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Valorization of marble waste in the manufacture of concrete

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Abstract. The building materials manufacturing industry generates a lot of waste and their landfill has many problems (including the place occupied by the storage sites, the importance of the costs and the impact on the environment). This industry does not pose problems only at the end of the life cycle of these materials. It is imperative to find means of recovery and reuse of these wastes and therefore to propose another alternative to the depletion of aggregate sources. The main objective of this study is to show technically the possibility of using the aggregates from the manufacture of marble as a substitute in hydraulic concrete. The article presents the methodology of study and characterization of marble scrap, as well as the different formulations of concretes; series of tests have been developed, with a constant W / C ratio for a variable recycled aggregate content. The study consists of analyzing the results obtained and its comparison with a control concrete (100% natural aggregates); the rheological properties in the fresh and mechanically hardened state of concretes with different proportions of aggregates from marble waste (25%, 50%, 75%, 100%). The results show that marble waste is ready to be used as substitute material.

1. Introduction

The realization of construction projects in the field of buildings and public works always generates enormous quantities of secondary products or waste, the latter directly affecting the environment. The construction sector is a generator of several types of waste: old buildings approaching the end of their life are demolished producing millions of tons of concrete, large quantity of red products is rejected for non-compliance with the required specifications. On the one hand marble deposits provided a large quantity of aggregates of different sizes induced by fragmentation operations, sawing of large stones, on the other hand the processing plants proliferate a very large quantity of wastes consisting mainly of powders and sludge. The storage of certain types of waste in the wild promotes air pollution, the contamination of groundwater and agricultural soils, it is therefore more than necessary to work towards the elimination of these products through recovery and recycling actions. reuse of this waste again. Current economic and ecological conditions make it necessary to recover and recycle waste and impose the need to protect the environment by protecting natural materials by eliminating waste stored in deposits. These can lead to certain pollution of the natural environment which will require the mobilization of very important capital to its cleaning. In Europe, more than 25% of waste comes from the demolition or renovation of buildings, and half of this waste clutters landfills. It is estimated that only 30% of the materials used are currently recycled, while the practice in some European countries shows that 90% is recyclable [1]. Algeria has a significant deficit in building materials and in particular sand, the demand rises annually to more than 15 million cubic meters [2]. The main objective of this study is to contribute to the reuse of marble waste (aggregates: the fraction of sands) in the manufacture of hydraulic concrete and this will allow:

-To eliminate waste by recycling and reuse, hence the protection of the environment,
-Help solve some problems related to the lack of aggregates,

-Preserve our natural resources that are not infinite,
-Reduce the landfill and give a second life to our waste.
A marble is a limestone that has undergone a weak metamorphism, the density of the marble is on average equal to 2.7. In a dry atmosphere, it is practically unalterable, although its hardness is mediocre in humid or slightly acid air, it has a tendency to crumble [3]. The color and appearance of the marble is a function of its degree of purity, its color comes essentially from the metallic iron oxide, if the base rock is composed of calcite only, its color will be white [4,5]. Algerian marble products are well known in the world, they are extracted and processed according to European standards. The processes used in Algeria for the marble work are those used in the world. The waste rate is of the order of 50,000 m3 (block quarry) and 12,000 tons of marble derivatives at ORAN, 10,000 m3 (block quarry) at GUELMA and 8,000 m2 (processing plant) at SIG. In this study we have introduced marble waste from the FIL-FILA deposit. This deposit is 25 km east of SKIKDA. The FIL-FILA deposit is divided into two quarries:
-A quarry with white marble blocks and green Reseda, the waste of this quarry are falls and rubble with different geometric shapes, the rate of waste is 56% of the production.
The waste of the processing plant is the fall of block sizes and falls of tiles and slabs and marble powders, the waste rate is 22 m2 / m3, the stock is of the order of 20,000 m3.
-A quarry derived from CHATT, the waste of this career is a whole coming (marble of different granular classes), the rate of waste is 19% of the production and the stock is of the order of 18000 tons.

2. Characterization of the materials used and experimental programs

2.1. Characterization of the materials used

The gravel used is 5/15 and 15/25 grade crushed limestone gravel from the AIN SMARA - CONSTANTINE quarry. The sand is class 0/5 of rolled nature (sea sand) from CHATT - SKIKDA.
For the determination of the characteristics of the materials. Drying in an oven for 24 hours at 105 °C. is carried out until a constant weight is obtained.
The laboratory analyzes give the following results:

2.1.1. Apparent volumetric mass. It can be seen from the table below that the apparent density of the gravels is in the theoretical range, whereas for both sands it is slightly high because of the settlement of the two materials, which causes the voids to decrease between grains (table 1).

Table 1. Apparent volumetric of aggregates

Aggregates type	Sample	$M_V$app en g/Cm^3 1	2	3	$M_V$appMoy en g/cm^3
	Sand 0/5	1,723	1,725	1,723	1,723
Ordinary aggregates	Gravel 5/15	1,588	1,595	1,543	1,575
	Gravel 15/25	1,555	1,557	1,543	1,551
Recycled aggregates (Sands)	Sand with corrected granulometric 0/5	1,661	1,666	1,674	1,667

2.1.2 Absolute density. Note that the density values of all aggregates fall within the theoretical range (Table 2).

Table 2. Absolutedensity

Aggregates type	Sample	MVabs en g/cm^3 1	2	3	MVabsMoy en g/cm^3
	Sand 0/5	2,614	2,580	2,580	2,591
Ordinary aggregates	Gravel 5/15	2,666	2,666	2,666	2,666
	Gravel 15/25	2,666	2,666	2,666	2,666
Recycled aggregates (Sands)	Sand with corrected granulometric0/5	2,666	2,666	2,666	2,666

2.1.3. Equivalent of sand. It can be seen that the first two sands are clean, while the third Sand 0/3 contains many fines (Table 3).

Table 3. Equivalent of sand

Aggregates type	N° ofSample	Total height H1	Visible sandheight	Piston sandheight H2	ES= $\frac{H2}{H1}\times 100$	ES %
Ordinary	01	10,0	34,90	43-34,90=8,10	79,41	
aggregates	02	10,1	34,40	43-34,40=8,60	83,49	81 %
Sand 0/5	03	10,3	34,80	43-34,80=8,20	79,61	
Recycled	01	10,0	33,30	43-33,30=9,70	97,00	
aggregates	02	9,80	33,60	43-33,60=9,40	95,91	96 %
Sand 0/5	03	9,90	33,50	43-33,50=9,50	95,95	
Recycled	01	12,0	37,20	43-37,20=5,80	48,33	
aggregates	02	11,9	38,20	43-38,20=4,80	40,33	44%
Sand 0/3	03	12,6	37,20	43-37,20=5,30	42,06	

2.1.4. Chemical analysis of aggregates. AIN SMARA aggregates and marble aggregates are characterized by a high CaCO3 content.

Table 4. Chemical analysis of aggregates

Ordinary aggregates							
Sample	($CaCO_3$) in %	Cl in %	(SO_4) in %	PH	Contents organic in %	Insoluble in %	VB in %
Aggregate of AinSmara	88,00	0,25	Traces	6,79	1,98	4,975	--
Sea sand	25,56	0,12	Traces	6,84	2,08	83,125	0,33

Recycled aggregates (Sands)								
Sample	($CaCo_3$) en %	Al_2O_3 en %	Fe_2O_3 en %	SiO_2 en %	MgO en %	K_2O en %	Cl^- en %	SO_3 en %	Insoluble en %
Marble	98,67	0 ,14	0,09	0,53	0,2	0,01	0,025	0,04	0,035

2.1.5. Particle size analysis. Ordinary sand is thinner than recycled sand. Granular curves of ordinary aggregates are common (figure 1 and 2).

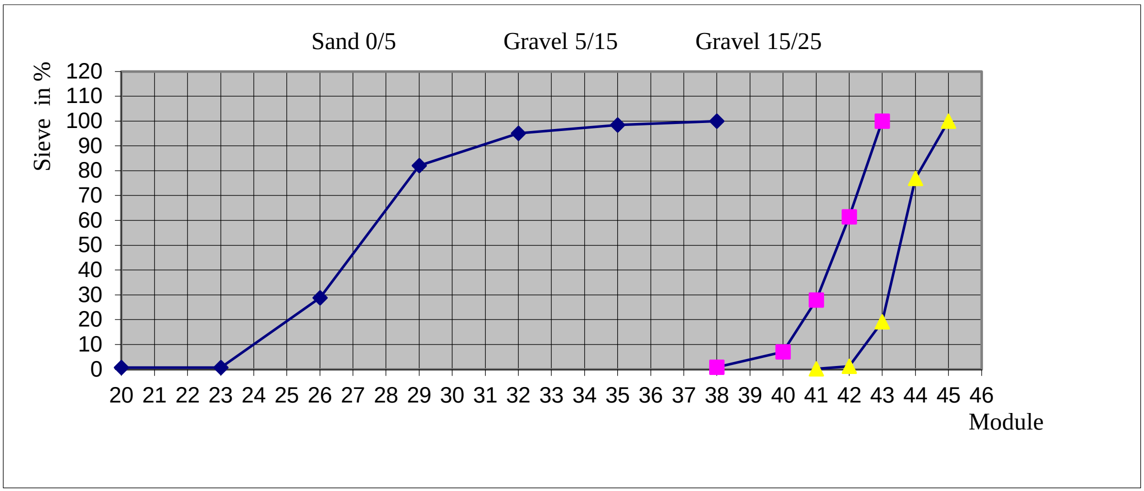

Figure 1. Granulometric curve of ordinary aggregates.

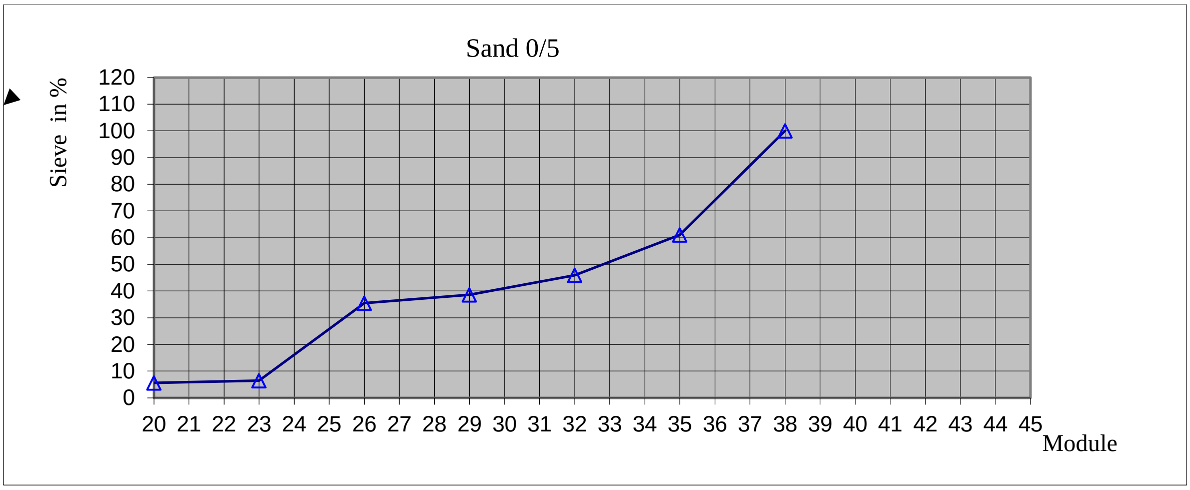

Figure 2. Granulometric curve of Recycled aggregates (Sands).

2.1.6. *Cement.* The cement we used for the manufacture of concrete is a CEM II / A 42.5 Portland Cement from HDJAR-SOUD resulting from the milling of:

-From 75% to 85% clinker
-From 10% to 20% addition (Dairy and tuff)
-From 5% of gypsum.

2.1.7. *Mixing water*. The water used in mixing in this study comes from the BOURRICHE EL-HADDAIEK well. The chemical analysis of the water is given by the following table 5*:*

Table 5. Chemical analysis of water

Sampling place	Cl Mg/l	PH	T°	Salinité	TDS Mg/l	ConductivityUs/cm	Observation
PuitsBourriche	0,1	7,3	28,5	0,2	297	541	Turbidity: 1.44ntu Good chemical quality water

3. Experimental programs

A constant W/C ratio is adopted and the substitution rate of recycled sand is varied [6, 7].
- E / C ratio equal to 0.5,
-Dosage cement equal to 350 kg / m3,
-Granular skeleton continues.
We present in the table below the compositions of the mixtures, the number of mixes and test pieces.

Table 6. Composition of concrete formulations

	Component	Cement	Water	Sea sand 0/5	Gravel 5/15	Gravel15/25
S1(0%)	Dosage in Kg	350	175	600,23	505,31	748,61
	Component	Cement	Water	Sea sand 0/5	Gravel 5/15	Gravel15/25
	Dosage in Kg	350	175	450,17	505,31	748,61
S2(25%)	Component	--	--	Recycled sand 0/5	Recycled sand 0/3	--
	Dosage in Kg	--	--	93,63	88,18	--
	Component	Cement	Water	Sea sand 0/5	Gravel 5/15	Gravel15/25
	Dosage in Kg	350	175	300,11	505,31	748,61
S3(50%)	Component	Cement	Water	Recycled sand 0/5	Recycled sand 0/3	--
	Dosage in Kg	--	--	187,27	176,36	--
	Component	Cement	Water	Sea sand 0/5	Gravel 5/15	Gravel15/25
	Dosage in Kg	350	175	150,05	505,31	748,61
S4(75%)	Component	Cement	Water	Recycled sand 0/5	Recycled sand 0/3	--
	Dosage in Kg	--	--	280,91	264,54	--
	Component	Cement	Water	Sea sand 0/5	Gravel 5/15	Gravel 15/25
	Dosage in Kg	350	175	--	505,31	748,61
S5(100%)	Component	Cement	Water	Recycled sand 0/5	Recycled sand 0/3	--
	Dosage in Kg	--	--	374,55	352,73	--
Number of mix			20			
Number of specimens			60 specimens 16x32cm + 60 specimens 7x7x28cm			

On fresh concrete, tests are carried out on the density, airtightness and cone collapse of ABRAMS for hardened concrete. It is concerned with the measurement of compressive strengths on 16x32 specimens and on the measuring flexural tensile strengths on 7x7x28 specimens at ages 2, 14, 28 and 90 days respectively.

4. Discussion of the results

4.1. Density

For each step of 25% substitution rate, the density varies from one step to another, the maximum value is obtained for a substitution rate of 25%.

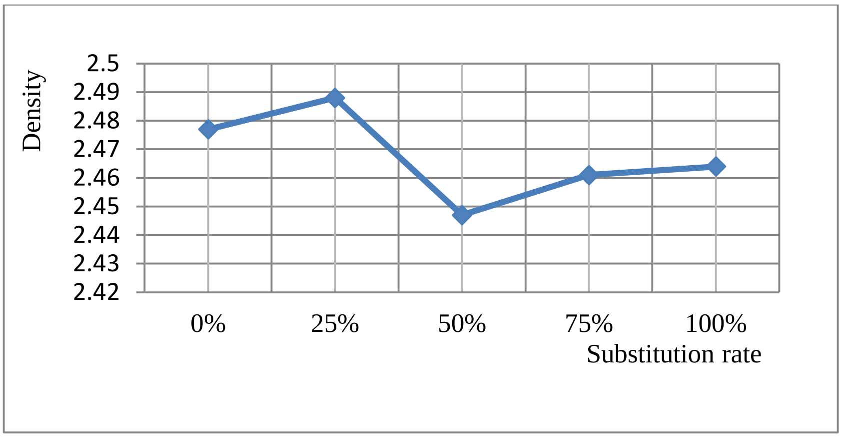

Figure 3. Variation of the density according to the rate of substitution of sand.

4.2. Occluded air

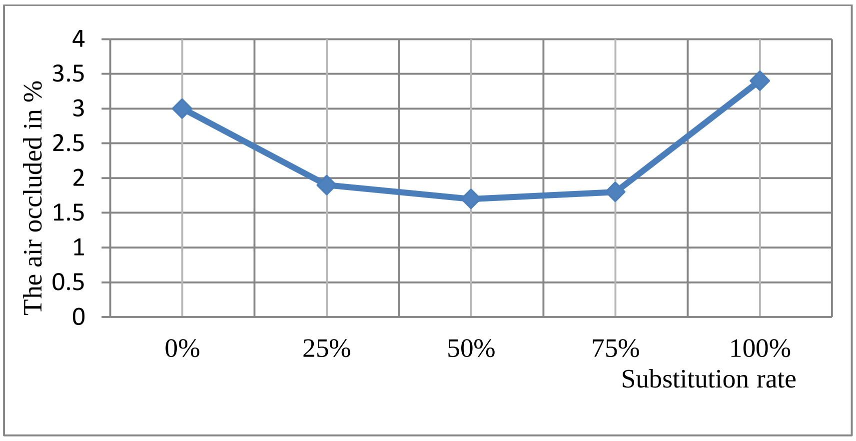

Figure 4. Variation of the air occluded according to the rate of substitution of sand.

Figure 4 shows a 1.1% decrease in occluded air between natural aggregate concrete and 25% recycled sand substitution followed by stagnation with moderate variation between concrete 25% substitution rate and 75% substitution rate while a larger increase up to 100% substitution rate reaching 3.4% of the occluded air. The introduction of recycled sand decreases the occluded air content. Correction and evolution of the finesse module influenced the occluded air content.

4.3. Workability

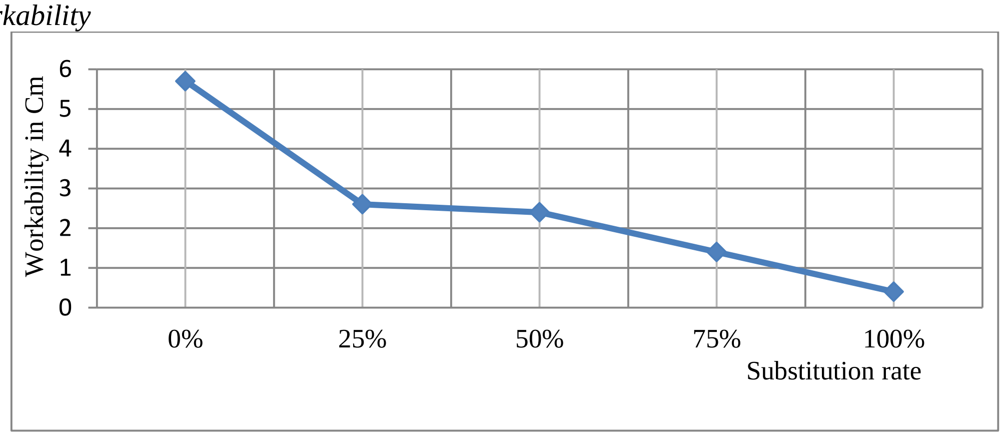

Figure 5. Variation of the workability according to the rate of substitution of sand.

ABRAMS cone collapse decreases as the rate of substitution increases, the higher the rate of substitution, the lower the collapse. The best workability is given by ordinary aggregate concrete this can be explained by the presence of the fine elements of the sand. The curve (Figure 5) shows that recycled sand absorbs more water.

4.4. Study of the influence of the substitution rate on fresh concrete

4.4.1. Compressive strength

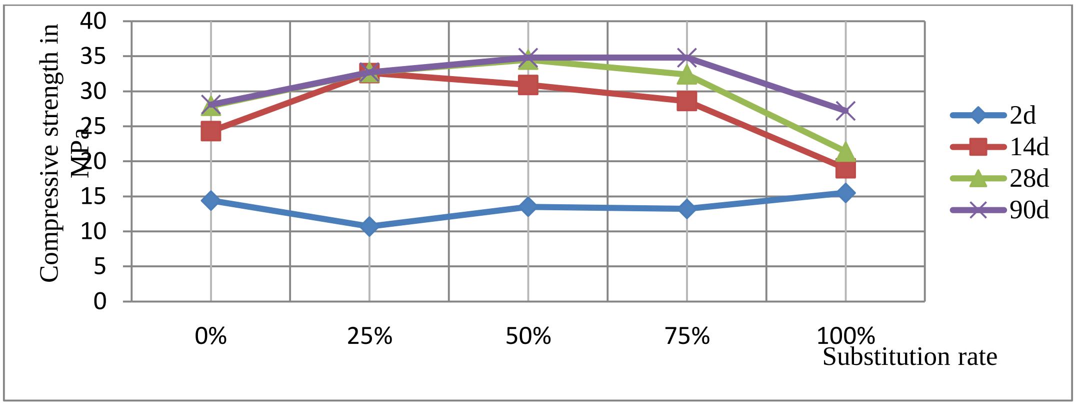

Figure 6. Evolution in time of the compressive strength as a function of the substitution rate of sand.

The 14, 28 and 90 day concretes exhibit the same behavior, the curves are very close together and the variation as a function of time for a substitution rate of 25% is insignificant.

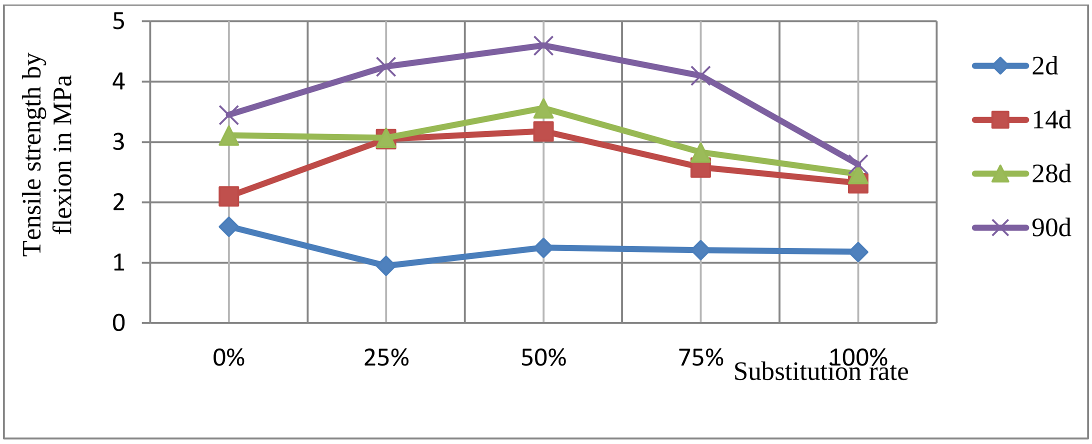

Figure 7. Evolution over time of the bending tensile strength as a function of the sand substitution rate.

In these formulations, the resistance is an increasing function with time, between 14 and 28 days the curves are closer together they present from 25% of substitution rate the same behavior.

5. Conclusion

This work focused on the study of the possibility of recovering marble waste in hydraulic concrete.
An experimental approach was followed when replacing cement with marble waste fillers and replacing ordinary aggregates with marble waste aggregates (the fraction of sands), the basis of which is to determine the performance of each composition that makes it possible to understand the behavior of marble waste aggregates in concrete and fillers in cement and mortar. The introduction of recycled sand decreases the occluded air content. The correction and evolution of the fineness module influenced the occluded air content. ABRAMS cone collapse decreases with increasing substitution rate of recycled

sand (coarse sand). Thus, it can be seen that the higher the substitution rate, the lower the subsidence. Total substitution aggregate blends give the highest compressive strengths compared to blends of recycled sand partial substitution aggregates. In comparison with the results of 2d, 14d and 28d, we can say that the recycled sand retards the hardening at a young age, since the sand is coarse, it does not return quickly in the hydration reaction of the cement. At a young age, recycled sand slows the increase in tensile strength. The best performance in compression and bending tensile is obtained for the substitution of 50% in the medium term 28d in recycled sand.
Prospect: Study of the introduction of recycled sands in mortars.

6. References

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