ISSN 1996-3394

Asian Journal of Materials Science

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research
http://knowledgiascientific.com

OPEN ACCESS Asian Journal of Materials Science

ISSN 1996-3394
DOI: 10.3923/ajmskr.2016.11.16

Research Article
Effect of Composition of Marble and Granite Waste on Mechanical Properties of Concrete

[1]C. Madivate, [1]A. Manhique, [2]H. Filimone and [3]M. Vieira

[1]Department of Chemistry, Eduardo Mondlane University, Maputo, Mozambique
[2]Laboratório de Engenharia de Moçambique, Maputo, Mozambique
[3]Laboratório Nacional de Engenharia Civil, Aveiro, Portugal

Abstract
As part of the increasing efforts to promote recycling or reutilization of residues generated from industrial activities, for environmental reasons, the effect of the partial replacement of sand was studied by (a) Marble reject samples, (b) Granite reject samples and (c) Mixtures of marbles and granite rejects with an unknown composition, resulting from processing of different marbles and granites, on the mechanical properties of concrete masses. With that aim, samples were collected, dried and grinded to obtain a grain similar to that of the sand used in preparation of concrete masses. Grinded samples were then used to prepare masses with a composition similar to the reference material, with content of residues varying from 10-40% sand replacement and compressive and flexural strength of prepared specimens measured. Compressive strength results of specimens with 28 days curing age were then statistically tested for eventual differences using ANOVA, with a confidence of 95%. Results for the compressive strength show a similar behaviour to that of the reference material, with compressive strength increasing with curing age. Granite residues show a much better performance than marble ones. This was attributed to granite composition which is closer to that of sand. Granite assayed between 50 and 60% of SiO_2 plus Al_2O_3. Agreement between results is more pronounced with increasing curing age. Addition of residues up to 30% give, in general, values of the compressive strength over the minimum value prescribed on the norm. Flexural strength gave, in general, results higher than conventional masses but more disperse.

Key words: Marble rejects, granite rejects, residues in mortars, concrete

Received: November 26, 2015 Accepted: December 05, 2015 Published: December 15, 2015

Citation: C. Madivate, A. Manhique, H. Filimone and M. Vieira, 2016. Effect of composition of marble and granite waste on mechanical properties of concrete. Asian J. Mater. Sci., 8: 11-16.

Corresponding Author: C. Madivate, Department of Chemistry, Faculty of Science, Eduardo Mondlane University, Avenida Julius Nyerere, No. 3453, P.O. Box 257, Main Campus, Maputo, Mozambique Tel: +25821493377

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Due to the increasing attention paid to environmental problems, there is an increasing effort to promote recycling or reutilization of residues generated from mining activities, agricultural and other industrial activities.

Recycling or reutilization of these rejects has the following advantages (Demir, 2006; Dominguez and Ulmann, 1996; Jordan *et al*., 2005; Monteiro and Vieira, 2005; Russ *et al*., 2005):

- Saving on non-renewable resources, through partial replacement of conventional raw materials by these rejects
- Saving of energy in case of residues with a potential use as fuel or residues which exhibit exothermic reactions during its processing
- Elimination of the costs associated with processing and removal of these residues
- Inactivation of toxic residues without the emission of vapours as occur in incinerators

The problem of waste generation has been also registered during processing of marbles and granites. To avoid its deposition and the resulting negative impact, efforts have been made to promote its reuse. A literature survey carried out show the use of marble and granite rejects in the production of mineral wool (Rodrigues *et al*., 2012), steel industry (Oliveira and Avelar, 2009) and production of soda-ash glasses with compositions similar to container glasses (Babisk, 2009). Goncalves (2000) and Demirel (2010) showed the beneficial effect of use of these rejects in concrete masses. Goncalves (2000) reported a beneficial effect by addition of rejects up to 10% while, Demirel (2010) reported improvement of the compressive strength when marble rejects in powder form are added. Tayeb *et al*. (2011) reported a beneficial effect on viscosity and consistency of concrete but a reduction of the compressive strength at 28 days age. Rai *et al*. (2011) studied the effect of replacement of cement and sand by marble rejects. They reported a beneficial effect on replacement of sand but an undesirable effect on replacement of cement.

In a study carried out at the Department of Chemistry (Madivate *et al*., 2012), the effect of residues was compared from sawing and polishing of marble and granite, obtained by PROMAR, main marble and granite processing company in Maputo, on the mechanical properties of a fired plastic clay, which is industrially processed under addition of a low plastic clay to reduce its plasticity and ensure its workability and improvement of mechanical properties. Obtained results showed a beneficial effect (better mechanical properties) independently of the composition and type of residue (no statistically significant differences were observed for the different additives). This is particularly important since residues from industrial processing of marble and granite at PROMAR are a mixture of marble and granite residues with a varying and unknown composition.

Inspired on the results of the study of the addition of the marble and granite rejects to the plastic clay, it is analyzed hereby the effect of the partial replacement of sand by (a) Marble reject samples, (b) Granite reject samples and (c) Mixtures of marbles and granite rejects with an unknown composition (slurry) resulting from processing of different marbles and granites on the mechanical properties of mortars.

MATERIALS AND METHODS

Marble and granite samples with extreme compositions and mixtures of marble and granite residues with unknown compositions were collected. Selection of the marble and granite samples was based on the chemical and mineralogical composition of the samples (Madivate *et al*., 2012). Samples were then dried and grinded to obtain a grain similar to that of the sand used in preparation of mortars.

Samples were then used to prepare masses with a composition similar to the reference material (mass without replacement of sand, with a mass proportion of cement: sand: water of 1:3:0.5, respectively), with contents of residues varying from 10-40% replaced sand. The maximum replacement of sand was maintained by 40% based on preliminary results obtained with mixtures of marble and granite residues with unknown composition and results reported by Goncalves (2000).

Prepared masses were then used to prepare cubic and prismatic specimens for the compressive strength and bending stress tests, based on the norm LNEC E 255.

Results of the compressive strength, main indicator to evaluate product quality of concrete, were tested for significant statistical differences.

RESULTS AND DISCUSSION

Table 1 shows the mineralogical composition of the marble and granite samples used in this study. Marbles are basically composed of dolomite and some calcite, while granites are mainly composed of biotite (0.0-60.23%), microcline (3.0-12.0%), plagioclase (31.0-67.0%) and quartz (1.0-72.0%).

Results obtained for the compressive strength show a similar behaviour to that of the reference material, with the compressive strength increasing with curing age (Fig. 1). Additions of 40% residue with undefined composition show values of the compressive strength lower than the ones with the reference material and the individual marble and granite additives, suggesting a maximum sand replacement of 30% corresponding to 20% residue on the concrete mass.

Similarity is more pronounced between the reference material and the granite residues, due probably to the more similar composition of granites, composed basically by aluminium silicates, with contents of SiO_2 plus Al_2O_3 between 50 and 60% and a hardness ranging 6-6.5 (Mohs scale). Silica sand has a closer composition and similar hardness. Marble residues showed slightly lower compressive strength compared to reference material as opposite to what was observed by Binici *et al.* (2008).

Agreement between results is more pronounced with increasing curing age, particularly for compressive strength (Fig. 2), showing a better performance at the highest curing age (28 days). Results of the flexural strength show, even after 28 days curing age, some dispersion of measured data. But on the other hand the relative flexural strength show for some compositions values higher than 100% (Fig. 3) compared to compressive strength that presents values slightly lower than the reference material but more uniform for the different additives (Fig. 4).

For a better assessment of the performance of the additives, relative values of the flexural and compressive strength, measured against the conventional mortar (with 0% additive) are presented in Fig. 5 and 6. Results of the flexural strength gave in general results higher that the ones of the conventional mortar, even for compositions with up to 40% additive, with the exception of the residues with the complex and unknown composition. Relative compressive strength show values slightly below 100%, with granites showing the best values, with values ranging from 97-99% of the conventional mortar. The residues with complex and unknown composition show the poorest performance with 96 at 10% substitution and a decrease to 91 and 88% for 20 and 30% substituted sand.

Results obtained by Gonçalves (2000), Almeida *et al.* (2007) and Aliabdo *et al.* (2014) are similar to the ones obtained for the residues with unknown composition, with an increase or negligible reduction of the compressive strength by additions up to 10% and a decrease from 15% onwards. Hebhoub *et al.* (2011) reported a beneficial effect by substitution of natural aggregates by waste marble up to 75% addition, result much higher than the results obtained in this study, when working with the same cement type as used in

Table 1: Mineralogical composition of marble and granite samples used in this study

Minerals	GG	GP	GC	MB	MC
Calcite	1.29	0.00	2.04	3.29	9.34
Dolomite	0.00	0.00	0.00	92.27	74.81
Biotite	21.53	0.00	10.37	0.00	0.00
Chlorite	2.03	0.00	0.00	0.00	0.00
Diopside	3.07	8.26	6.80	0.00	0.00
Entstatite	0.00	14.31	0.00	0.00	0.00
Hornblende	0.00	0.00	0.00	0.00	12.85
Magnetite	0.00	1.85	0.00	0.00	0.00
Microcline	31.33	4.08	17.70	0.00	0.00
Muscovite	0.00	2.24	0.00	0.00	0.00
Plagioclase	17.42	67.69	31.47	4.45	3.00
Quartz	23.33	1.58	31.63	0.00	0.00

GG: Grey granite, GP: Black granite, GC: Granite castanho, MB: Marble branco, MC: Marble cinzento

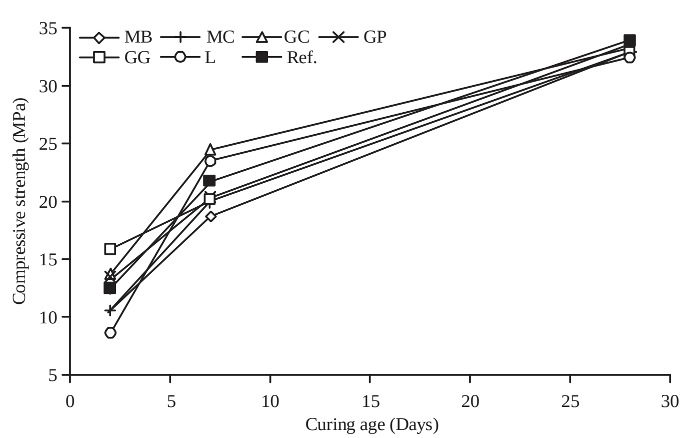

Fig. 1: Compressive strength of mortar with 10% additive, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite, L: Mud and Ref.: Reference material

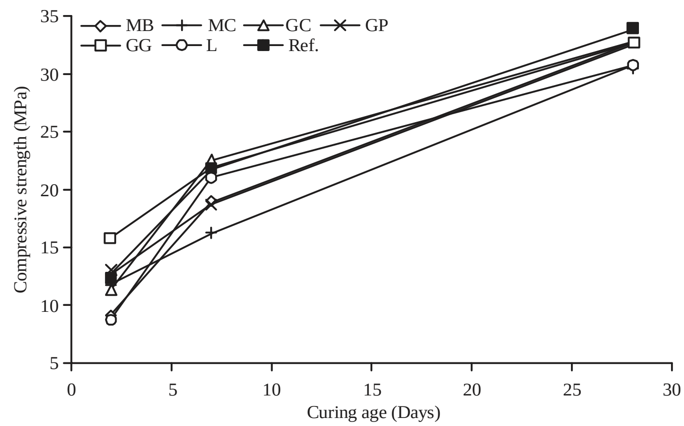

Fig. 2: Compressive strength of mortar with 20% additive, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite, L: Mud and Ref.: Reference material

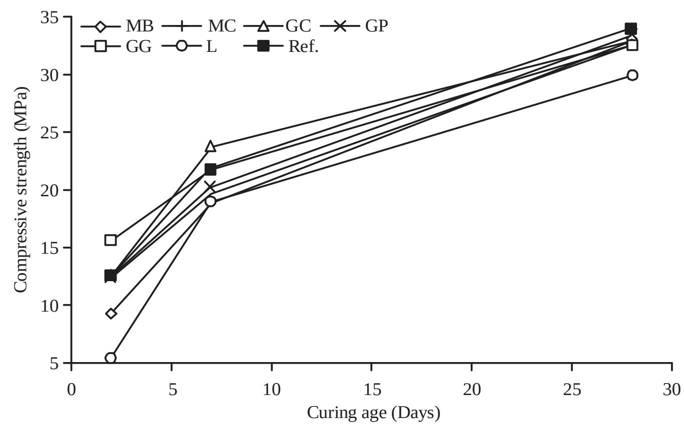

Fig. 3: Compressive strength of mortar with 30% additive, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite, L: Mud and Ref.: Reference material

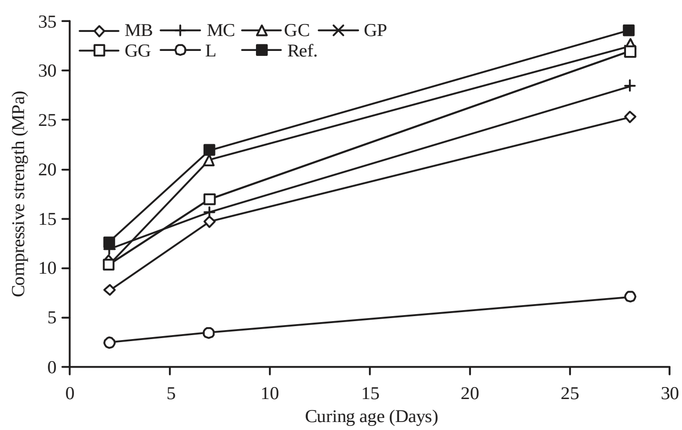

Fig. 4: Compressive strength of mortar with 40% additive, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite, L: Mud and Ref.: Reference material

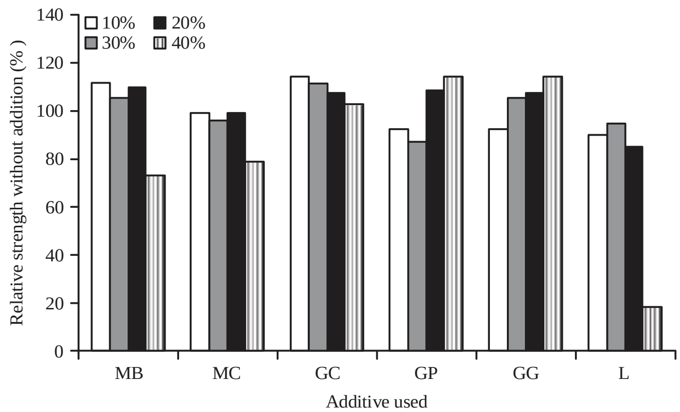

Fig. 5: Flexural strength of the mortars with different amounts of marble and granite additives at 28 days of cure, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite and L: Mud

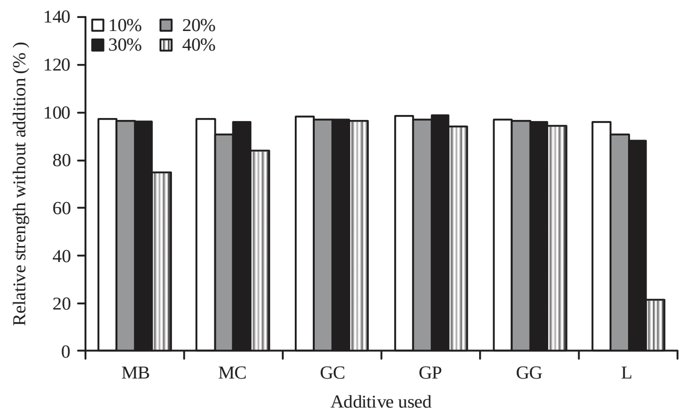

Fig. 6: Compressive strength of the mortars with different amounts of marble and granite additives at 28 days of cure, MB: White marble, MC: Grey marble, GC: Brown granite, GP: Black granite, GG: Grey granite and L: Mud

our study (the 32.5 cement-ASTM type II). Bacarji *et al*. (2013) reported a negligible reduction or slightly increase in the interval up to 50% substitution but significant decrease at values higher than 50%, with small differences on compositions with different water: cement ratios.

Hameed and Sekar (2009) and Demirel (2010) reported an increase of the compressive strength in the entire interval (0-100%). Hameed and Sekar (2009) replaced completely sand by mixtures of quarry rock dust and marble sludge powder and found that maximum strength was obtained at 50% quarry rock dust and 50% marble sludge powder, while, Demirel (2010) reported a continuous increase of the progressive strength during substitution of fine aggregate by 25, 50 and 100% marble dust. These results are not in agreement with results from Kou *et al*. (2011) who reported a reduction of the compressive strength by nearly 20% when natural aggregates are totally replaced by recycled aggregates.

Results presented do not show a clear difference between results obtained with samples prepared with a 32.5 or a 42.5 N cement and further studies should be made to clarify the effect of using different types of cement on properties of the obtained mortars and concrete.

Statistical analysis of the results of the compressive strength show in general some significant statistical differences between the results, in the entire interval (0-40%) but results of the compressive strength obtained in the interval 0-30% are within compressive strength values prescribed for these materials according to the norm NM NP EN 197-1, 2005, results that support use of these residues as partial sand replacement up to 30% replaced sand, with some exceptions for the residues with varying and unknown composition which gave good results for a maximum of 10% replacement, similar to the results obtained by Goncalves (2000), Almeida *et al*. (2007) and Aliabdo *et al*. (2014).

CONCLUSION

Although, statistical analysis of the compressive strength of masses with added residues show significant differences, when compared to the conventional mass, results of the compressive strength presented hereby show practicability of replacement of sand by generated residues up to a limit of 30% additive (nearly 20% of residue in the mass), with values of the compressive strength above the minimum value prescribed in relevant norms.

Differences observed on results with samples using the 32.5 and the 42.5 cement are not necessarily explained by the difference in cement type. Further studies are required with samples using same residues and similar compositions; to see in as far difference of cement type influences the results.

ACKNOWLEDGMENT

The authors wish to acknowledge the financial support from SIDA, from the Swedish government, to PROMAR for the availability of samples and LEM-Mozambique for the technical support.

REFERENCES

Aliabdo, A.A., A.E.M. Abd Elmoaty and E.M. Auda, 2014. Re-use of waste marble dust in the production of cement and concrete. Constr. Build. Mater., 50: 28-41.

Almeida, N., F. Branco and J.R. Santos, 2007. Recycling of stone slurry in industrial activities: Application to concrete mixtures. Build. Environ., 42: 810-819.

Babisk, M.P., 2009. [Development of soda-calcic glasses from ornamental rocks waste]. M.Sc. Thesis, Instituto Militar de Engenharia, Rio de Janeiro, Brasil, (In Portuguese).

Bacarji, E., R.D. Toledo Filho, E.A.B. Koenders, E.P. Figueiredo and J.L.M.P. Lopes, 2013. Sustainability perspective of marble and granite residues as concrete fillers. Constr. Build. Mater., 45: 1-10.

Binici, H., T. Shah, O. Aksogan and H. Kaplan, 2008. Durability of concrete made with granite and marble as recycle aggregates. J. Mater. Process. Technol., 208: 299-308.

Demir, I., 2006. An investigation on the production of construction brick with processed waste tea. Build. Environ., 41: 1274-1278.

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: 1372-1380.

Dominguez, E.A. and R. Ullman, 1996. Ecological bricks made with clays and steel dust pollutants. Applied Clay Sci., 11: 237-249.

Goncalves, J.P., 2000. [Use of granite cutting residues as additives in concrete production]. M.Sc. Thesis, Universidade Federal do Rio Grande do Sul, Brasil, (In Portuguese).

Hameed, M.S. and A.S.S. Sekar, 2009. Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate. ARPN J. Eng. Applied Sci., 4: 83-89.

Hebhoub, H., H. Aoun, M. Belachia, H. Houari and E. Ghorbel, 2011. Use of waste marble aggregates in concrete. Constr. Build. Mater., 25: 1167-1171.

Jordan, M.M., M.B. Almendro-Candel, M. Romero and J.M. Rincon, 2005. Application of sewage sludge in the manufacturing of ceramic tile bodies. Applied Clay Sci., 30: 219-224.

Kou, S.C., C.S. Poon and M. Etxeberria, 2011. Influence of recycled aggregates on long term mechanical properties and pore size distribution of concrete. Cem. Concr. Compos., 33: 286-291.

Madivate, C., R. Manjate, H. Filimone, H. Muiambo and A. Manhique, 2012. Reutilization of solid waste from ornamental rocks processing. Mol. Cryst. Liquid Cryst., 555: 129-137.

Monteiro, S.N. and C.M.F. Vieira, 2005. Effect of oily waste addition to clay ceramic. Ceram. Int., 31: 353-358.

Oliveira, J.R. and L.M. Avellar, 2009. [Use of marble cutting residues on the production of pellets for iron-foundry]. Proceedings of the II Jornada de Iniciacao em Desenvolvimento Tecnologico e Inovacao do IFES, October 21-22, 2009, Brasil, (In Portuguese).

Rai, B., N.H. Khan, K. Abhishek, S.T. Rushad and S.K. Duggal, 2011. Influence of marble powder/granules in concrete mix. Int. J. Civil Struct. Eng., 1: 827-834.

Rodrigues, G.F., J.O. Alves, J.A.S. Tenorio and D.C.R. Espinosa, 2012. [Manufacture of mineral wool from slag of ferroalloy production FeSiMn]. Ceramica, 58: 529-533, (In Portuguese).

Russ, W., H. Mortel and R. Meyer-Pittroff, 2005. Application of spent grains to increase porosity in bricks. Constr. Build. Mater., 19: 117-126.

Tayeb, B., B. Abdelbaki, B. Madani and L. Mohamed, 2011. Effect of marble powder on the properties of self-compacting sand concrete. Open Constr. Build. Technol. J., 5: 25-29.