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Reuse of Glass Industrial Wastes and Waste Granite Powder in Cement Products

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Abstract —*This paper presents the results of a study conducted to evaluate the possibility of utilizing the Grounded Glass Waste (GGW), Granite Powder (GP) and Grounded Granite Powder (GGP) as a partial replacement of cement. The influence of GGW, GP and GGP on the compressive strength of mortars was investigated. In addition, X-ray diffraction analysis was performed, to evaluate the pozzolanic activity. The results show that the incorporation of the GGW and GP yields mortars with improved strengths at the later ages (28 and 91 days), in comparison with that of a control mortar (ordinary Portland cement only); while the GGW and GP caused lower early ages (3 and 7 days) strength than that of control. The density of the mortars can be reduced by incorporating GGW, GP and GGP. These results indicate that the GGW and GP have higher reactivity; and therefore, can be used as a pozzolanic admixture in cement composites.*

Index terms — *GGW, GP, GGP, XRF and XRD.*

I. Introduction

Concrete has been a leading construction material for over a century and its annual global production is about 12 billion m^3 roughly 1.5 tons per capita [1]. The natural stone industry engages in quarrying and dressing the rock found on the Earth's crust. The end product of this industry contributes to the economy of many developed countries which used in the construction industry, funeral art and sculpture, interior and exterior decorating and for a variety of artistic purposes.

Since the end of the 1970s, many researchers have studied the incorporation of waste glasses as aggregate or cement replacement in concrete [2–11]. Due to chemical compositions and physical characteristics of waste glass, produced from window panes, and glass containers (bottles and jars) for beverages, food, and other commodity items, can been reused as a construction material. Adjustments and improvements in concrete making methods have encouraged researchers to investigate and identify supplementary industrial by-product materials that can be used as substitutes for constituent materials in cement products [12]. The reduced effective particle size of GW is obtained by repeated grinding by using a ball mill, average glass particle size should be fine compared to cement or FA [13]. They were usually prepared by crushing and grinding the bottles and jars glass in a ball mill, and by sieving the glass powder to the desired particle size. In order to reduce its particle size to an effective size, these processes should be repeated, and the glass powder crushed using a ring mill has a broader wide particle size spectrum, as compared to cement, even though the average glass particle size is fine [13,14]. Waste glass bottles and jars are disposed of by landfilling after dewatering and such practice is causing environmental problems. Generally, the physical characteristics of mixtures containing a pozzolanic admixture are dependent on its pozzolanic activity which is characterized by the sum of SiO_2 and Al_2O_3, and its surface area. GGW has a high content of SiO_2 and Al_2O_3, and has very fine particles. Therefore, if GGW is utilized as a cement replacement material for a concrete, the improved mechanical properties of the concrete may be expected. Kim et al,.[15] reported that WGS enhanced the resistance of freezing and thawing with and without de-icing salts, the chloride ion penetration and the resistance of surface scaling of the concrete.

The aim of this study is to investigate a possible use of the GGW as a pozzolanic admixture in mortar. Firstly, material characterizations of GGW, GP and GGP in terms of chemical composition and particle distribution are found out. Portland cement Type I was replaced with GGW, GP and GGP at 5% and 15% by the weight of cement and the control cement mixture were prepared for comparison. The compressive strength, bulk density, and X-ray diffraction (XRD) of the pastes were investigated.

In today's context of sustainability, the Granite Powder constitutes a serious problem for producers like

a) The huge volume generated (0.1m3/t processed rock).
b) The need to find suitable places for its temporary stockpiling and subsequent evacuation [16].
c) The economic and environmental (CO_2 emissions) cost of shipping it to sanitary landfills.
d) The adverse effects of uncontrolled dumping on water quality and plant life photosynthesis.
e) The risk for human health posed by the suspension of small particles in the air [17].

Worldwide marble quarrying and processing generate about 25% to 40% of the marble stone wasted which are dumped widespread in the environment [18]. Indian marble industry has been growing at annual rate of around 10% every year and it is reported that about 3127 thousand tons of marble dust was produced in year 2009-2010 [19].

Solid waste generation/day of Peshawar city is 1888 tons [20].

Municipal solid waste of Pakistan consists of 6% glass [21].
Over the last 10 years a number of authors have attempted to explore the viability of valorizing this granite waste by using it in construction, in light of the industry's capacity to absorb large volumes of waste in a wide range of products.
This study explored the effect of calcination temperature on granite sludge composition, structure, pozzolanic activity and mineralogy, and identifies the hydrated phases in the granite waste, $Ca(OH)_2$ system and their fluctuations. To that end, the waste was studied using X-ray florescence and X-ray diffraction.

II. Experimental program

1. Materials

The granite waste used in this study was the dust generated during cutting and polishing for use as dimension stones. The water from the cutting and polishing are carried off to ponds where large volumes of a solid waste characterized by a very small particle size settle. This was the waste subsequently collected and shipped to the laboratory.
Granite powder was grounded so that to checked the effects. Granite powder was grounded for 2 minutes in ring milling machine. Concrete mixes containing 30% recycled red granite dust with appropriate particle size distribution and potential pozzolanic activity showed good fresh properties, better expected mechanical properties and excellent surface finish better early age strength than similar fly ash [22].
Glass wasted as solid waste after use was collected and cleaned before powdered. After drying the clean glass was powdered by using ring milling machine. Portland cement was partial replacement of GGW shows high 28 day compressive strength, good resistance of ASR expansion then control cement motor and very high pozzolanic reactivity then fly ash [23].

2. Method

1. XRF

XRF tests were performed to find the composition of Granite Powder and Grounded Glass wastes. Through X-rays the atoms are excited and on de-excitation the energy is released giving different spectrum. Through detector the different spectrum gives different oxides and its quantities.

2. Compressive Strength Test

The mortar mixtures containing the GGW, GP and GGP were prepared by ASTM-C-109. The mortar strength is necessary as the bond strength between the masonry units is totally dependent on the strength of the mortar. Cement sand ratio used was 1:6 i: e one part cement and six part of sand. First made the control Cement Sand Mortar samples as standard for pozzolanic cement mortar using cement sand ratio 1:6. Samples cubes dimension are 50×50×50 mm which are casted in 2 layers by given 12 numbers of blows to each layers. Then blended cement sand mortar was casted by adding pozzolanic material by specific percentage of cement replacement. Pozzolanic materials used are Grounded Glass Waste (GGW), Granite Powder (GP) and Grounded Granite Powder (GGP). The GGW, GP and GGP were added to the mortar at the percentage of 5% and 15% cement replacement. Total numbers of blended cement mortar cubes are 108. The mortars with the GGW were compared with the mortars having the same percent replacement level of cement by 5% and 15% of GP and GGP, as well as with the pure cement mortar. According to ASTM standard, water to binder ratio of 0.5 was utilized for all batches, and the mixture proportions are given in Table 1.

Table 1: Mixture proportions

S. No	Name	Water (g)	Cement (g)	GGW (g)	GP (g)	GGP (g)
1	Cement sand mortar	450	900	0	0	0
2	5% GGW		791	108	0	0
3	15% GGW		575	234	0	0
4	5% GP		783.5	0	116	0
5	15% GP		552	0	247	0
6	5% GGP		783.5	0	0	116
7	15% GGP		552	0	0	247

3. X-ray Diffraction

The pastes containing GGW, GP and GGP were analyzed with X-ray diffraction (XRD) to evaluate the pozzolanic activity. XRD patterns of all samples were recorded with XRD machine using Cu radiation of wave length 1.5405. The diffracted rays are detected between 2 and 65 with a step size of 0.05 and step time 1 sec. The intensities of calcium hydroxide were compared, because the extent of pozzolanic reaction can be demonstrated by monitoring the decrease in calcium hydroxide over time [24-26]. After finding the intensity of $Ca(OH)_2$ in different mortar samples the different intensity of calcium hydroxide $Ca(OH)_2$ were compared because the extent of pozzolanic reaction can be demonstrated by monitoring the decrease in calcium hydroxide over time. The intensity of calcium hydroxide ($Ca(OH)_2$) was compared, because the extent of pozzolanic reaction can be demonstrated by monitoring the decrease in calcium hydroxide over time.

4. Results and Discussion

5.1 Material characteristic

The particle size analysis is performed on granite powder cement and sand as shown in the Figure 1. Fineness modulus of fine aggregate was 2.33 which is in the range of ASTM C33 i.e. 2.3 < F.M < 3.1. Fineness modulus of granite powder was 1.55. Fineness of cement was 96% and fineness of granite powder was 70%.

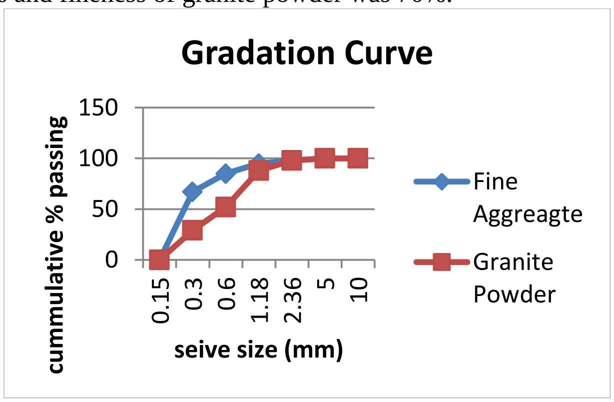

Figure 1: Practical size distribution

XRF tests were performed to find the composition of Granite Powder and Grounded Glass wastes. From the XRF results as listed in Table 2 and Table 3 concluded that Grounded Glass Waste and Granite powder are pozzolanic materials because the combine percentage of SiO_2 and Al_2O_3 of GGW and GP are more than 70%. As shown in Figure 2 and Figure3.

XRF Grounded Glass Waste	
Element	Percentage
SiO_2	72
Na_2O	19
Al_20_3	5.34
MgO	0.63

Figure 2: XRF of GGW

XRF of Granite Powder	
Element	Percentage
SiO_2	56
Na_2O	4.2
Al_20_3	15.05
MgO	4.75

Figure 3: XRF of GP

5.2 Compressive Strength Test

The tests were performed at the age of 3rd, 7th, 28th and 91st days. The strength reported was the average of three specimens for each mixture and results is shown in Figure 4.

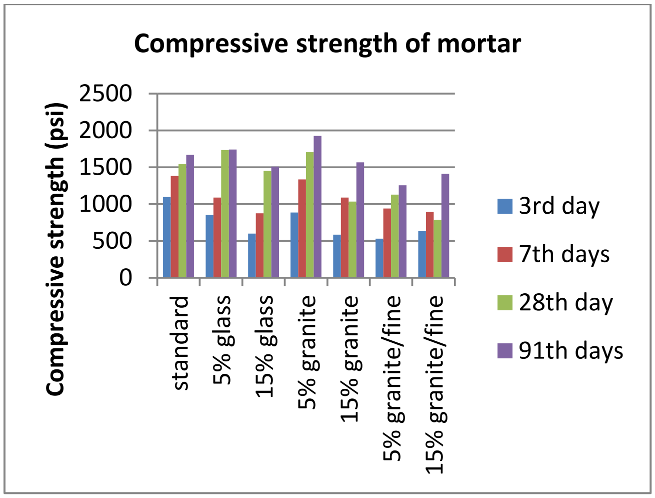

Figure 4: Compressive strength of mortars

The early strength of cement sand mortar was highest then other pozzolanic cement sand mixes. Strengths of cement sand mortar at 3rd day and 7th day were 1095psi and 1381.6psi respectively which are higher than pozzolanic cement sand mortar as pozzolanic reaction is slow reaction and the cement content are less. At 28th days the strength of 5% GGW and 5% GP were 1545psi and 1576.3psi respectively which were higher than cement sand mortar strength 1541psi this is due to pozzolanic reaction which give extra strength. At 91st day the strength of 5% GP and 5% GGW were 1732.5 psi and 1695.7 psi which were higher than that of standard cement sand mortar i.e. 1666psi.

5.4 X-ray diffraction of cement

Figure 5 to Figure 7 shows the XRD patterns of pastes with 5% and 15% of GGW, GP and GGP at age of 3rd, 7th, 28th and 91st days. It is well known that the amorphous or glassy silica which is the major component of pozzolanic materials was reacts with calcium hydroxide ($Ca(OH)_2$) formed from the hydration of the calcium silicates. The degree of pozzolanic reaction may be monitored by the consumption of calcium hydroxide in a cement paste.

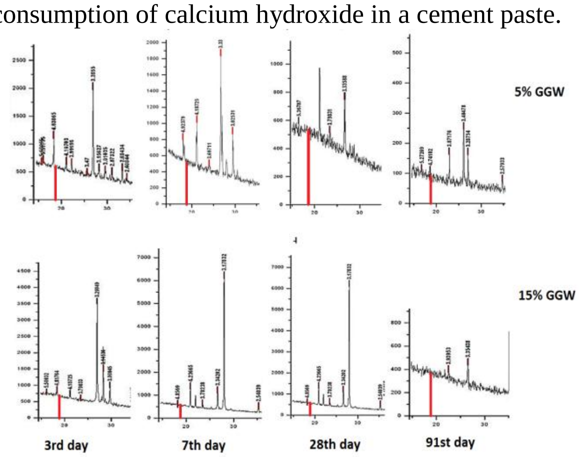

Figure 5: Grounded Glass Waste

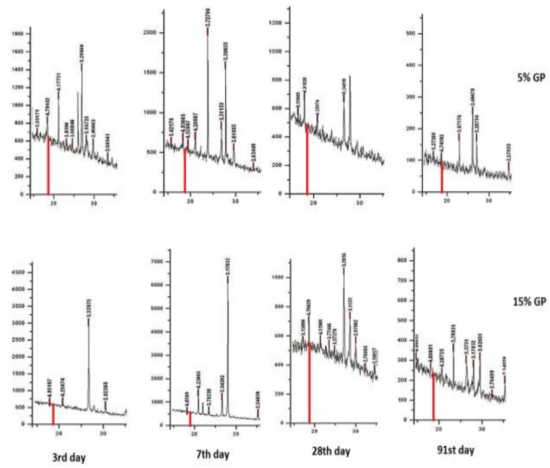

Figure 6: Granite Powder

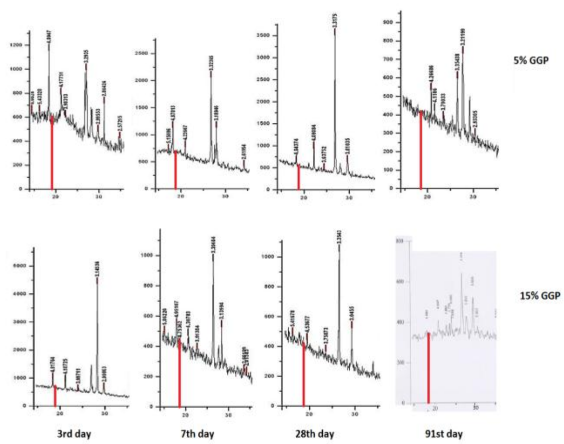

Figure 7: Grounded Granite Powder

The peak intensity of calcium hydroxide were been compared as shown in Figure 5 to Figure 7. The higher the WGS replacement, the lower the calcium hydroxide intensity at 3 days, because the higher replacement of cement results in the reduction of tricalcium silicate (C-3-S) in the paste and the intensity of calcium hydroxide was less at early curing ages. With increasing hydration time the intensity of calcium hydroxide decreased as react with GGW and GP. While the intensity of calcium hydroxide of plain paste increased until 28 days of reaction. This result indicates that a secondary pozzolanic reaction with $Ca(OH)_2$ occurring. Therefore, the reduction of calcium hydroxide intensity of pastes with GGW and GP shows that the incorporation of GGP and GP yields the pozzolanic reaction. However, GGW paste has the higher rate of calcium hydroxide consumption or declining rate of calcium hydroxide by 28 days, than that of GP. These results show that the pozzolanic reactivity of GGW is higher than that of GP.

5. Conclusions

An experimental study was conducted to evaluate the possibility of utilizing GGW, GP and GGP as a pozzolanic admixture in mortar. The pozzolanic reactivity of GGW was confirmed through the compressive strength test and XRD patterns. The research findings from this study are as follows:

1) At the 3rd day the strength of pozzolanic cement mix was lesser the standard cement sand mix.
2) Even at 7th day the strength of pozzolanic cement mortar was lesser the standard cement mortar shows that pozzolanic reaction is slow reaction than hydration reaction.
3) After the 28th day tests the strength of pozzolanic mix mortar overcome standard cement mix which shows that pozzolanic reaction is take place.
4) At 91th days the strength of pozzolanic mix mortar got increase to much than standard cement.

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