2011 International Conference on Environment and BioScience
IPCBEE vol.21 (2011) © (2011) IACSIT Press, Singapore

Utilization of Marble and Granite Waste in Concrete Bricks

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Abstract. Marble and granite industry has grown significantly in the last decades with the privatization trend in the early 1990s, and the flourishing construction industry in Egypt. Accordingly, the amount of mining and processing waste has increased. Stone waste is generally a highly polluting waste due to both its highly alkaline nature, and its manufacturing and processing techniques, which impose a health threat to the surroundings. Shaq Al-Thu`ban industrial cluster, the largest marble and granite industrial cluster in Egypt is imposing an alarming threat to the surrounding communities, Zahraa El-Maadi residential area, and the ecology of the neighboring Wadi Degla protectorate. The objective of this paper is to utilize marble and granite waste of different sizes in the manufacturing of concrete bricks, with full replacement of conventional coarse and fine aggregates with marble waste scrapes and slurry powder of content up to 40%. The produced bricks are tested for physical and mechanical properties according to the requirements of the American Standards for Testing Materials (ASTM) and the Egyptian Code. The test results revealed that the recycled products have physical and mechanical properties that qualify them for use in the building sector, where all cement brick samples tested in this study comply with the Egyptian code requirement for structural bricks, with granite slurry having a positive effect on cement brick samples that reach its optimum at 10% slurry incorporation.

Keywords: marble waste, granite waste, slurry powder, Shaq Al-Thu`ban, recycling of marble and granite waste, concrete bricks.

1. Introduction

Nature has gifted Egypt with large deposits of high quality marble and granite. According to Strategic Study on the Egyptian Marble and Granite Sector that was prepared in August, 2005 by Ciccu et al. in [2], in 2005, the most likely estimations based on the information retrieved through local assessment attributed to Egypt: a quarry production of about 3.2 million tons and over 25 different types of Egyptian marble and granite in 2004. This indicates that the country lies among the top 8 world producers of raw material. The average annual rate of increase has reached 8.8% since 2002. The contribution of the natural stone industry to the Egyptian economy has grown tremendously over the past decades and especially post 1990s. There are around 500 big enterprises in this industry and at least 3000 workshops. About 70% of the industry is located in Shaq Al-Thu`ban, located in Katameyya near Maadi suburb of Cairo as indicated in [5], with a total investment in this place of around 6 billion EGP (equivalent to 970 Million USD)as stated in [4]. Shaq Al - Thu`ban industrial cluster poses the most imminent hazard to residents of neighbouring communities: WadiDegla protectorate, situated at the western edge of the Eastern desert and Zahraa El- Maadi residential area, which lies bottom hill west of Shaq Al - Thu`ban.

2. Marble and Granite Manufacturing Process

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During the processing of marble and granite, that takes place in Shaq Al-Thu`ban cluster, the raw stone block is cut as demanded either into tiles or slabs of various thicknesses (usually 2 or 4cm), using diamond blades. Water is showered on blades while stone blocks are cut into sheets of varying thickness to cool the blades and absorbs the dust produced during the cutting operation. The amount of wastewater from this operation is very large. It is not recycled as the water so highly alkaline that, if re-used, it can dim the slabs to be polished. In large factories, where the blocks are cut into slabs, the cooling water is stored in pits until the suspended particles settle (sedimentation tanks), then the slurry is collected in trucks and disposed of on the ground and left to dry. This water carries large amounts of stone powder. Eventually, the sludge dries in the sun and its particles become airborne. This causes air pollution problems for the surrounding area. Another solid waste generated by the marble and granite units is the cutting waste which results from cutting slabs into the required dimensions. After the stone has been cut to the specific dimensions, the slabs are finished either by polishing or texturing, as requested. The polishing operation is fully automated with the use of powdered abrasives that keep on scrubbing the surface of the marble until it becomes smooth and shiny. Water showers are essential to prevent overheating of the blades.

2.1. Waste Quantification

Actual figures about the quantity of waste produced in Egypt from the marble and granite industry are inaccessible since it is not calculated or monitored by the government or any other party. However, the waste produced during the processing stage only ranges from 20-50% as indicated in [1], [2], [3] and [6].Based on the lowest estimates of waste percentage, Shaq Al- Thu`ban only produces around 500, 000 tons of waste per year.

2.2. Environmental Impact

Cutting the stones produces heat, slurry, rock fragments, and dust. The wastes are dumped on the Wadi's roads and the adjacent land and the dust is airborne by the wind and scrap is scattered. The marble slurry could lead in the long run to water clogging of the soil, to increasing soil alkalinity, and to disruption of photosynthesis and transpiration. The net effect is a reduction of soil fertility and plant productivity. Many animal species in the Wadi are exclusively herbivores. Even if those plants did not die out, their internal chemistry will have been altered and their nutritional value poisoned by gases emitted by the industry. The interdependence of the parts of the ecosystem does not seem to be greatly emphasized in environmental public policy. It should also be realized that animal health, like human health, can be adversely impacted by inferior environment quality. Nevertheless, by blanketing plants and surfaces, slurry and dust compromise the aesthetic appeal of the Wadi's scenery, as detailed in [1], [3], [6] and [7].

3. Materials and Methods

Concrete bricks can be the best application to utilize marble and granite waste in large quantities to replace the conventional sand and aggregates. Normally, aggregates in concrete bricks are dolomite as the coarse aggregate, and sand as the fine component. These can be replaced by marble and granite waste aggregates of different sizes with slurry powder addition. The mix utilizes marble and granite mixed pieces of various sizes: coarse sand (A), fineness modulus (FM) of 4.596, fine sand (B), FM of 2.755, coarse aggregate (C) of maximum nominal aggregate size of 12.5 mm and coefficient of uniformity (C_u) of 1.9, and slurry powder. The slurry powder, both marble and granite, is of grain size less than 70 microns and surface area more than 4200 cm^2/g (comparable to that of cement, 2600-4300 cm^2/g), which gives cohesion and micro-filling ability. The mix design incorporates 10wt% cement, 30wt% fine aggregates with ratio 3:7 A:B (FM 3.307), 50 wt% coarse aggregates, and marble (M) or granite (G) slurry powder of 10, 20, 30 and 40 wt%, with proportional re-distribution of coarse and fine aggregates to accommodate the added slurry powder, beyond 10%. In addition, 0% slurry brick (zero), and control brick, with conventional dolomite coarse aggregates and sand, were tested, as shown in Table 1.

3.1. Sampling and Testing

The bricks produced are of dimensions 250 mm length, 120 mm width and 60 mm height in agreement with the brick dimensions specified by the Egyptian code for masonry works. Three samples of each brick formula are tested after 7 and 28 days for compression, moisture, absorption and durability (heating and cooling cycles and saturated salt solution, sodium chloride, immersion cycles followed by heating, of a 24±2 hours cycle for 7 days). Results are compared to ASTM C140, the Egyptian Code and the control samples. In addition, Bricks abrasion resistance is compared to ASTM C902-09.

Table 1: Concrete bricks mix design

Mix ID	Cement (kg/m^3)	Slurry		Fine aggregates		coarse aggregates	
		wt%	(kg/m^3)	wt%	(kg/m^3)	wt%	(kg/m^3)
Control	300	-			800		1000
Zero	235	0	0	33.75	704	56.25	1173
M10, G10	232	10	232	30.00	696	50.00	1160
M20, G20	220	20	441	26.25	579	43.75	965
M30, G30	210	30	630	22.50	472	37.50	787
M40, G40	204	40	818	18.75	383	31.25	639

3.2. Results

The results show that the marble and the granite slurry samples yield similar mechanical, in terms of compressive strength, and physical, in terms of density and absorption, properties. In terms of compressive strength, although both marble and granite show similar results, granite slurry samples show slightly higher values, as illustrated in Figure 1 and Figure 2, which is predictable due to the higher strength of natural granite stone and the apparent stronger bond with cement paste. This increase in strength in granite slurry bricks compared to the marble slurry ones is around 10%, 11%, 14%, and 33% in 10, 20, 30, and 40% samples respectively at 7 days. As for the 28 days test, the increase is 9%, 23%, 9%, and 48% for 10, 20, 30, and 40% samples respectively. It is worth mentioning, however, that the 40% granite slurry samples (G40) show much higher values of compressive strength (33%, and 48%), as compared to marble slurry. This can indicate that granite slurry can have a better interface with cement paste in the mix beyond purely physical micro filling action. This is more noticeable in higher incorporation percentages of granite fines. In addition, both marble and granite samples show similar trend in terms of the degree of strength achieved after 7 days when compared to that after 28 days. For example, the 10% slurry samples, both marble and granite, achieve 80% of the 28 days strength whereas the 20% marble and granite slurry samples, achieve 83% and 72% of the 28 days strength, respectively.

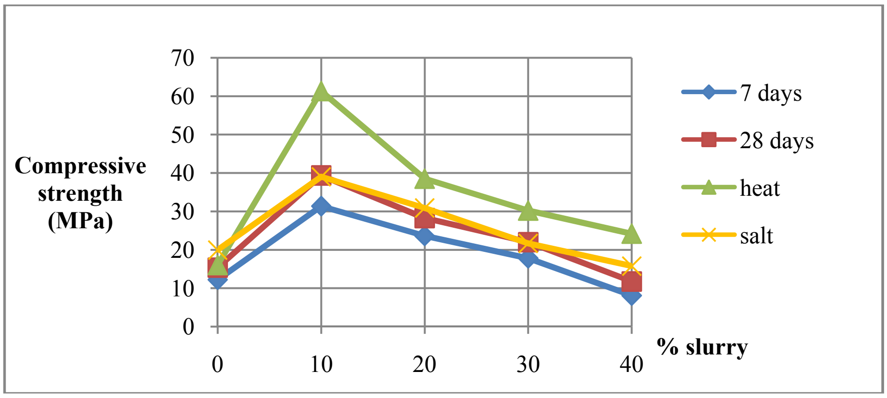

Figure 1: Compressive strength for marble slurry samples

Comparing with the control sample, in terms of compressive strength at 28 days, the 10% marble slurry (39.4 MPa) and granite slurry (43.48 MPa) samples yield results close to that of the control (39.6 MPa). The 20% granite slurry samples also show similar results (36.95) to that of the control. These results emphasize the positive effect of granite slurry on brick samples that reach its optimum at 10% slurry incorporation, while at higher percentages, agglomeration of slurry started to appear, which acts as media discontinuities, thus decreasing the compressive strength of samples. It is worth mentioning that zero slurry samples showed the lowest compressive strength of all samples and this is basically due to the poor grain size distribution and the lack of filling materials.

Comparing to the specifications, all samples are acceptable, in terms of compressive strength, compared to the Egyptian specifications even for structural requirements (7 MPa). However, as compared to ASTM

C55, the control (39.6 MPa), M10 (39.4 MPa), M20 (28.3 MPa), G10 (43.5 MPa), G20 (37.0 MPa), and G30 (24.1 MPa) are acceptable for grade N[4] (24.1 MPa (average of 3), and 20.7MPa (individual unit)), and M30 (22.0 MPa) and G40 (22.8 MPa) are acceptable for Grade S[5] (17.3MPa (average of 3) and 13.8 MPa (individual unit)) use. M40 is rejected for falling below the limits of Grade S. As for density, most samples, including the control, are of normal weight (>2000 kg/m^3), according to both the Egyptian specifications and ASTM C55, except for M30, G30, and G40, which are of medium weight.

Both heating and salt solution soaking and heating cycles increased the compressive strength of all samples with different ratios. Thus, it can be concluded that heating and cooling cycles did not adversely affect samples; on the contrary, they enhance compressive strength. This may be attributed to the accelerated cement hydration with higher temperature which apparently counter effected heat-associated volumetric changes.

Absorption is the major drawback of slurry incorporation in bricks, although the Egyptian specifications for concrete bricks do not impose limits for absorption in concrete bricks, but it specifies a maximum of 16% for wall bearing bricks, and 20% for non-wall bearing for fired clay bricks. All samples show absorption less than 15%. As for ASTM specifications, Zero, M10, G10, M20, G20, fulfil the requirements for grade S (208 kg/m^3, 10.1% for normal weight and 240 kg/m^3 for medium weight), with absorption values of 168 kg/m^3, 168 kg/m^3 ,185 kg/m^3, 193 kg/m^3, 201 kg/m^3, 179 kg/m^3 and 184 kg/m^3.

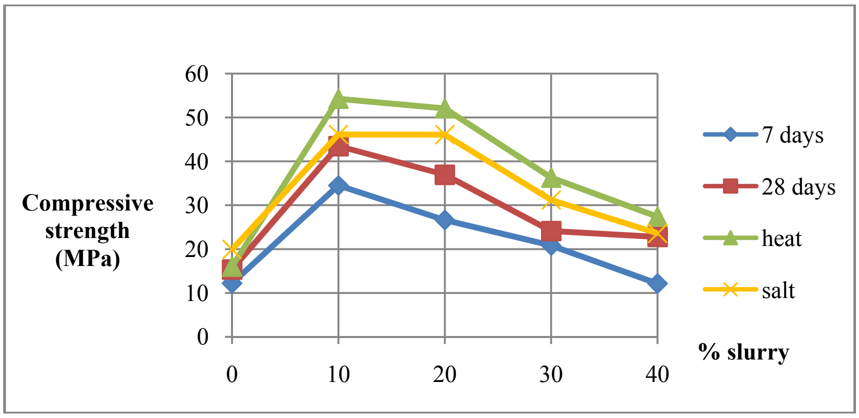

Figure 2: Compressive strength for granite slurry samples

As for the abrasion resistance of bricks for pedestrian and light traffic use according to ASTM C902, the control sample, zero, M10, M20, M30, G10, and G20, are all classified as class MX[6], type II[7]. G30 is classified as class MX, type III[8], while G40 is classified as class NX[9], Type III.

4. Conclusion

Marble and granite slurry cement bricks yield similar mechanical, in terms of compressive strength, and physical, in terms of density and absorption, properties. There is a positive effect of granite slurry on cement brick samples that reach its optimum at 10% slurry incorporation. Absorption is the major drawback of slurry incorporation in cement bricks according to the ASTM C55 where water absorption requirement is fulfilled only at Zero, 10 %, and 20% slurry samples for grade S. The accelerated hydration, endued by heating, compensated the detrimental effect of volumetric changes associated with temperature variation. Most cement brick samples, including the control, are of normal weight according to both the Egyptian specifications and ASTM C55.All cement brick samples tested in this study comply with the Egyptian code requirement for structural bricks. This is not true when compared to ASTM C55. Instead, 10% and 20%

[4]Grade N; for architectural veneer and facing units in exterior walls and for use where high strength and resistance to moisture penetration and severe frost action are desired
[5] Grade S; for general use where moderate strength and resistance to frost action and moisture are required
[6]Class MX: brick intended for exterior use where resistance to freezing is not a factor
[7] Type II: brick subjected to intermediate abrasion
[8] Brick subjected to low abrasion
[9] brick not intended for exterior use but which may be acceptable for interior use where protected from freezing when wet

marble and granite slurry yield Grade S. Most cement brick samples which contain marble and granite waste had sufficient abrasion resistance according to ASTM C902.

5. References

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