VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

STUDIES UNDERTAKEN TO INCORPORATE MARBLE AND GRANITE WASTES IN GREEN CONCRETE PRODUCTION

Garas G. L., Allam M. E. and Bakhoum E. S.
Department of Civil Engineering, National Research Centre, Egypt
E-Mail: gihangaras@yahoo.com

ABSTRACT

In the last 15 years marble, granite and natural stones wastes were estimated in Egypt as 100 million ton. These wastes were accumulated in wide areas that have a potential for new quarries thus hinder the sustainable development in the quarry areas. This study presents efforts undertaken in Egypt as well as other stone producing countries with an aim to adopt new ideas of re-using these wastes in the production of green concrete. Several attempts concluded the advantage of substituting these wastes to sand and cement in the concrete mix. Wastes improved the physical and mechanical properties of concrete due to its high fineness which provided good cohesiveness of concrete. Many tests revealed that 10% substitution of sand by the marble waste in the presence of a super-plasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing. Regarding higher contents of stone slurry (substitution of more than 20% of sand), the decrease of compressive strength values was significant. Concrete mixes containing 30% red granite dust showed comparable compressive strength using natural or recycled aggregates, good workability, and excellent reddish colored surface finish. In general, the use of marble dust as sand replacement has more significant effect on the mechanical properties of concrete compared with using it as cement replacement.

Keywords: green concrete, marble, granite, lime stone waste, compressive strength, re-use.

1. INTRODUCTION

Concrete has been a leading construction material for over a century: its annual global production is about 3.8 billion m^3 - roughly 1.5 tonnes per capita - according to Portland Cement Association data (Portland Cement Association).

In the past few years, great awareness has risen towards green concrete as it enhances sustainable development. Green concrete is characterized by application of industrial wastes to reduce consumption of natural resources, save energy and minimize pollution of the environment. Among the enormous varieties of industrial wastes there are the marble and granite wastes. These wastes can be used as a filler (substituting sand) to reduce the total voids content in concrete and/or pozzolanic material (substituting cement) in the concrete mix while maintaining its physical and mechanical properties.

2. BACKGROUND OF PROBLEM IN EGYPT

Egypt produces over 25 different types of marble and ranks as the 5th among the world's leading producers of marble preceded by Italy, Spain, Turkey and Iran (Ciccu R *et al*, 2005). The marble and granite industry in Egypt showed a tremendous development in the last 16 years, Investments of more than 9 billion Egyptian pounds (1.28 Billion US dollars) were inducted in this industry and the result is that Egypt occupy the Fifth order among the stone producing countries and has the fourth marble and granite industrial area (Shaq El Thoaban, East of Cairo) among the world. The great demand for the Egyptian stones in the international markets resulted in producing the required quantities regardless of their quality. The only possible way of producing these amounts was through using conventional quarrying methods (explosion) which has a destructive effect on the quarry site and cause huge wastes (> 66 %), which are accumulated in the areas near the quarries and has a negative effect on the sustainable development of those quarry sites. Inadequate studies were conducted on the full characterization of these wastes with an aim to reuse it.

Marble and granite processing lines in the factories produce also huge amounts of wastes either solid wasted (results from shaping of the irregular block and cutting slabs) or liquid wastes (slurry, resulted from sawing the blocks to slabs and grinding processes). All these wastes are thrown away in the areas near the factories (irrespective of their possible economic values) and cause severe environmental problems.

In the last 15 years wastes estimated in Egypt as 100 million ton are accumulated in the quarry areas and occupying wide areas that have a potential for new quarries which hinders the sustainable development in the quarry areas. Also the wastes accumulated in the areas near the marble and granite factories due to the unmanaged waste disposal processes formed areas of pollution of the air, soil and water in the nearby industrial, agricultural and domestic areas (Ciccu R *et al*, 2005). This major environmental problem encouraged researchers in Egypt to conduct some preliminary attempts to manage the huge amounts of waste in this industry. The main objective of these studies as well as others conducted worldwide was to re-use the stone wastes in concrete mixes in limited proportions while maintaining its mechanical and physical properties.

3. REVIEW OF STUDIES CONDUCTED IN EGYPT

In Egypt, Omar M. *et al*, 2012, conducted an experimental study to investigate the influence of partial replacement of sand with limestone waste (LSW), as well as marble powder (M.P) as an additive on the concrete properties. The replacement proportion of sand with limestone waste was practiced in the concrete mixes with proportions 25%, 50%, 75%. Besides, proportions of 5%, 10% and 15% marble powder were practiced in the concrete mixes. The program consisted of two phases. Phase I, with cement content 350 kg/m^3. One mix was control (normal concrete mix), and three mixes incorporating lime stone waste of 25 %, 50% and 75% replacement for sand only. In addition, twelve mixes incorporating limestone waste of 25%, 50% and 75% replacement for sand together with marble powder as additive by 5, 10 and 15% of cement weight. Phase II, the above experiment is repeated with the same components but with different content of cement. This content is 450 kg/m^3. The mechanical properties of green concrete were measured in term of compressive strength, indirect tensile (splitting tensile), flexural strengths, static modulus of elasticity test, and permeability test. The properties were measured at age 28 days for indirect tensile (splitting tensile) flexural strengths, static modulus of elasticity test, and permeability test. As for compressive strength, it was measured at 7, 28 and 90 days. Materials used consisted of natural siliceous sand, crushed stone from Suez area, ordinary Portland cement OPC Suez Cement Company, tap drinking water, marble powder, chemical admixture, limestone waste from Suez area. Testing of these materials was carried out according to Egyptian standard specification. A super plasticizer was used. Marble powder is brought from factories of Egyptian marble company.

The study concluded that the workability of green concrete was not affected by the addition of LSW to the concrete mix while the compressive strength increased by 12% after 28days when using LSW up to 50% of sand replacement. Increasing the cement content from 350 to 450 kg/m^3 increased the compressive strength by 6% after 28 days. Presence of marble powder with LSW (up to 50%) increased the compressive strength in the mixes with low cement content (350kg/cm^3) about7%. Indirect tensile strength increased about 17% when using 50 % LSW and 15 % M.P with different cement content.

Another study in Egypt was reported by Ali A. *et al*, 2014, to investigate the possibility of using waste marble dust generated during cutting and polishing process -in marble factories- in cement and concrete production. The research work was divided into two sections. The first section dealt with the properties of cement modified with marble dust (marble dust blended cement), whereas the second section discussed the properties of concrete that contained marble dust as cement and sand replacement (cement addition). Water to powder ratio (w/p) or water to cement ratio (w/c) were 0.50 and 0.40 in case of cement replacement and in case of sand replacement respectively. Physical, mechanical and chemical properties of cement and concrete modified with marble dust were investigated. Also, the effect of marble dust addition on the internal microstructure and hydration products of paste samples were also investigated.

Testing specimens were prepared by blending marble dust with cement and sand in 0.0%, 5.0%, 7.5%, 10.0% and 15.0% replacement ratios by weight. Ordinary Portland cement CEM I 42.5 N was used which complies with the ASTM C150. Natural siliceous sand with fineness modulus of 2.35 and crushed pink lime stone with nominal maximum size of 19.0 mm was used. Marble dust used was obtained in wet form as slurry; from marble factories as a by-product resulted from marble cutting and shaping process; therefore it was dried in an oven in the laboratory then manually sieved through sieve No. 200. For control mixtures, cement content was taken as 400 kg/m^3, for marble dust modified concrete, cement content varied according to replacement ratios of marble dust. Physical properties, mechanical properties, X-ray diffraction (XRD), thermo gravimetric analysis (TGA) and scanning electron microscope (SEM) were investigated for marble dust blended cement.

This intensive study revealed that the compressive strength of concrete made with 15.0% marble dust as cement has been found to be either comparable or less than control mix. In addition, the concrete compressive strength increases with the increase of marble dust ratio as sand replacement up to 15.0% of sand by weight. In general, the use of marble dust as sand replacement is more effective with lower w/c ratio.

Table-1 presents the chemical analysis of marble wastes of the two studies conducted in Egypt. The calcium oxide value reported by Abd Elmoaty M. *et al*, 2014 was 83.22% which is considered an odd value especially that the marble usually contains a percentage of calcium oxide ranging between 40-55%.

Table-1. Chemical analysis of marble waste used in Egyptian studies.

Author	CaO	SiO_2	Fe_2O_3	MgO	Al_2O_3	SO_3	Na_2O	LOI	K_2O
Omar M. et al, 2012	42.14	14.08	1.94	2.77	2.69	-	0.91	-	0.63
Ali A. et al, 2014	83.22	1.12	0.05	0.52	0.73	0.56	1.12	2.5	0.09

4. INTERNATIONAL RESEARCH FOR RE-USE OF MARBLE/GRANITE WASTE IN MORTAR AND CONCRETE

Many studies have been carried out in different countries to use marble/granite waste in mortar and concrete. Most of these researches used marble, granite and lime stone waste as a replacement of cement or sand in concrete mix.

4.1. Marble waste and natural stone slurry substitution

4.1.1. Sand replacement

Almeida, N., Branco F., and Santos, J., (2007) presented an overview of solutions and the results of a research project where natural stone slurry was used to replace fine aggregates in concrete mixtures. The concrete mechanical properties were investigated and the technical viability of this new construction material was illustrated. Eight concrete mixtures with stone slurry were produced substituting 0% (reference mixture), 5%, 10%, 15%, 20%, 34%, 67% and 100% of the volume of fine aggregate. The collected specimens processed only marble and limestone. The studied properties were compressive strength at 7 and 28 days of age, splitting tensile strength and modulus of elasticity. It was found that at 5% sand replacement by stone slurry, 10.3% higher compressive strength after 7 days, and 7.1% after 28 days when compared with reference mixture. This increase can be related to the higher concentration of hydrated cement compounds within the available space for them to occupy. At 10%, 15%, 20% presented a reduction of compressive strength ranging from 3.6% to 10.6% at 7 days of age, and from 6.7% to 8.9% at 28 days of age (when compared to 0%). Regarding higher contents of stone slurry (substitution of more than 20% of sand), the decrease of compressive strength values was significant. When substituting all the sand for stone slurry (100%), test results showed 50.3MPa at 28 days and 30.1MPa at 7 days. The relative reduction amounted to 40.9% for 28 days and 50.1% for 7 days. The benefits obtained in compressive strength property due to the microfiller effect induced by stone slurry particles was even further important regarding the splitting tensile strength tests (relative increase of 14.3% detected for 5% substitution). The results showed that the substitution of 5% of the sand content by stone slurry induced higher compressive strength, higher splitting tensile strength and higher modulus of elasticity.

In a later study, Hameed, M., and Sekar, A., (2009) presented the feasibility of the usage of quarry rock dust and marble sludge powder as 100% substitutes for natural sand in concrete. It was found that the compressive, split tensile strength and durability studies of concrete made of quarry rock dust are nearly 14 % more than the conventional concrete. The concrete resistance to sulphate attack was enhanced greatly. It was found that the compressive strengths of green concrete at 7 and 28 days were 6.49% and 9.49% higher than controlled concrete respectively. All the experimental data showed that the addition of the industrial wastes improves the physical and mechanical properties due to its high fineness of the marble sludge powder it provided to be very effective in assuring very good cohesiveness of concrete. Replacement of fine aggregate with 50% marble sludge powder and 50% Quarry rock dust (Green concrete) gave an excellent result in strength aspect and quality aspect. However, increase the marble sludge powder content by more than 50% improved the workability but affected the compressive and split tensile strength of concrete.

In a more recent attempt, Valeria C. *et al*., (2010) studied the characterization of marble powder for its use in mortar and concrete. In this study very fine marble powder obtained as a by-product of marble sawing and shaping was used. Due to its high fineness, marble powder showed a filler effect (particularly important at early ages) and did not play any noticeable role in the hydration process. The filler effect was enhanced when marble powder was used together with a super-plasticizing admixture. In terms of mechanical performance, the tests revealed that 10% substitution of sand by the marble powder in the presence of a super-plasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing.

Demirel, B., (2010) reached the same results as the concrete compressive strength increased approximately 10 and 5% at 28 and 90 days respectively when adding marble waste dust. This result was explained that as the curing age increased, its contribution to the compressive strength of the marble waste dust is reduced. As curing time increases, the waste contribution to the compressive strength decreases.

Similarly, another attempt to study the effect of using marble powder and granules as constituents of fines in mortar and concrete was conducted by Rai, B., *et al*., (2011). In mortar mixes, when marble waste granules were partially replaced in fine aggregate by weight, there was an increase in compressive strength at each curing age up to 15% replacement of fine aggregate with marble granules. Rai B. *et al* attributed this result to the fact that marble granules have cementing properties. On increasing the percentage replacement beyond 10%, there was a slight reduction in the compressive strength value. Furthermore, the mean strength of concrete mixes with marble granules was 5-10% higher than the reference concretes. However, there is a slight decrease in compressive strength value of concrete mix when 20% marble granule is used as compared with that of 15% marble granule mix. Similar results have been reported earlier by Binici *et al*, (2007) and Patel, N., Raval, A., and Pitroda, J., (2013).

To the contrary of all previous research, Hebhoub, H., *et al*., (2011) demonstrated the possibility of using marble wastes as a substitute rather than natural aggregates in concrete production from another point of view. The results showed that natural aggregates are harder than the recycled ones. The recycled aggregates had a higher carbonate content than the natural ones which improves the aggregate-cement paste bond. Hebhoub observed that the substitution of natural aggregates by waste marble aggregates up to 75% of any formulation is beneficial for the concrete resistance. The main critical parameter in the workability was that natural aggregates absorb more water than waste marble aggregates. Therefore, the correct quantity of water required for the mixes needed correction and depended on the mix proportions. Compressive and tensile strength with the substitution rate of 25%, 50% and 75% were fairly greater than values obtained with natural aggregates. The results showed that the concrete with 100% substitution rate provided poor results in strength.

Table-2 presents the chemical analysis of marble waste samples conducted by researchers in various stone producing countries. All results reported indicated typical chemical constituents except for the study conducted in India by Hameed, M., and Sekar, A., (2009). In this study the marble sludge powder contained 64.86% SiO2 and 1.58% CaO which is considered more likely a granite sample rather than a marble sample.

Table-2. Chemical analysis of marble waste.

Author	CaO	SiO_2	Fe_2O_3	MgO	Al_2O_3	SO_3	Na_2O	LOI	K_2O	Ca SO_3	MnO
Almeida N., Branco F., and Santos J., 2007	54.29	0.91	0.4	0.3	3.72	0.09	-	43.4	-	-	-
Binici et al, 2007	50.13	5.1	1.98	2.72	0.4	-	0.04	35.5	0.09	6.32	-
Hameed, M., and Sekar, A., 2009	1.58	64.86	11.99	8.74	4.45	-	2.08	-	2.33	-	0.08
Alzboon, K., and Mahasneh, K., 2009	54.22	0.83	0.11	0.91	0.21	0.11	-	43.6	-	-	-
Demirel, B., 2010	40.45	28.35	9.7	16.25	0.42	-	-	-	-	-	-
Hebhoub, H., et al., 2011	54.86	0.15	0.04	1.03	0.08	-	-	-	-	-	-
Patel, N., Raval, A., and Pitroda, J., 2013	49.07	1.69	0.21	4.47	1.04	-	-	43.46	-	-	-

4.1.2. Cement replacement

Alzboon, K., and Mahasneh, K., 2009 studied the possible use of stone cutting sludge waste as a source of water in concrete production. Samples of sludge were collected and analyzed to determine sludge characteristics: water content, size distribution, density, total suspended solid (TSS), total volatile solid (TVS), and chemical composition by using X-ray diffraction method. Ratios of slurry sludge to the total amount of water 100% 75%, 50%, and 25% were used, in addition to the reference sample (clean water). It was found that there was a great compositional difference in sludge derived from different cutting processes. This variation in the mineralogical and chemical composition of the sludge was attributed to the variation in the type and origin of rocks. Water contents in the slurry samples ranged from 95.1 to 99.4%, so the sludge was considered as a significant source of water. Sludge contained high quantity of calcium oxide (54.22%) while undetectable limit of K2O, Cl were found. In addition, small amount of silica, ferric oxide, aluminum oxide and volatile solid were detected. The high content of CaO confirmed that the original stones were marble and limestone. Results showed that the compression strengths of all samples were complying with the standard. In comparison with the reference sample, there was insignificant variation in compression strength values of all samples due to the fact that the suspended particles represent less than 3% of the slurry sludge volume. The research work showed that the sludge generated from the stone cutting processes can be regarded as a source of water used in concrete mixes. Results indicated that the using of slurry sludge as a source of water in concrete production has insignificant effect on compression strength, while it has a sharp effect on the slump values.

However, Valeria C. *et al*., (2010) indicated a decrease in compression strength of 20% than control mix using a substitute of 10% of cement by marble powder in the presence of a super-plasticizing admixture.

4.2. Granite waste

Abukersh, S. and Fairfield, C., (2011) assessed red granite dust (RGD)arising from the rock-crushing process for suitability as a replacement for up to 30% by mass of the cement content of structural grade concretes made with recycled coarse aggregates. The characteristic, 28 day, compressive strength of the authors' natural aggregate control concrete was 50 N mm^2 yielded the following proportions (per m^3 of fresh concrete): a free w/c ratio of 0.4, a cement content of 425 kg, a water content of 170 kg, a fine aggregate content of 545 kg and a coarse aggregate content of 1280 kg. The recycled aggregate concrete (RAC), based on the natural aggregate control concrete was modified to account for the properties of the recycled aggregate, differed slightly in that it had a free w/c ratio of 0.4, a cement content of 425 kg, a water content of 170 kg, a fine aggregate content of 530 kg and a coarse aggregate content of 1235 kg. The cement was replaced by RGD with 10, 20, 30, 40, and 50%.

The chemical analysis of RGD was shown in Table-4. It was investigated that the sum of ferric oxide (Fe2O3), alumina (Al_2O_3) and silica (SiO_2) must be at least 70% in pulverized fuel ash PFA for possible use in concrete: the sum of these oxides is over 80% in the chosen RGD, leading to the belief that it may be useful for concrete mixes and It must be noted that the RGD's high silica and alumina contents suggested a potential pozzolanic reaction. Substantial quantities of RGD, estimated at between 1% and 2% by mass of the total aggregate crushed, are produced in quarries. This RGD is currently disposed of as waste: its large-scale use as a cement replacement in concrete mixes could therefore be beneficial. The RGD's physical and chemical properties exhibited similarities to PFA allowing mix design to proceed along well-established lines. The results showed that natural aggregate concretes produced with RGD at 30% cement replacement level had strengths either comparable to, or better than, equivalent control mixes, although they were marginally weaker than similar PFA-

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

based concretes. An equal, or improved, modulus of elasticity ensued.

In the same way, recycled aggregate concretes with 30% RGD showed strengths comparable to equivalent PFA-based concretes: in these cases a higher elastic modulus was achieved with the RA concretes. Concrete mixes containing 30% RGD showed good workability, better than expected mechanical properties and excellent (albeit reddish coloured) surface finish. Concrete with 30% RGD demonstrated better early age strength than similar PFA-based concrete. Any RGD addition beyond 30% caused a decrease in strength, although the mechanical properties remained acceptable at up to and including 50% RGD-for-cement replacement.

Table-3. Chemical analysis of granite waste.

Author	CaO	SiO_2	Fe_2O_3	MgO	Al_2O_3	SO_3	Na_2O	LOI	K_2O	Ca SO_3	MnO	CL
Abukersh, S. and Fairfield, C., 2011	3.69	61.4	3.66	1.7	16.3	0.05	3.62	5.01	3.75	-	-	-

5. CONCLUSION AND RECOMMENDATIONS

Based on the analysis of studies undertaken by researchers in various stone producing countries to re-use the marble and granite waste in mortar and concrete mixes to produce green concrete, it can be concluded that:

- Although several researchers had undertaken efforts in re-using marble in concrete from different points of view, rare researches were conducted on granite wastes either in the quarry stage or during the processing stages especially in Egypt. Therefore, it is recommended to make more future efforts to study the effects of using granite waste in concrete properties.
- Using marble and granite waste in concrete mix proved to be very useful to solve environmental problems and produce green concrete. Therefore, it is recommended to re-use these wastes in concrete to move towards sustainable development in construction industry.
- Marble and granite waste can replace cement and/or fine aggregate in concrete or mortar mixes with different percentages due to its high fineness which provides good cohesiveness of the mix.
- Many tests revealed that 10% substitution of sand by marble waste in the presence of a super-plasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing. Regarding higher contents of stone slurry (substitution of more than 20% of sand), the decrease of compressive strength values was significant.
- Using marble and granite waste increases the workability of concrete. Permeability tests demonstrated that the permeability of green concrete (using marble waste) is less compared to that of conventional concrete.
- The increase in the marble dust content caused significant increase in the sodium sulphate resistance of the concrete produced thus more durability properties. In addition, due to its high fineness (i.e., high specific surface area), marble dust improved cohesiveness of mortar and concrete especially in the presence of a super plasticizing admixture.
- Green concrete produced using natural or recycled aggregate with 30% red granite dust RGD replacement of cement had strengths comparable to or better than, equivalent control mixes.
- Concrete mixes containing 30% RGD showed good workability, better mechanical properties excellent (albeit reddish colored) surface finish and better early age strength than similar PFA-based concrete.
- Finally, it was very difficult to make an accurate comparison between the results of previous studies due to the:
- Different origins of materials used whether marble, natural stones or granite wastes as each type had its own chemical and physical properties although each fall in the same range of chemical constituents
- Difference in the tests conditions due to the variety of objectives studied. For example, marble waste can be used as a powder or slurry, and can be dried in oven or used as its original case (as delivered from the factory or quarry).

REFERENCES

Ciccu R, Cosentino R, Montani C C, El Kotb A and Hamdy H. 2005. Strategic Study on the Egyptian Marble and Granite Sector (Industrial Modernisation Centre Ref-PS_1).

Almeida N., Branco F. and Santos J. 2007. Recycling of stone slurry in industrial activities: Application to concrete mixtures. Building and Environment. (42): 810-819.

Binici et al. 2007. Influence of marble and limestone dusts as additives on some mechanical properties of concrete. Scientific Research and Essay. 2(9): 372-379.

Alzboon K. and Mahasneh K. 2009. Effect of Using Stone Cutting Waste on the Compression Strength and Slump Characteristics of Concrete. International Journal of Environmental Science and Engineering. 1(4).

Hameed M. and Sekar A. 2009. Properties of Green Concrete Containing Quarry Rock Dust and Marble Sludge Powder as Fine Aggregate. ARPN Journal of Engineering and Applied Sciences. 4(4): 83-89.

Demirel B. 2010. The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete. International Journal of the Physical Sciences. 5(9): 1372-1380.

Valeria C. *et al*., 2010. Characterization of marble powder for its use in mortar and concrete. Construction and Building Materials. (24): 113-117.

Abukersh S. and Fairfield C. 2011. Recycled aggregate concrete produced with red granite dust as a partial cement replacement. Construction and Building Materials.

Hebhoub H., *et al*. 2011. Use of waste marble aggregates in concrete. Construction and Building Materials. (25): 1167-1171.

Rai B., *et al*. 2011. Influence of Marble powder/granules in Concrete mix. International Journal of Civil and Structural Engineering. 1(4).

Omar M. *et al*. 2012. Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties. Housing and Building National Research Center Journal. (8): 193-203.

Patel N., Raval A. and Pitroda J. 2013. Marble Waste: Opportunities for Development of Low Cost Concrete. Global Research Analysis. 2(2).

Ali A. *et al*. 2014. Re-use of waste marble dust in the production of cement and concrete. Construction and Building Materials. (50): 28-41.

Portland Cement Association. Cement and concrete basics. PCA on-line. Skokie, Illinois, USA: PCA http://www.cement.org/basics/concretebasics_lessononec.asp.