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THE USE OF GRANITE SLURRY IN MASONRY MANUFACTURING

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Abstract: The waste powder produced during granite manufacturing has been a source of significant pollution and health hazards. The use of this waste powder in concrete has been studied by several researchers. The current study involves partial replacement of the fine aggregates by five different proportions of granite waste powder in the mix of the concrete used for producing concrete bricks. Wet and dry tests on concrete bricks are performed. The effect of varying the percentage of granite waste powder on the various properties of the produced masonry are assessed and compared to a control group with no powder involved. The mixtures having the highest strengths are determined and used to construct masonry prisms subjected to compression. The mix used to construct the prism surviving the highest compression is considered as the one adequate for future masonry production. The initial results indicate that incorporating such waste in masonry walls can be one promising venue for its utilization in the construction industry.

Keywords: Granite Waste; Cement bricks; Granite Slurry; Masonry

1 INTRODUCTION

Egypt has got huge stores of amazing granite and stone. World Stone generation achieved the pinnacle of somewhere in the range of 75 million tons (or 820 million m^2 proportionate), net of quarry waste (El-Sayed, 2016). The official generation figures of Egypt are striking; yet, the genuine creation is extensively higher than the level demonstrated by the official insights and possibly past the levels assessed over the span of the examination featured. The estimations in light of the data recovered through neighborhood appraisal credited to Egypt: a quarry generation of around 3.2 million tons and more than 25 unique sorts of Egyptian stone (El-Sayed, 2016). This shows the nation lies among the main 8 world makers of crude material. The normal yearly rate of increment has achieved 8.8% since 2002(Allam, 2014).

Concerning quarry creation and crude fare, Egypt is positioned the fourth separately with an offer of 4.3% and 6.6% of aggregate world market of Granite and rock. This implies Egypt can be viewed as the seventh exporter on the planet, as far as volume, after China, India, Italy, Spain, Turkey and Brazil. During the process of granite manufacturing, a massive amount of water is used while cutting the granite piles with diamond blades to cool off the process. The result is water absorbing dust and granite slurry powder without any proper way to recycle it or getting rid of it. If the water is disposed on the ground, the slurry powder dries, and it causes air pollution. The main issue that water use in the granite manufacturing process is essential to cool down the blades.

Several researchers have worked on utilizing the use of this slurry powder byproduct in cement bricks. One of these works was done by Hamza et al (2011) who produced cementbricks with partial replacement of the aggregates with the slurry. The partial replacement was done for increments of 10%, 20%, 30% and 40% of the aggregates. The bricks were tested for physical and mechanical properties and 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 (Hamza et al, 2011).

Similarly, other researchers such as (Allam and Bakhoum, 2014), (Kumara, 2015) and (Dhanapandian and Shanthib, 2009) did similar works to that done by Hamza et al (2011). However, none of these researchers narrowed down the window of the study of varying the percentage slurry than increments of 10%. Also, none of them studied the durability of the produced bricks or their performance under axial loads in the walls. These issues are important as they will affect the decision of using such products in various conditions of loading and in various environments.

The current research covers the variation in usage of the percentage of slurry in increments of 5% by producing cement bricks with percentages of 0%, 5%, 10%, 15%, 20% and 25% slurry in replacement of aggregates and tested for compressive strength. Following on that,and in lieu of the results, the increments were reduced to 2.5% in order to get the most accurate possible percentage of slurry. Also, the durability of the bricks was studied by immersion in salt solutions in addition to regular fresh concrete tests. Finally, the performance of brick prisms under compression was studied.

2 EXPERIMENTAL PROGRAM

The experimental work initially involved preparing 6 mixes, by replacing fine aggregates in conventional brick mix with slurry in different increments of 0%, 5%, 10%, 15%, 20% and 25%. The 0% slurry brick and 2 other mixes, that have the highest compressive strength, were used to build 9 masonry prisms, 3 from each mix, to determine the best mix in terms of performance within a masonry wall. The compressive results after 7 day were considered as indication for the strength after 28 days and selecting the mixtures for the prism tests to reduce the duration of the test program and limit the number of the produced bricks. Furthermore, two additional mixtures with 2.5% and 7.5% of slurry were prepared in order to determine a more accurate figure for the percentage slurry corresponding to the maximum strength.

2.1 Material Properties

The materials in the mixtures were as follows:

- **Cement:** Type I Portland Cement Concrete with specific gravity of 3.15.
- **Fine Aggregates:** Well graded sand with specific gravity of 2.55, 0.4% absorption, and a fineness modulus of 2.85.
- **Coarse Aggregates:** Well graded crushed dolomite with specific gravity of 2.57 and 1.8% absorption.
- **Water:** Ordinary municipal tap water was used in producing and curing process of the concrete mixtures.
- **Granite slurry:** A Granite slurry powder from a plant in Alexandria was used.

2.2 Bricks Mix Design

The only variable targeted within the present study is the slurry in partial replacement of fine aggregates while keeping all the rest of the mix constituents constant. These percentage of slurry replacement ranged between 0% to 25 % with 5% initial increments. This range was determined in accordance to the results published in the literature by previous researchers (Allam and Bakhoum, 2014), (Kumara, 2015), (Dhanapandian and Shanthib, 2009) and (Hamza et al, 2011) which indicated that the percentage slurry producing the maximum compressive strength lies between 0% and 20%. However, these researchers performed their studies for increments of 10% of slurry-to-aggregates replacement.

Two additional mixtures with 2.5% and 7.5% of slurry were prepared in order to determine a more accurate figure for the percentage slurry corresponding to the maximum strength Table 1 shows the mix design for all mixes used in the present study.

Table 1: Bricks mix design

Mix	Cement (kg/m3)	Slurry (kg/m3)	Fine Aggregates (kg/m3)	Coarse Aggregates (kg/m3)	Water (kg/m3)
0%	493	-	661	998	185
2.5%	493	17	646	998	185
5%	493	33	628	998	185
7.5%	493	50	612	998	185
10%	493	66	597	998	185
15%	493	99	564	998	185
20%	493	134	531	998	185
25%	493	165	497	998	185

2.3 Mortar Mix Design

The mix design of the mortar used in the construction of the masonry prisms consist of water, cement and sand with a ratio 0.485: 1: 2.75 respectively. 7.5% of the sand was replaced by granite slurry. Accordingly, after this replacement the mix ratio become 0.485: 1: 2.675: 0.206.

2.4 Tests Performed

2.4.1 Fresh tests

- **Slump test:** This test was conducted according to ASTM C143 to evaluate the consistency of the fresh mix.
- **Air content:** The test was conducted according to ASTM C231 to identify the Air content in the fresh concrete mix.
- **Unit weight test:** This test was conducted according to ASTM C138 to determine the density of the mix.

2.4.2 Hardened Concrete/Mortar tests

- **Brick Compressive Strength:** The test is conducted according to ASTM 109 standards to evaluate and determine the strength of each mix.
- **Mortar cubes test:** Compressive strength of each mortar mix was determine by testing 50x50x50 mm cubes according to ASTM 109 standards..
- **Cycles of Immersion in Salt Solution and Drying:** The bricks were weighed, after 28 days of being casted. Then subjected to heat, at 110 ºC for 48 ±2 hrs. After that left for 4-5 hrs to cool down and reach room temperature. After weighting the specimens again theywere immersed in a fully saturated salt solution (sodium chloride), for 24 ±2 hrs. These cycles were repeated for 3 times, then the bricks were weighed after each cycle.

2.4.3 Prism Compressive Strength

In this test, five bricks were tested as a unit as they were used to build a prism with a 10 mm layer of mortar between each two successive bricks to form a prism as shown in **Error! Reference source not found.**. Each prism had an aspect ratio of 4 between the its height and the thinnest side which was factored according to pre-specified factors by the ASTM. This was done three times for three different mixes having percentage slurry of 0, 5 and 10%. The load was applied to satisfy a deflection rate of 3 mm/minute in a load control loading scenario. The full record of load versus deflection was recorded and used to plot the stress - strain curves for each specimen.

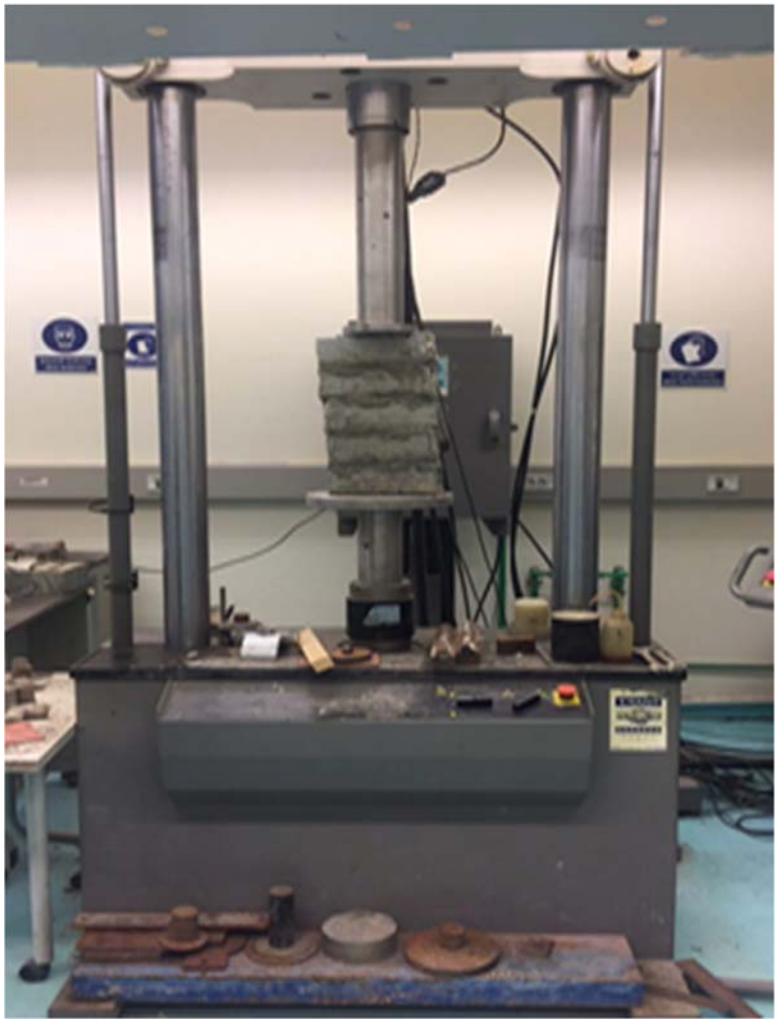


Figure 1: A prism sample during testing it under compression.

3 TEST RESULTS AND DISCUSSION

3.1 Results of Fresh Tests

Table 2 shows the results of the fresh tests. The results shown indicate variations in the unit weight within limited ranges meaning that the powder/slurry had a limited effect on the air content and the unit weight. This limited effect could be attributed to the fact that originally the difference between slurry and sand (that it is partially replacing) in unit weight is minor as previously reported by (Hamza et al, 2011) which caused the impact on the unit weight and air content to be limited. Furthermore, the low water-to-cement ratio caused the slump to be of zero for all of the mixtures as this low water-to-cement ratio was kept constant for all of the mixtures.

Table 2: Results of Fresh Tests

Percentage Slurry	Slump (mm)	Air Content	Unit Weight kg/m^3
0%	0	8%	2090.0
5%	0	6%	1964.3
10%	0	2.8%	2300.0
15%	0	9.0%	2075.7
20%	0	7.8%	1867.1
25%	0	8.5%	1742.9

3.2 Brick Compressive Strength

The compressive strength results after 7 days for the concrete brick units with 0%, 5%, 10%, 15%, and 20% of slurry replacement are shown in Table 3. The results indicated that the highest strength was obtained at 5% slurry replacement. However, to determine more precise percentage mixes with 2.5% and 5% were tested after 3 days which showed that the mix with 7.5% has the highest compressive strength. Table 3 shows the obtained compressive strength for all mixes after 3 and 7 days

Table 3: 3-Days and 7-Days Brick Compressive Strength

Slurry Percentage	Average Compressive Strength (MPs)	
	After 3 days	After 7 days
0%	-	27.4
2.5%	19.5	-
5%	18.3	29.3
7.5%	21.0	38.5
10%	17.3	21.9
20%	-	20.0
25%	-	19.0

According to the results presented in Table 3, the 7.5% granite slurry replacement shows much higher value of compressive strength when compared to its counterparts. This can indicate that granite slurry can have a better interface with cement paste in the mix beyond purely physical micro filling action. In addition, granite samples show high trend in terms of the degree of strength achieved after 7 days. It is worth mentioning that 10% and 20% slurry samples showed nearly the same range of compressive strengthswhich is consistent with the results presented previously by Hamza et al (2011). The brick was not tested at 28 days because in real life they don’t wait 28 days for the brick, so the concern was on 3 & 7 days compressive strength.

3.3 Mortar Cubes Test

Figure shows the compressive strength of mortar cubes. The figure shows that the compressive strength of the mortar with 7.5% slurry replacement was significantly higher than the control mortar mixes. Therefore it is concluded that adding 7.5% granite could significantly increase the mortar compressive strength. The 2.5 % increament was obtained at the end of the scoope because it was important to know excatly the highest compressive strength and it was in the range between 5 % & 10 %. So , another samples was made with the increment of 2.5 % and the results is in figure 2.

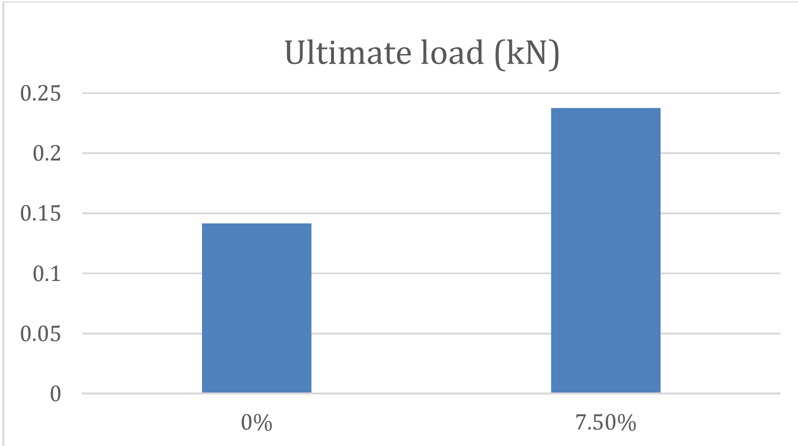


Figure 2: Comparison between the ultimate compressive load carried by the control mortar sample and the mortar sample containing 7.5% slurry

3.4 Cycles of Immersion in Salt Solution and Drying

The results of three cycles of immersion in salt solution followed by oven drying for six mixtures with different percentage slurry are illustrated in Figure . As observed, it was found that throughout the cycles the weight increased and this might be because the salt particles that became immersed inside the bricks because of being fully immersed in the solution. However, this variation in weight from one cycle to the other was not major as shown in Figure . This may be attributed to the fact that all of the mixes had low water-cement ratios which caused the bricks to have less voids and hence a good level of durability in general.

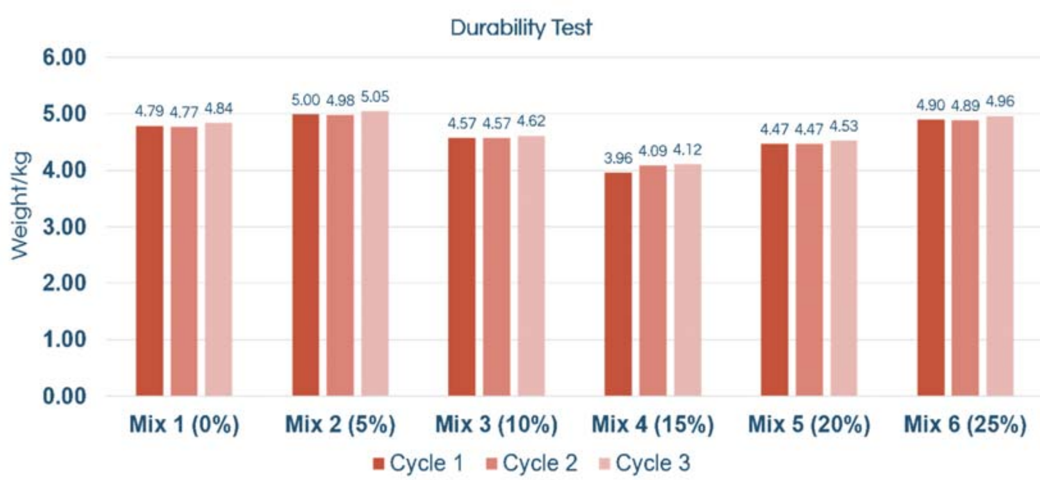


Figure 3: Cycles of immersion in salt solution

3.5 Prisms Test

The maximum compressive load for each prism was recorded and the average value was calculated for each group as shown in Figure 1. It could be obviously seen that the control group (0%) failed at a significantly lower load when compared to its counterparts including a percentage of slurry. It could also be noticed that the 5% and 10% groups got results very near to each other.The obtained stress-strain curves are shown in Figure 5.

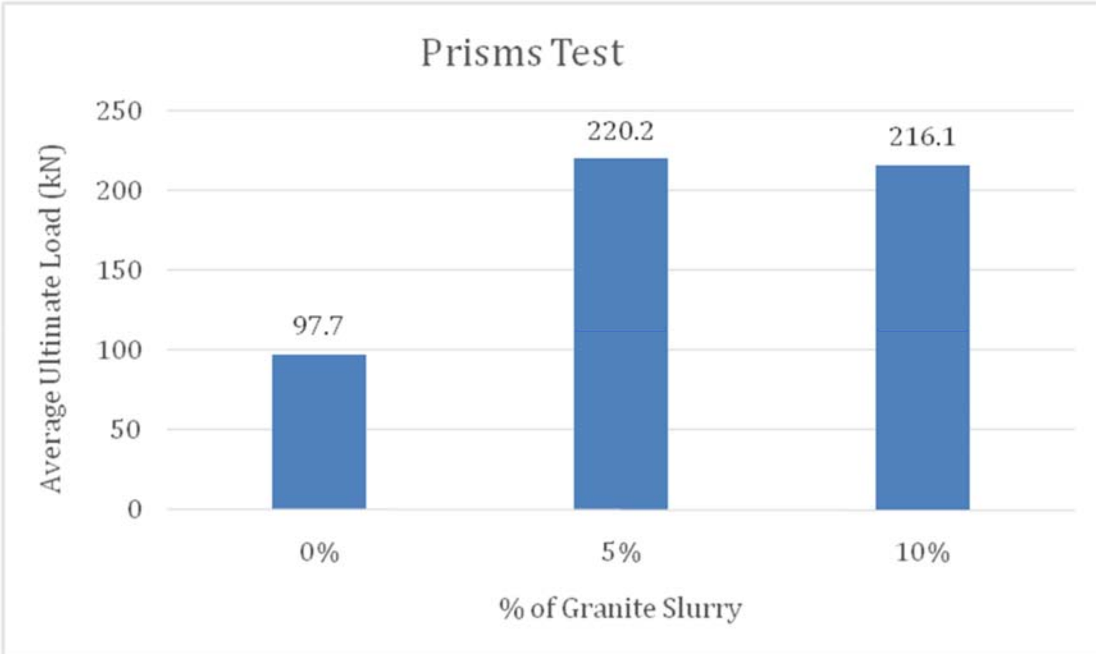
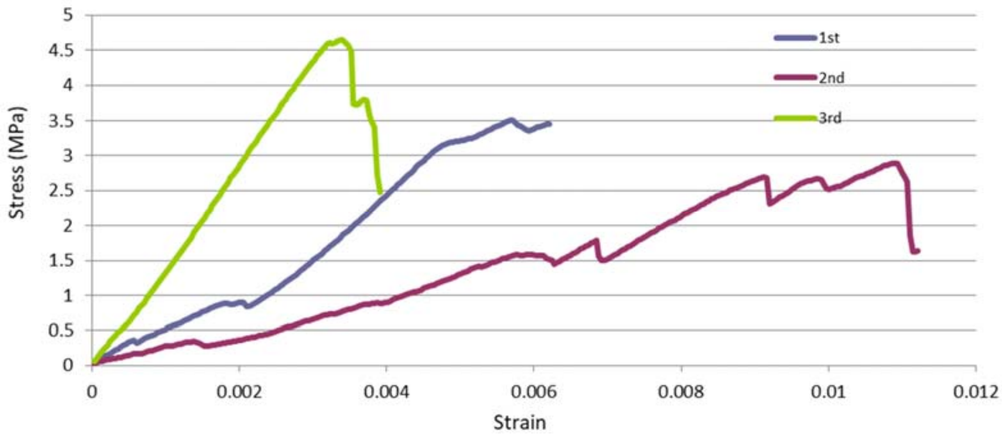


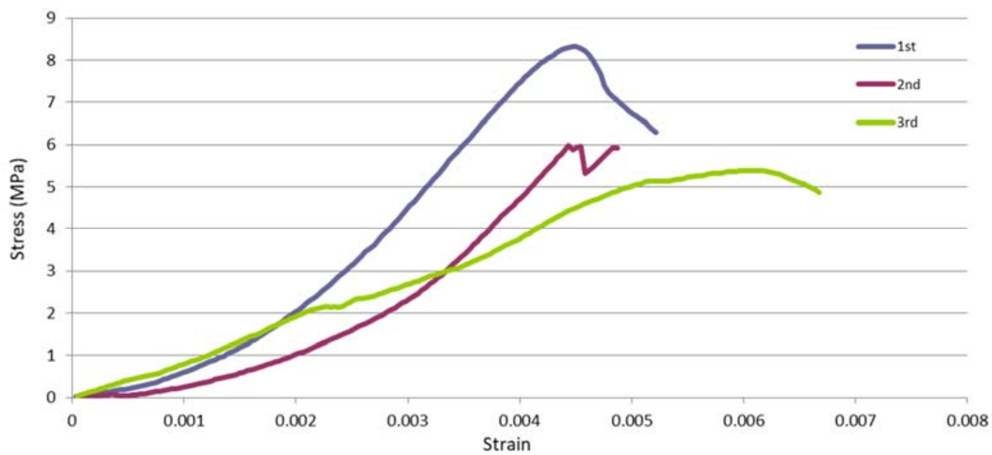
Figure 1: The average ultimate load carried by prisms with different percentages of slurry.

From the three stress-strain diagrams shown in Figure 2 it could be noticed that the three samples had high variability in their results. However, when comparing all of the three control samples to the others shown in Figure 2b and Figure 2c, it could be noticed that all of the control samples failed at stresses lower than these withstood by the two groups that included a percentage of slurry. Meanwhile, the 5% group shown in Figure 2b has some degree of variability that could be attributed to the human error during constructing the prisms as it was very challenging to have exactly the same thickness of the mortar layers between the bricks and having an ideal verticality of the prism. This same variability in construction caused one of the 10% samples shown in Figure 2c to experience early failure as this sample in specific failed at an angle as it was obviously not ideally vertical.

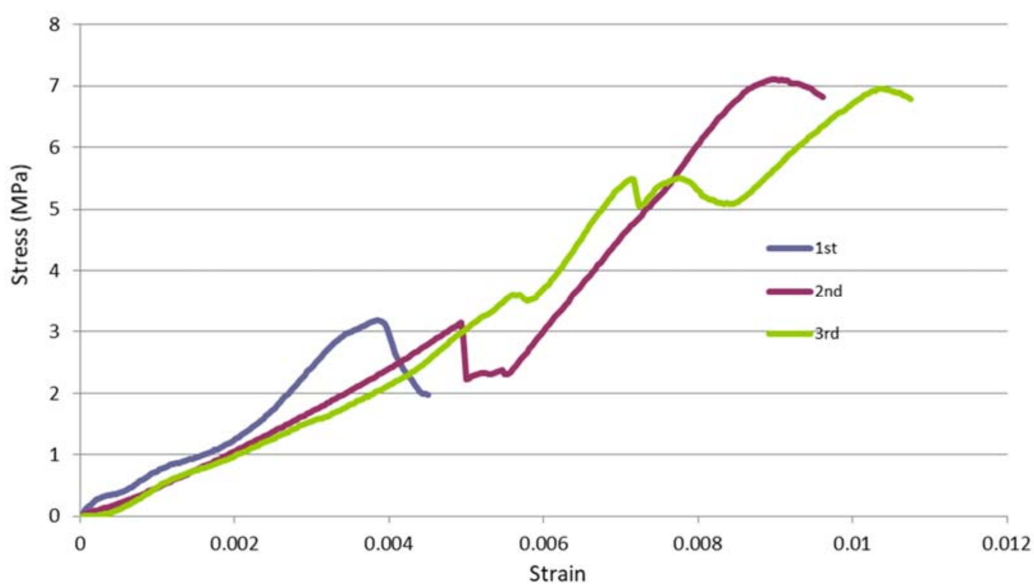
Meanwhile, when comparing the stresses shown in the stress-strain diagrams in Figure 2 to the brick compressive strength shown in Table 3, it could be noticed that the stresses at which the prisms failed were less than what the bricks could actually withstand. This was due to the fact that for all of the prism samples the failure happened in the layer of mortar between the bricks and none of the samples have experienced failure in the bricks themselves.



a. Stress-strain curve for the 0% (control) prism sample.



b. Stress-strain curve for the 5% slurry prism sample.



c. Stress-strain curve for the 10% slurry prism sample.

Figure 2: The stress-strain curves for the prism samples.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The application of granite slurry into the bricks was investigated. Many tests were conducted to further understand this unique material and enhance the research available on it. Four tests were conducted and their results analyzed. Taking the materials and techniques implements into consideration, the following can be concluded:

1. Granite slurry is a promising innovative material that has potential yet to be explored in the construction industry.

2. Manufacturing of bricks with granite slurry contribute to both environmental as well as technical merits as the incorporation of slurry into the bricks compute to the enhancement of mechanical properties.

3. The fresh test results were quite similar while the slurry had a unique behavior in the slump tests as the result was zero because the w/c ratio was very low.

4. The compressive strengthof the prisms made with brick with granite slurry replacement is more than double the that of the conventional units.

5. It is also important to note that the granite and slurry exhibited superior performance and advantageous qualities in the chemical durability test which means that these bricks can withstand chemical solution at least for a short period of time.

4.2 Recommendations

For the purposes of further research, the following is recommended:

- ● Investigating mixes with different cementitious component.
- ● Investigating the thermal resistance of Granite Slurry bricks.
- ● Further research can be done in exploring the possibility of producing mortar with Granite Slurry and exploring its physical properties and durability.
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- In the application of usage of granite slurry in the industry the authors would recommend the following:
- ● Study the possibility of producing bricks with Granite slurry on large scale in order to replace the conventional cement bricks.
- ● As units of brick with mortar in between (prisms) have resulted in more than double the load carrying capacity of conventional units, it is worth to apply this technology in the industry and monitor its performance.

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References

Allam, M. E., and E. S. Bakhoum. "Re-use of granite sludge in producing green concrete." *ARPN Journal of Engineering and Applied Sciences,* vol. 9, no. 12, Dec. 2014.

El-Sayed, Hamdy A. “Characteristics of the marble processing powder waste at Shaq El-Thoaban industrial area, Egypt, and its suitability for cement manufacture.” *HBRC Journal*, 13 June 2016.

Kumara, Virendra. “Experimental study on granite sludge blocks.” International Journal of Informative & Futuristic research, vol. 2, no. 10, June 2015, pp. 3773–3781.

Mehta, Jitesh, and JayeshkumarPitroda. “Effective utilization of granite powder as replacement of marble powder in marble brick.” effective utilization of granite powder as replacement of marble powder in marble brick, vol. 2, no. 3, may 2016, doi:10.15438/rr.4.4.22.

Hamza,Rania A., Salah EL-Haggar, and SafwanKhedr, “Marble and Granite waste: Characterization and Utilization in concrete bricks”. International Journal of bioscience, biochemistry and bioinformatics, vol. 1, no. 4, November 2011.

DhanapandianS. and OM. Shanthib., Utilization of marble and granite wastes in brick products”, Jr. of industrial pollution control, volume 25, issue 2, 2009, pp 145-150.

Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, ASTM C140/C140M – 17a.

Standard Test Methods for Conducting Strength Tests of Masonry Wall Panels, ASTM C1717 – 12.

Standard Test Method for Compressive Strength of Masonry Prisms, ASTM C1314 – 16.