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Effect of marble waste fines on rheological and hardened properties of sand concrete

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Abstract. Faced with the growing needs of material resources and requirements of environmental protection for achieving sustainable development, it has become necessary to study and investigate all possibilities of exploring crushed and dune sand, reusing industrial wastes and by-product, and also applying new technologies including sand concrete which can replace the conventional concretes in certain structures to surmount the deficit on construction materials, conserve natural resources, lessen the burden of pollutants to protect the environment and reduce the consumption of energy sources.

This experimental study is a part of development and valorization of local materials project in Skikda region (East of Algeria). It aims at studying the effects of partial replacement of sand with marble waste as fines on several fresh and hardened properties of sand concrete in order to reuse these wastes in the concrete manufacturing, resolve the environmental problems caused by them and find another source of construction materials.

To achieve these objectives, an experimental program has been carried out; it was consisted to incorporate different percentages of marble waste fines (2, 4, 6, 8, 10 and 12%) in the formulations of sand concrete and study the development of several mechanical and rheological properties. We are also trying to find the optimal percentage of marble waste fine replaced in sand concrete that makes the strength of the concrete maximum.

Obtained results showed that marble waste fines improve the properties of sand concrete and can be used as an additive material in sand concrete formulation.

Keywords: sand concrete; marble waste; mechanical properties; fines; rheological properties

1. Introduction

Sand concrete is a fine concrete consisting of a mixture of sand, cement, additives, and water. Besides these basic components, sand concrete typically includes one or more admixtures. The incorporation of fine gravel (d/D) authorizes the use of the name sand concrete as long as the mass ratio G/S remains below 0.7 (with G=gravel, S=sand).

This material is to be distinguished from a conventional concrete by its high proportion of sand, the absence or small proportion of fine gravel and the incorporation of additive(s). It is also distinguished from a mortar by its composition (mortar generally contains high concentration of

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cement) and especially by its destination, as sand concretes are primarily intended for more traditional uses. The scarcity of aggregates, its easy technique, its low cost makes it the favorite of many researchers around the world.

If the sand concrete is compared with the ordinary concrete (gravel+ sand), it could be observed that the porosity of sand concrete is higher. This porosity imposes the use of fillers to eliminate pores between particles according to the study of Sablocrete (1994).

In this study we are attempting to fill this porosity by the marble waste fines. The marble waste fines used was obtained from wastes of the white marble quarry of Fil-Fila (Skikda, East of Algeria). The rate of waste is 56% of production in 2007, the stock until the end of 2007 is of the order of 5823 m^3. Many studies evaluating the use of these wastes in cement, mortars and concrete, the publications (Aruntas *et al*. 2010, Corinaldesi *et al*. 2010, Hebhoub *et al*. 2014, Vaidevi 2013, Patel *et al*. 2013, Binici *et al*. 2007, Rai *et al*. 2011, Hebhoub *et al*. 2010) reported that the use of these industrial by- products can improve some properties of these materials and lead to greener environment.

2. Materials used

2.1 Fine aggregate

The sand is the main component of sand concrete. In our case it is dune sand taken from Collo region located in the West of Skikda (north-east of Algeria). The physical properties of sand are given in Table 1, Moreover particle size distribution is presented in Fig. 1.

This sand has a fineness modulus of 1.92 (fine sand), the majority of the particles have

Table 1 Physical characteristics of fine aggregate

Physical characteristics	Fine aggregate
Apparent density (g/cm^3)	1.459
Absolute density (g/cm^3)	2.597
Equivalent sand (%)	75.89
Fineness modulus	1.92
Fines content (%)	0.48

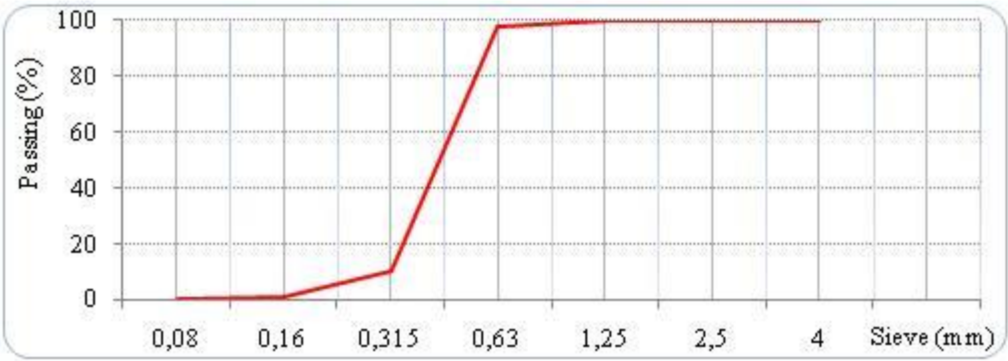

Fig. 1 Particle size distribution of the fine aggregate

Table 2 Physical and mechanical characteristics of cement used

Physical and mechanical characteristics	Cement
Initial setting time (min)	76
Final setting time (min)	180
Absolute density (g/cm^3)	3.125
Specific surface (Blaine) (cm^2/g)	3155
shrinkage for 28 days (microns/m)	792
Compressive strength for 2 days (MPa)	26.91
Compressive strength for 7 days (MPa)	43.56
Compressive strength for 28 days (MPa)	58.45
flexural strength for 2 days (MPa)	5.08
flexural strength for 7 days (MPa)	7.22
flexural strength for 28 days (MPa)	8.81

Table 3 **C**hemical characteristics of cement used

Chemical characteristics	Cement
CaO	61.38
Al_2O_3	5.18
Fe_2O_3	3.34
SiO_2	19.97
MgO	0.99
Na_2O	0.2
K_2O	0.44
Cl^-	0.19
SO_3	2.9
CaO (free)	0.6
Loss in ignition	3.71
C_4AF	10.25
C_3A	8.08
C_3S	58.45
C_2S	13.24

dimensions between 0.315 and 0.63 with a nominal particle size of 4 mm. It is characterized by a big specific surface and a high water demand according to Baron and Ollivier (1999).

2.2 Cement

Artificial portland cement CEM I of class 42.5 used in this study was obtained from Sotacib, Plant of Kairouan (Tunisia). The physical and mechanical properties and chemical composition are given in Tables 2-3.

These tables show that the cement has a half-slow setting because it has low C_3A content according to Nafa (2007), it has also a high compressive strength at early age due to their high content of C_3S compared to the other components.

Table 4 Physical and chemical characteristics of marble waste fines used

Physical and chemical characteristics	Marble waste fines
Color	White
Absolute density (g/cm^3)	2.72
Absorption (%)	0.39
Compressive strenght (dry state) (MPa)	9.61
Wear strenght (g/cm^2)	1.82
Impact strenght (kg/cm^3)	40
$CaCo_3$	96.12
CaO	53.85
Al_2O_3	0.38
Fe_2O_3	0.22
SiO_2	1.11
MgO	2.81
Na_2O	0.15
K_2O	0.04
Cl^-	0.02
SO_3	0.00

Table 5 **C**haracteristics of superplasticizer

Characteristics	Superplasticizer
Color	Brown
Absolute density (g/cm^3)	1.08
Solid in aqueous solution (%)	24
PH	7

2.3 Marble waste fines

Fines used in the composition of the sand concrete were obtained by grinding with a ball mill of marble waste sand. Table 4 shows the results of the characterization tests.

2.4 Superplasticizer

A polycarboxylic-ether type superplasticizer SP ‘GLENIUM 26’ was used in all mixtures. The properties of this superplasticizer are given in table 5.

3. Sand concrete mix design, casting, curing and testing

The method used is that proposed by Sablocrete (1994).The formulations of the sand concrete mixtures are given in Table 6. For all sand concrete mixtures used in this investigation, cement content, water/cement (W/C) ratio and superplastizer content were kept constant at 400 kg/m^3, 0.77 and 2% by weight of cement respectively.

Table 6 Formulations of various sand concrete mixtures

Concrete	Cement (kg/m^3)	Water (l/m^3)	Sand (kg/m$^{3)}$	Marble waste fines (kg/m^3)	Superplasticizer (%)	W / C
0%	400	308	1445.91	0	2%	0.77
2%	400	308	1416.66	30.30	2%	0.77
4%	400	308	1388.07	60.61	2%	0.77
6%	400	308	1359.14	90.92	2%	0.77
8%	400	308	1330.24	121.22	2%	0.77
10%	400	308	1301.32	151.54	2%	0.77
12%	400	308	1272.37	179.14	2%	0.77

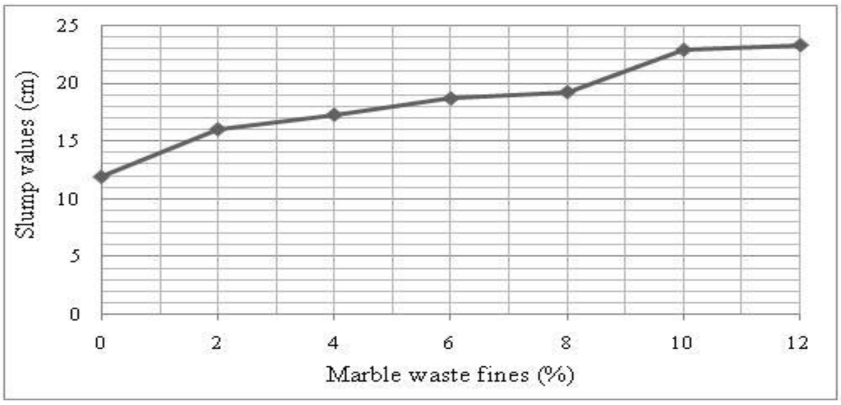

Fig. 2 Workability of sand concrete with varying percentage of marble waste fines

These mixes were modified to 2, 4, 6, 8, 10 and 12% marble waste fines in place of fine sand aggregate.

For each mixture, the air content, density, the slump test, the compressive strength and the flexural strength were determined. 160 mm×320 mm cylinders were used for the determination of compressive strength at 7 and 28 days and for determination of flexural strength we are used 70×70×280 mm prisms (three samples were tested at each age).

The test specimens were cured under two types of curing until the day of testing. These were water curing, and air curing. In water curing, the specimens were immersed in water at (20℃±2; 100% RH).

Normal tap water was used in water curing. In case of air curing, the specimens were exposed to air at (20℃±2; 65%RH).

These tests were carried out according to the relevant Algerian standards.

4. Results and discussion

4.1 Fresh properties

4.1.1 Workability

The test results of slump test of sand concrete are given in Fig. 2.

It was observed that the workability of sand concrete depended on marble waste fines content, the slump value increases with an increase in the marble waste fines content in the mixture. This is due to the increase in marble waste fines that contributes to improve workability by facilitating the sand grain movement according to study of Baron and Ollivier (1999).

4.1.2 Density

The density of sand concrete increases with an increase in the marble waste fines content in the mixture (Fig. 3).

Bederina *et al*. (2005) explain this increase by the fact that marble waste fines has higher density when compared to the other aggregate used in the mixture, and also because fine particles fill spaces between grains of sand, thereby increasing the density of the mix. Once the voids are completely filled, fine particles then begin to occupy the place of sand grains, which decrease the proportion of sand grains, and consequently the density of the mix.

4.1.3 Air content

The test results are also presented graphically in Fig. 4.

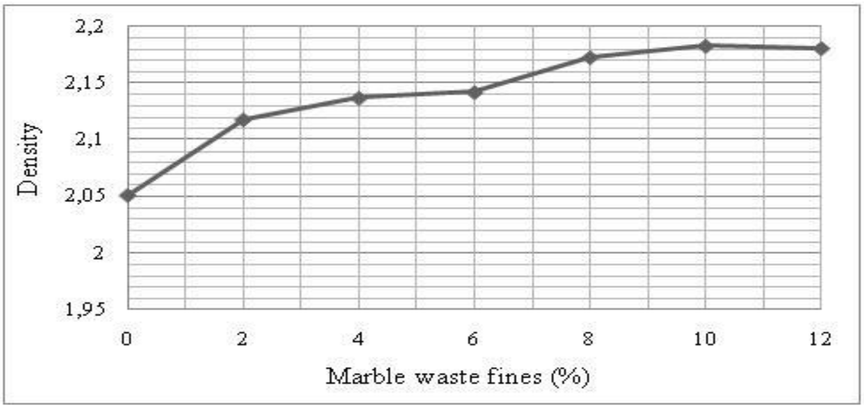

Fig. 3 Density of sand concrete with varying percentage of marble waste fines

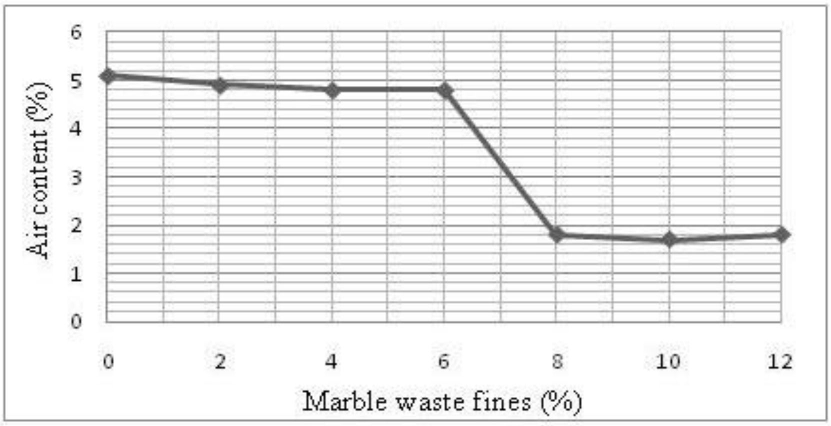

Fig. 4 Air content of sand concrete with varying percentage of marble waste fines

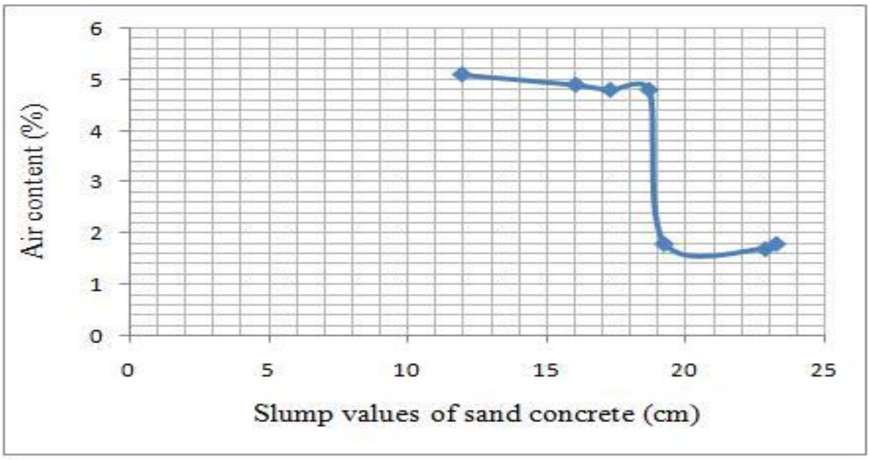

Fig. 5 Effect of workability on air content of sand concrete

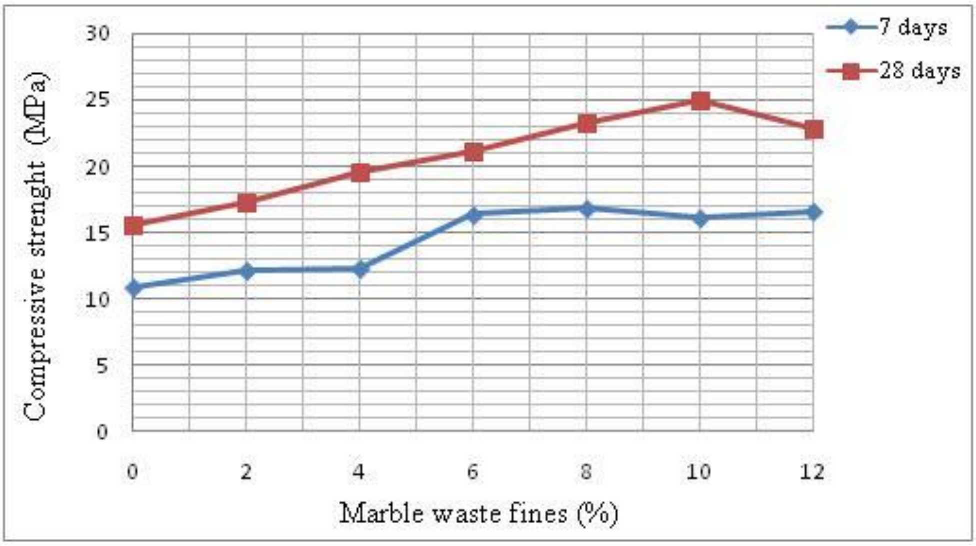

Fig. 6 Influence of marble waste fines content on compressive strength of sand concrete

By increasing the marble wate fines, the air content values of concrete tends to decrease until an optimum value situated between 8 and 12%. We can explain this trend by:

• The fines of marble waste play a filling effect and contribute to reduce the void volume.

• Improvement of the workability of sand concrete by adding the marble waste fines contributes to the reduction of the air content (Fig. 5) (Baron and Ollivier 1999).

4.2 Hardened properties

4.2.1 Compressive strength

The results of the compressive strength tests are illustrated in Fig. 6. These results show that the compressive strength of sand concrete increases with the increase of marble waste fines content in

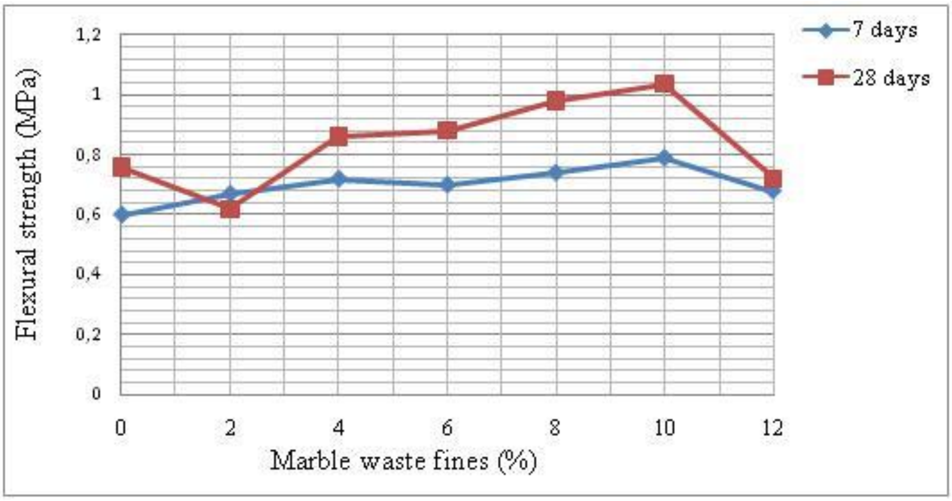

Fig. 7 Influence of marble waste fines content on flexural strength of sand concrete

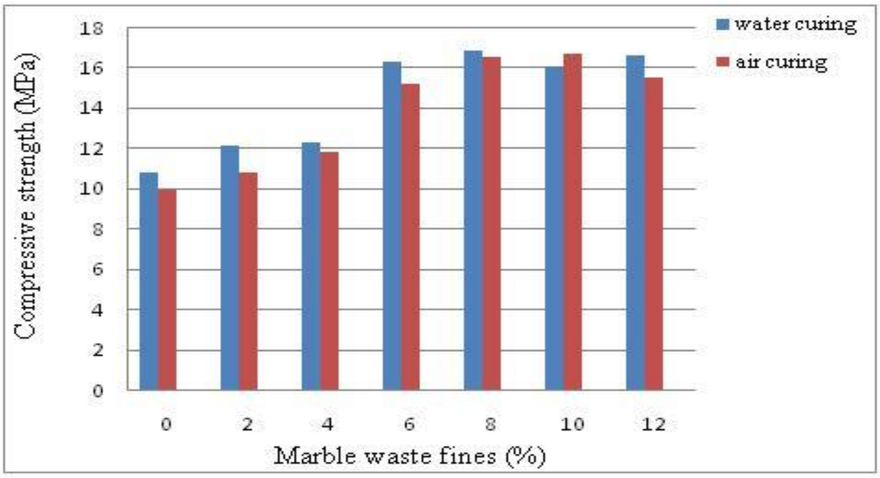

Fig. 8 Effect of curing on the compressive strength of sand concrete at 7 days

these mixtures.

This increase can be attributed to the fact that adding of marble waste fines decreases porosity of mixtures correlated with the results obtained with Baron and Ollivier (1999), De larrard (1999).

However, there is a slight decrease in compressive strength value of sand concrete mix when 12% marble waste fines are used compared with that of 10% marble waste fines mix (optimal marble fines concentration).

4.2.2 Flexural strength

The flexural strength of sand concrete increase with increase of marble waste fines content in these mistures as illustrated in Fig. 7.

This trend can be attributed to the decrease of the porosity by adding of marble fines (Baron and Ollivier 1999, de Larrard 1999).

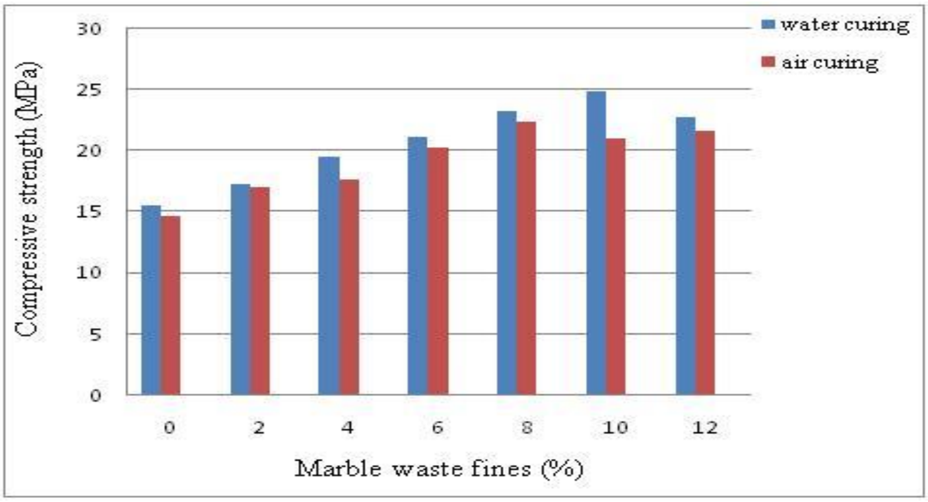

Fig. 9 Effect of curing on the compressive strength of sand concrete at 28 days

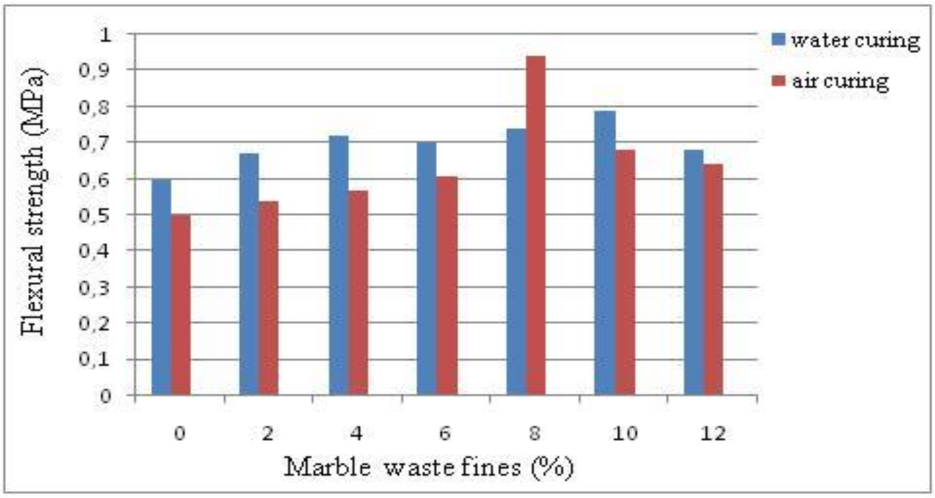

Fig. 10 Effect of curing on the flexural strength of sand concrete at 7 days

4.3 Curing effect

The Effect of curing on the compressive and flexural strength of sand concrete has been presented in Figs. 8, 9, 10, 11. In all curing methods, the compressive strength of sand concrete increased with increasing age. The highest compressive and flexural strength at all ages was produced by water curing. The development of higher strengths in water can be explained by:

• Sufficient moisture, which was maintained to continue the hydration of cement.

• the drying which causes cracks affect the mechanical properties of sand concrete, which is characterized by a strong drying according to the studys of Reynouard and Gilles (2005), Baron and Ollivier (1999), Safiuddin *et al*. (2007).

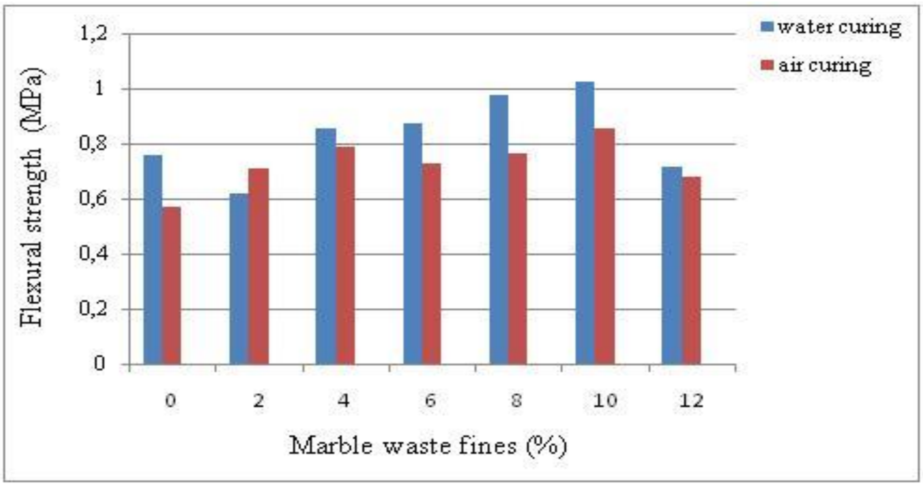

Fig. 11 Effect of curing on the flexural strength of sand concrete at 28 days

5. Conclusions

In this study, the effects of marble waste fines on the fresh and hardened properties of sand concrete were investigated. Based on the experimental investigation reported in this paper, the following conclusions are drawn:

• The use of marble waste fines in the production of sand concrete improve the fresh properties of this material and marble fines proved to be very effective in assuring very good cohesiveness of concrete.

• In terms of mechanical behavior, the increase of marble waste fines improves the hardened properties of sand concrete; 10% substitution of sand by the marble fines provided maximum compressive strength in our case.

• Water curing was the most effective method of curing. It produced the highest level of compressive and flexural strength.

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