Structural Engineering and Mechanics, *Vol. 49, No. 4 (2014) 491-498*
DOI: http://dx.doi.org/10.12989/sem.2014.49.4.491

Introduction of sand marble wastes in the composition of mortar

H. Hebhoub*, M. Belachia and R. Djebien

Department of Civil Engineering, LMGHU Laboratory, University of Skikda, Algeria

(Received August 27, 2013, Revised November 15, 2013, Accepted December 27, 2013)

Abstract. During the past years, the protection of the environnement has become a major concern out passing the state frontiers to reach a planetary dimension. Depository waste sites have become a serious problem in terms of their locations and costs. On the other hand, the construction industry has a leading place in terms of quantities of waste produced from the start to the end of each construction site, by the large amounts of raw materials used and their respective consequences on the environment. The recycling of quarry wastes products, of demolished concrete, bricks and large quantities of waste resulting from the transformation of marble blocks can provide ideal solutions and advantages for the preservation of the environment, to become a supplementary source of aggregates. The main purpose of this study is to show technically the possibility of recuperating the aggregates of marble wastes as a partial substitute or total in the mortars. The aggregates used in this study is a sand of marble wastes (excess loads of sand exposed to bad weather conditions) of the quarry derived from Fil-fila marble (Skikda, east of Algeria). To achieve this work, we have studied the effect of sand substitution of marble wastes in the mortar with rates of (25, 50, 75, 100%); comparing the results obtained with reference samples (0%), the properties when the samples are fresh, and the mechanical performances of mortars at solid state (loss and gain of weight, dimensional variations). The introduction of recycled sand in the mortars gives good results and can be used as granulates.

Keywords: wastes; valorization; granulates; marble; performance; substitution; mortar

1. Introduction

Waste is a problem inherent in all biological life and all industrial, agricultural and urban areas and as such, the search for solution is a real need for communities. Hebhoub (2011), Akbulut and Gurer (2007) suggest that the use of recycled aggregates has a great importance from the point of view of environment because it allows on one side to recover materials and their reuse, on the other side, to protect nature from excessive operations on ordinary aggregates.

The granite quarries and marble provided a large amount of scrap and waste volumes coming from both cutting and sawing of stone blocks. Therefore, transformations plants generate a very large amount of waste consisting essentially of powders and slurries.

Storage of such waste in the deposits favours air pollution and contamination of water resources and rural lands; so it is necessary to eliminate these products in order to enhance their

*Corresponding author, Ph.D., E-mail: hebhoubhouria@yahoo.fr

Copyright © 2014 Techno-Press, Ltd.
http://www.techno-press.org/?journal=sem&subpage=8 ISSN: 1225-4568 (Print), 1598-6217 (Online)

Fig. 1 Declassified powder of Fil-fila quarry (Algeria)

qualities and reuse them again.

Algeria is experiencing a significant short fall in construction materials particularly cement and sand, demand rises annually to more than 15 million cubic meters of sand according to Azzouz *et al*. (2000).

The main objective of this study is to contribute to the reuse of waste marble deposits of Fil-fila substituted in mortars; this type of wastes is a marble powder thrown away and subjected to weather conditions (declassified powder) and occupies useful spaces in the quarry (Fig. 1) approximately 19% of the production.

Several researchers have shown that it is possible to recover the marble wastes such as aggregates in concrete and mortars or as dust added to cement.

Firstly in 2008 Karaca and Elçi (2008) studied the opportunity and feasibility of using wastes coming from stone production in quarries which are exploited in Turkey as concrete aggregates. For this study, we selected several samples (four types of marble, two limestones, two travertine and two types of granite). Tests results show that wastes of dolomitic marble and limestone can be used as substitute of aggregates in the composition of concrete.

Another study by Erhan *et al.* (2009), Saboya *et al.* (2007) examines the effect of marble powder and granulated slag on mortar. Marble powder was obtained as an industrial product during the sawing, shaping and polishing phases of marble transformation, the results indicate that the insertion of marble powder increases the flow time, setting time and the viscosity of mortars, while it is noticed that properties decrease when reaching a hardened state. In the same manner Hebhoub *et al.* (2010) studied the use of marble waste as aggregate replacement in concrete. The results obtained show that the workability decreases with the increase of substitution and recycling sand (coarse sand) shows increased mechanical strength at early age.

Finally Rai *et al.* (2011) detected the influence of powder and granulated marble on the properties of concrete. The study is based on the partial replacement by 5%, 10%, 15 % and 20% of the sand incorporated in mortars by aggregates originating from marble waste and compares the results with a reference mortar 0%. Results obtained show that the compressive strength increases with age and decreases beyond 10% of the replacement rate. The tensile strength increases with the increase of the substitution rate of marble waste. Marble waste aggregates possess cementing properties and are more efficient or effective in reinforcing cohesion.

The introduction of marble waste as fine sand in concrete leads to the increase of density and compressive strength, and the highest value of strength is given by 100% specimens, according to Demirel (2010).

Table 1 Physical and chemical characteristics of marble waste sand

Physical and chemical characteristics	Marble waste sand
Apparent density (g/cm^3)	1.74
Absolute density (g/cm^3)	2.67
Equivalent Sand (%)	83
Absorption (%)	0.133
$CaCO_3$	98.67
CaO	55.29
Al_2O_3	0.14
Fe_2O_3	0.09
SiO_2	0.53
MgO	0.20
Na_2O	0.00
K_2O	0.01
Cl^-	0.025
SO_3	0.04
Loss on ignition	43.40
Insoluble residue	0.035

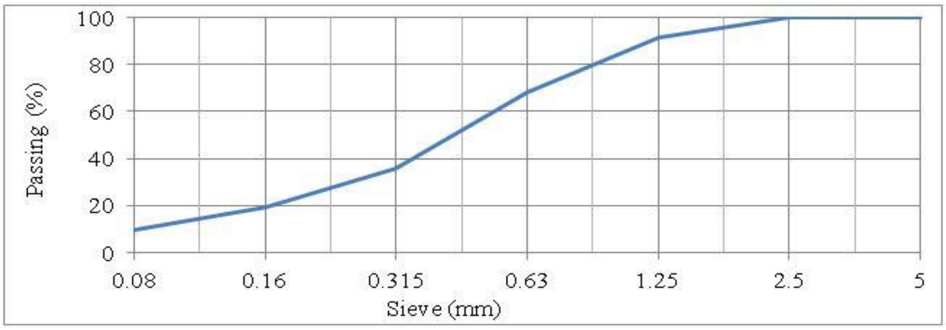

Fig. 2 Granulometric curve of marble waste sand

2. Experimental program or procedure

2.1 Material characterizations

Sand originating from marble waste from the quarry (marble quarry of Fil-fila). Table 1 shows the results of the characterization tests.

Normalized sand CEN according to the EN 196-1 standard, siliceous natural sand with an apparent density 1.63 g/cm^3 and an absolute density of 2.5 g/cm^3. This sample of sand is inert from the chemical point of view and has a fineness modulus of 2.33.

Cement CEM I of class 42.5 coming from Batna factory (East of Algeria) was used.

According to the chemical analysis tests, sand obtained from marble waste is a limestone ($CaCO_3$ 98.67%). It is a sign that the recycled sand presents a good bond with the matrix/aggregate interface, correlated with the results obtained with Dreux and Feasta (1995).

From the equivalent sand test, the recycled sand is a clean one.

The curve represented in Fig. 2 shows the results for the granulometric analysis of recycled sand. The value obtained for the fineness modulus of the recycled sand is 1.85. This value indicates a fine sand which is similar with the experimental condition by Dreux and Feasta (1995); where fine particles content is only 10%, in other words this means that the recycled sand absorbs water. From the granulometric curve Fig. 2, we notice that the recycled sand is of 0/3 class and has a good regularity in the grain sizes.

2.2 Production of mixtures

In the experimental program, we studied the substitution in mortars of ordinary sand with marble waste sand at variable substitution rates of 0% 25%, 50%, 75% and 100%.

The constant parameters in this study are the cement content of 450 g and the water / cement ratio which is equal to 0.5. Tests on fresh mortar samples were conducted in order to obtain values for the density and workability.

Tests on hardened mortar samples were conducted in order to obtain values for both the compressive and tensile strength in flexion at 2, 7, 28 and 90 days as well as the values for loss in weight, gain in weight, shrinkage and swelling (3, 7, 14, 21 and 28 days).

3. Results and discussion

The Fig. 3 indicates that above a 25% substitution rate, density increases with the increase in the substitution rate in accordance with (Demirel 2010**,** Corinaldesi *et al.* 2007, Binici *et al.* 2008)

Workability tests carried out on fresh mortar samples show that it decreases according to the increase in the substitution rate of marble waste sand; it is due to the presence of fine particles in the recycled sand which allows the absorption of water. The addition of a superplastifier with a rate of 1% allows a better workability.

At an early age (Fig. 4), the compressive strength increases according to the increase of the substitution rate. This phenomenon is due to the amount of fine sand existing in marble waste samples, which speeds up the hydration reaction adding to this, the recycled sand possesses cementing properties (Rai *et al.* 2011). The maximum value is obtained at two days with a 100% substitution rate mortar. The presence of large amount of carbonates gives higher strength according to the study of Hebhoub (2011), Belachia *et al.* (2006, 2008).

Mean term test values give a decrease in the strength values according to the substitution rate,

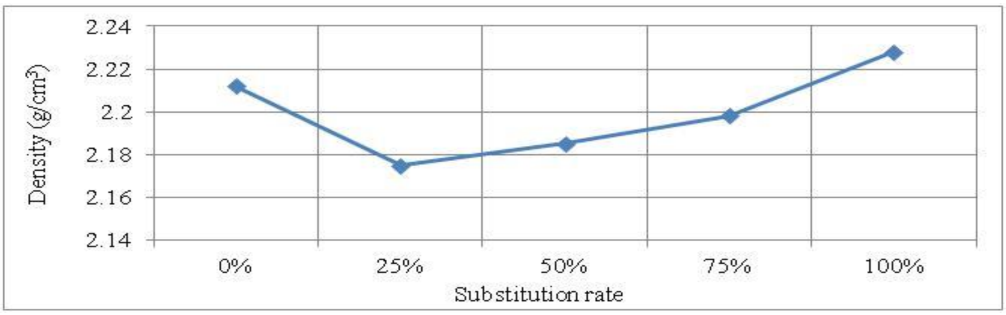

Fig. 3 Variation of the density versus the substitution rate

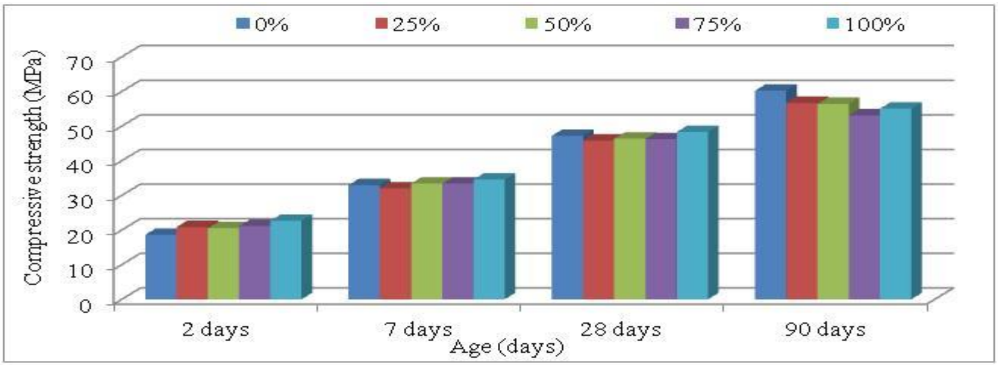

Fig. 4 Variation of the compressive strength versus the substitution rate

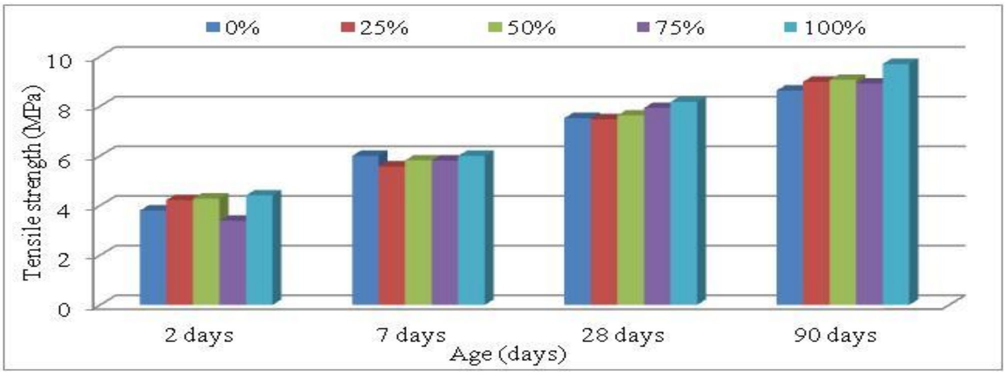

Fig. 5 Variation of the tensile strength in flexion versus the substitution rate

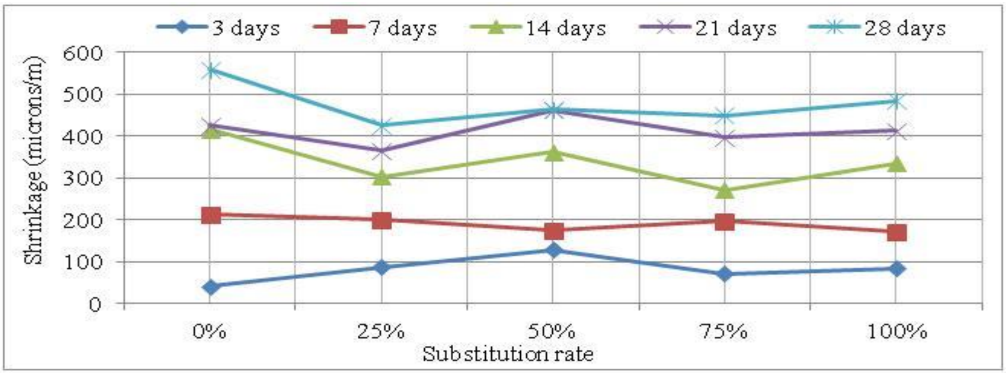

Fig. 6 Variation of shrinkage versus the substitution rate

when compared with the reference mortar; this is largely due to the large initial increase at two days.

The strength values increase with the age of the sample. (Rai *et al.* 2011, Hebhoub. 2011, Binici *et al.* 2007), they can reach 60.23 MPa at 90 days for the reference mortar.

The addition of recycled sand leads to increase the cohesion, the presence of carbonate in waste sand marble gives a good bonding, matrix/granulate (Hebhoub *et al.* 2010, Rai *et al.* 2011) which

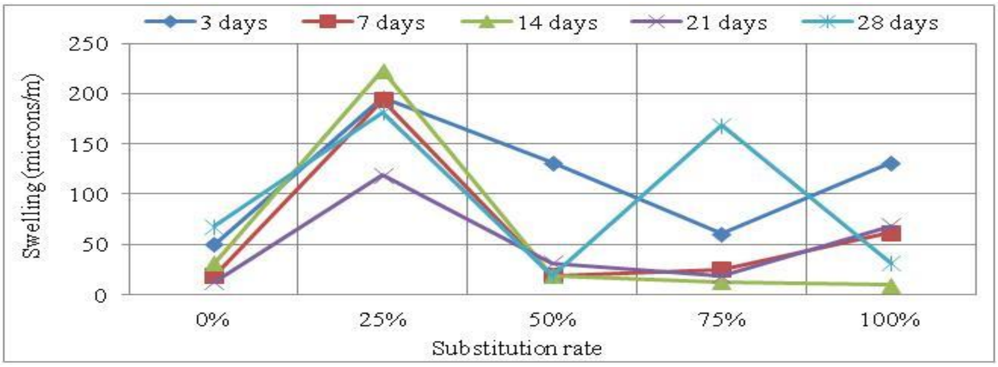

Fig. 7 Variation of the swelling versus the substitution rate

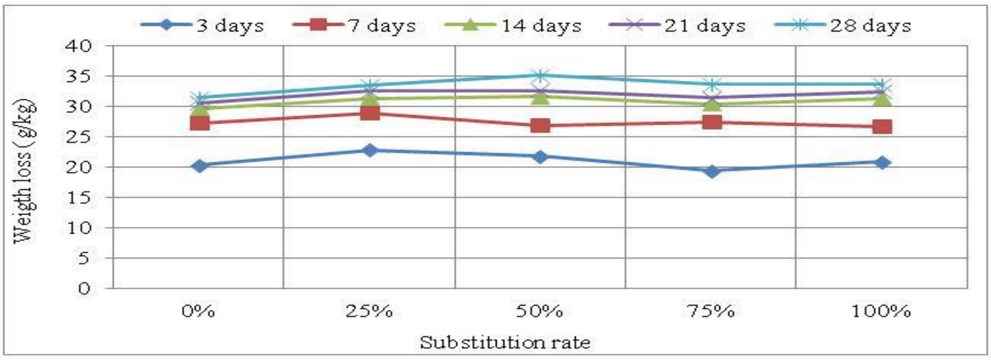

Fig. 8 Variation of weight loss versus the substitution rate

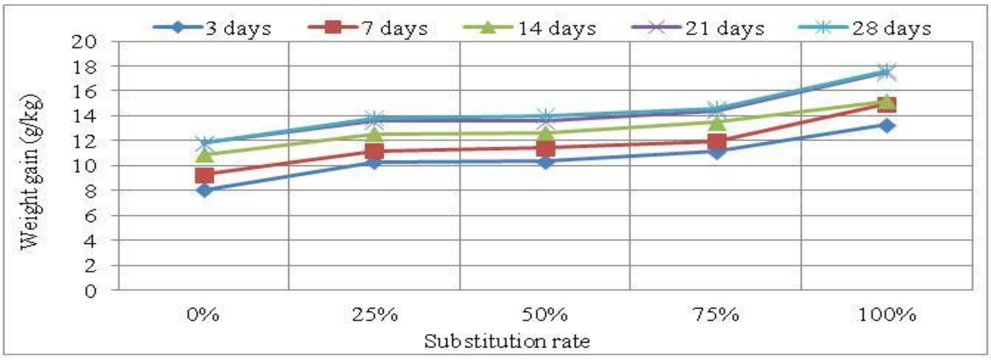

Fig. 9 Variation of weight gain versus the substitution rate

explains the increase in tensile strength depending on substitution rates (Fig. 5), with maximum strength obtained by the mortar of 100% substitution rate at short and medium term.

Shrinkage variations according to the substitution rate (Fig. 6) show that the introduction of recycled sand decreases the value of shrinkage from the first week. The variation according to age is more noticeable between 7 and 14 days and less important between 21and 28 days.

A substitution rate of 25% leads to an increase of swelling of the reference mortar (Fig.7). Beyond this value, the grading order of the mixtures is not respected neither for the substitution rate nor for age.

Fig. 8 shows the variation of weight loss versus the substitution rate. This variation is more pronounced between 3 and 7 days when compared with values obtained for 14, 21 and 28 days. Results show that the shrinkage is proportional with weight loss.

Graphics represented in Fig. 9 indicate a similar evolution independently from age, on the contrary, weight gain evolution according to age is relatively insignificant.

4. Conclusions

This work has focused on the possibility of recovering marble waste in mortars. It shows:

- The workability of the mortar decreases with the increasing degree of substitution of recycled sand.
- Recycled sand with a low fineness modulus value, speeds up hardening of young and fresh mortar samples.
- The best performance in compression and tension in bending is obtained for a 100% substitution rate at mean term (28 days with recycled sand).
- Both compressive and tensile strength in bending increase proportionally to time.
- The granularity of recycled aggregates provides a better cohesion with the matrix cement.
- The introduction of recycled sand leads to reduce shrinkage.

Results show that it is possible to produce mortars mainly with aggregates from recycled marble waste.

References

Akbulut, H. and Gurer, C. (2007), “Use of aggregates product from marble quarry waste in asphalt pavement”, *Build. Environ.*, **42**, 1921-30.

Azzouz, L., Bouhicha, M., Kenai, S. and Hadjoudja, M. (2000), “Recyclage des déchets de briques dans le béton de sable de dunes”, *Proceedings du 1er Colloque National de Génie Civil, Matériaux de Construction*, Université de Mostaganem, Algérie, Novembre.

Belachia, M., Aoun, H., Bensebti, S. and Hebhoub, H. (2008), “Use of marble waste in the composition of hydraulic concretes”. *In Seventh International Congress Concrete: Construction’s Sustainable, Option: Role for Concrete in Global Development*, UK.

Belachia, M., Aoun, H. and Hebhoub, H. (2006), “Marble wastes as a substitute in hydraulic concrete”, *Proceedings of the Twentieth International Conference on Solid Waste Technology*, Winder University, School of Engineering, USA.

Binici, H., Kaplan, H. and Yilmaz, S. (2007), “Influence of marble and limestone dusts as additives on some mechanical proprieties of concrete”, *Sci. Res.*, **9**, 372-9.

Binici, H., Shah, T., Aksogan, O. and Kaplan, H. (2008), “Durability of concrete made with granite and marble as recycle aggregates”, *J. Mater. Procs. Technol.*, **208**, 299-308.

Corinaldesi, V., Giacomo Moriconi, G. and Tarun, R.N. (2007), “Characterization of marble powder for its use in mortar and concrete”, *Constr. Build. Mater*, **21**, 1950-60.

Demirel, B. (2010), “The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete”, *Int. J. Phys. Sci.*, **5**(9), 1372-1380.

Dreux, G. and Feasta, J. (1995), “Nouveau guide du béton et de ses constituants”, Édition Eyrolles, Paris, France.

Erhan, G., Mehmet, G. and Erdogan, G. (2009), “Effect of marble powder and slag on the properties of self compacting mortars", *Mater. Struct.*, **42**, 813-826.

Hebhoub, H., Aoun, H., Belachia, M., Houari, H. and Ghorbel, E. (2010), "Use of waste marble aggregates in concrete", *Constr. Build. Mater.*, **25**, 1167-1171.

Hebhoub, H. (2011), "Recycled aggregate substitution for hydraulic concrete « marble waste»", PhD Thesis, Department of Civil engineering, Skikda University, Algeria.

Karaca, Z. and Elçi, H. (2008), "Using dimension stone quarry wastes as concrete aggregate", *Int. Conf. Const. Build. Tech. (ICCBT*), **A**(3), 45-56.

Rai, B., Naushad, H.K., Abhishek, Kr., Rushad, S.T. and Duggal, S.K. (2011), "Influence of marble powder /granules in concrete mix", *Int. J. Civil Struct. Eng.*, **1**(4), 828-834.

Saboya, F., Xavier, G.C. and Alexandre, J. (2007), "The use of the powder marble by product to enhance the proprieties of brick ceramic", *Constr. Build. Mater.*, **21**, 1950-60.