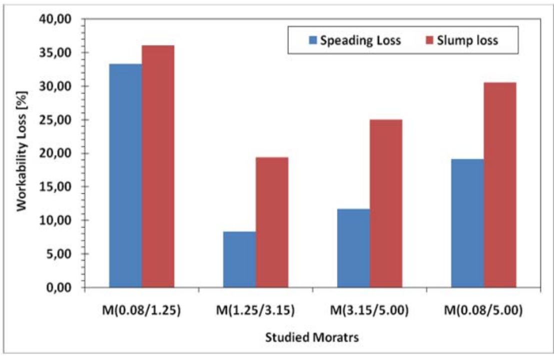

Fig. 1 Effect of different fractions of sand on the workability of mortar (without adjuvant)

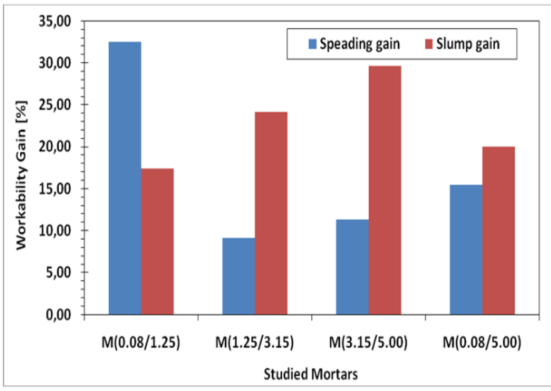

Fig. 2 Effect of adjuvant on the workability of mortar (with adjuvant)

2. Compressive and Flexural Strength of Mortars

The increase in compressive strength and flexural strength with time for all compositions is well established (Figs. 3 and 4). The effect of the reduction of water used in the mechanical strength is illustrated adjuvant, knowing that it is high for the recycled sand mixture versus control. Although the best performance is obtained with the sand mortar 0.08/5 due to the hydration of cement in the recycled sand which ensures a good bond with the new aggregate cement paste.

B. Effect of Recycled Aggregates on the Concrete Properties

1. Bulk Density

Fig. 5 shows the workability of recycled concrete compared to conventional concrete. From Fig. 5 we can see that the collapse differs from concrete to another with the same W/C ratio, which the concrete with natural aggregates works best maneuverability. This translates into the presence of the former covering the mortar from the aggregate breaking concrete, secondly by the presence of fine particles (fillers) in the recycled sand which absorb a lot of water because of their porosity higher [22] and finally that recycled aggregates are broken (rough surface) and thus provide less concrete workability.

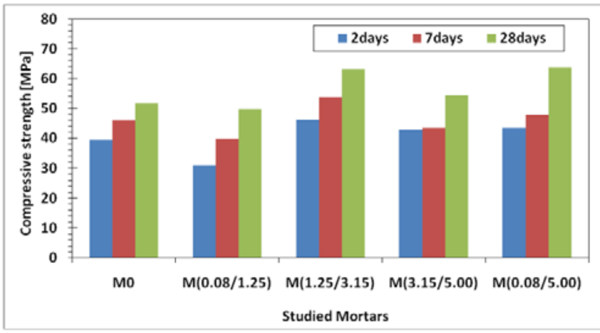

Fig. 3 Compressive strength evolution as function of the type of studied mortars

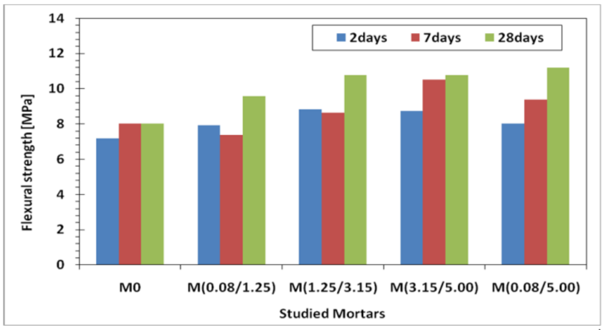

Fig. 4 Flexural strength evolution as function of the type of studied mortars

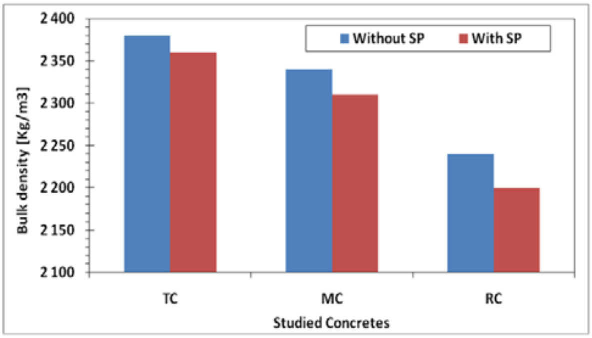

Fig. 5 Bulk density of studied concretes

The results confirm the conclusions of bibliographic: the real density concretes recycled concrete aggregate is less than that of natural aggregate concrete due to the porosity which causes the lightweight concrete; secondly these results are due to the density recycled aggregates.

2. Workability of Studied Concretes

Fig. 6 clearly shows the influence of the superplasticizer on the workability of the concrete; improving sagging despite the decrease in W/C ratio. The additive helps to densify the concrete paste reducing pores (modification of the microstructure).

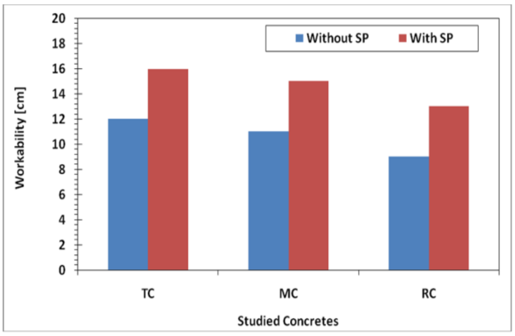

Fig. 6 Workability of concretes

3. Compressive and Flexural Strength of Concretes

Tricalcium acuminate C_3A cement gives a very good initial resistance to 2 days. In addition, the majority of tricalcium silicate hydrate and 28 days to form new components (hydro-silicates) crystallizing and occupy the free volume in the structure (pores). CSH crystallization leads to the homogenization and cohesion of the constituents of concrete, which is due to the improvement of mechanical strength over time.

Concrete surfaces indicate that recycled aggregates and cement paste are related (old recycled aggregates and the new cement paste) routed through its shape and rough surfaces that ensures good cohesion of the aggregates with cement paste (Figs. 7 and 8). This explains the good mechanical strengths obtained on recycled concrete aggregate and which are very close to those of natural aggregates.

4. Porosity and Water Absorption of Studied Concretes

Figs. 7 and 8 show the action of superplasticizer on improving the mechanical strength of their effect in decreasing the ratio W/C of concrete. From the results it is observed that the absorption and porosity characteristics are proportional. The increase of the porosity is due to increased absorption (Figs. 9 and 10). The concrete base of recycled aggregates with a high porosity concrete mixed due to fine particles from the sand and secondly the old mortar stuck to the aggregates that is a weak link and provides additional nuisance by producing more of fines in the granular skeleton [21], [24]-[26]. The additive contributes to the reduction in porosity, so the decrease in absorption [18].

IV. Conclusion

First, a study of the mortars was carried out to determine the efficacy of the polycarboxylate-based superplasticizer on workability thereof and deflocculating action on the sand fines recycled. The rheological behavior of mortars recycled fine was characterized and the results confirm the results of studies carried out previously. Mortars composed of different fractions of recycled sand (fillers 0.08/1.25, sand 1.25/3.15, coarse sand 3.15/5 sand around 0.08/5) recycled, do not seem to have the same compressive strength and tensile strength. Mortar sand around 0/5 exhibits better mechanical properties compared to other recycled and mortars from the normal mortar.

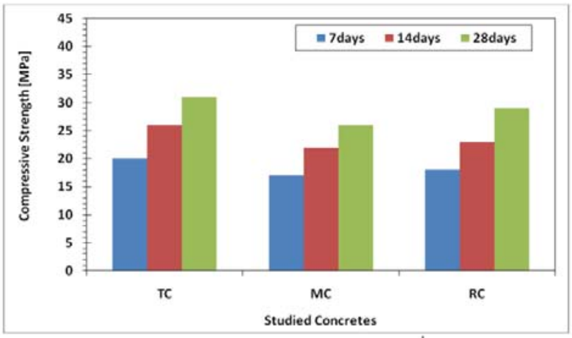

Fig. 7 Compression strength evolution as function type different of concrete (without adjuvant)

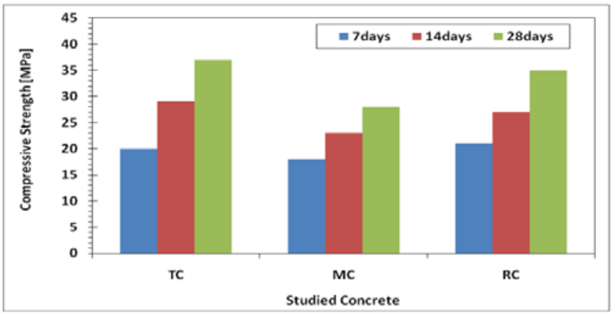

Fig. 8 Compression strength evolution as function type different of concrete (with adjuvant)

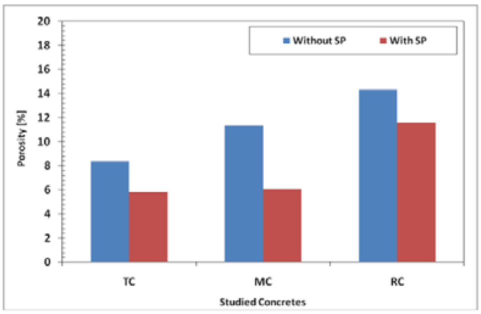

Fig. 9 Porosity of studied concretes

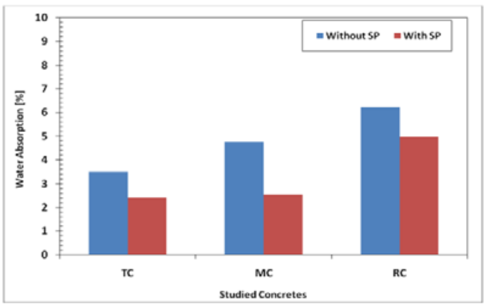

Fig. 10 Water absorption of studied concretes

A porosity analysis was performed to determine the influence of porosity on the physical and acoustic properties of the concretes. It appears that an increase in porosity would cause a decrease in the density and an increase in the absorption of a hand and a reduction in the speed of propagation of the waves secondly recycled concrete aggregate concretes.

- The substitution of natural aggregates by fully or partially recycled concrete aggregates provides a new source of supply and saves materials and careers.
- The use of recycled materials in the manufacture of concrete aggregates offers a good solution to the problem of management of demolition waste for the environment.
- The recovery and reuse of demolition waste can eliminate the dumps provided government support this issue through legislation and appropriate regulations

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