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Effect of waste material as binding material and crushed glass as filler material in cement mortar

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***Abstract*— Infrastructure is increasing day by day and a developing country are facing shortage of site for post consumer disposal waste and has become very serious problem. While cutting and polishing, the materials like marble dust are piling up at the cutting shops which become a challenge for the solid waste management to dispose the same. The aim of this experimental program was to see the effect of waste marble dust along with the waste glass which is not only hazardous but also striving for the landfills, these materials has the huge potential to be re-used in the constructional activities in the form of building materials which can offset the natural resources at some extent. The study was focused on the utilization of waste marble dust as partial replacement of cement and waste crushed glass as partial replacement of fine aggregates in mortar. The study was carried out in two stages. In first stage, cement mortar was prepared with cement as partial replacement of waste marble dust at the ratio of 0%, 5%, 10%, 15% and 20% and evaluated the optimum ratio of waste marble dust. In second stage cement mortar cubes was prepared keeping the optimum ratio of waste marble dust as binding material along with replacement of waste glass powder with natural river sand at ratio of 0%, 5%, 10%, 15% and 20%. Compressive strength, morphology and cost analysis has been studied. It was observed that for first stage, the compressive strength increases to 7.10% and 10.53% for the partial replacement ratio of 5% and 10% and decrease to 20.24% and 31.59% at the partial replacement ratio of 15% and 20%. It has been concluded that the optimized ratio of waste marble dust is 10%. Morphology of the optimum ratio mixture was studied and image showed the presence of CSH gel formation and hydroxide crystals. In stage 2, it has been observed that the compressive strength increases with the increase in ratio of waste crushed glass at ratio of 20% by 31.67% and decreases at ratio of 5%, 10%, and 15% by 44.62%, 25% and 10.58% respectively. Cost analysis of sample has been done and analyzed that the samples having waste materials had more cost than the controlled one by 1.5% and 4% for 15% and 20% samples ratio. This increase in cost can be offset by solid waste management for disposal of these waste materials and proves to be an eco-friendly solution.**

Keywords*— *cement mortar, compressive strength, waste, glass, marble dust, morphology, SEM analysis, EDS.

I. INTRODUCTION

Now a days developing country are facing shortage of site for post consumer disposal waste and has become very serious problem. The materials like waste glass, marble dust has the huge potential to be used in the civil engineering. As far as prices are concerned for the raw materials such as fine sand, cement, aggregates and usage of natural resources are increasing day by day. To resolve such situations some alternatives materials should be tested and can be used for the production of cement and aggregates in constructional activities. Also the rising prices of these raw materials are major concern.

The waste glass from various areas such as window panes, glazing etc can be used as waste material in the concrete which could otherwise end up in the landfill or become a challenge to locate the disposable sites. Marble dust which remains at the shops after cutting of marble and from making of marble statues tuned into heaves and became a challenge for the marble suppliers to dispose off. Millions of tons of waste marble powder are generated in India while cutting the marble to desired sizes in different civil works. The disposal of this material is a challenge. As in [7], author has reviewed various studies and shown the potential of re-use of various types of glass such as clear glass, brown glass, green glass, crushed glass and glass powder in the concrete and cement mortar. The particle size of waste glass plays a vital role in the ASR destructive reaction and the performance of the concrete. The pozzolanic properties of glass increased with decreasing the particle sizes finer than 100 μm, while all the experimental results showed that on increasing the percentage of waste glass aggregate reduces the maintenance of concrete. It has been emphasized that a full study is needed to find the optimum percentage of waste glass as aggregate replacement and particle size which can be used without any effect on the properties of the produced concrete. [10] showed the usage of Portuguese recycled glass material as replacement in cement-based mortars has been studied. In this study it has been observed by author that 100 % replacement of waste glass has a slow and delayed reaction to alkalis. To higher substitution ratios serious expansion and cracks were observed at 28- days. It has been observed that on partial replacement with cement (grain size < 125 μm) alkali silica reaction (ASR) expansion decreases [8, 10]. As in [2,3,4] the use of waste marble dust as partial replacement of cement as additive mineral has been

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studied with ratios 0%, 5%, 7.5%, 10% and 15% by weight and observed that marble dust acting as filler in the concrete and no noticeable change was shown in the hydration process. The compressive strength of cement mortar is increased. Compressive strength of cement mortar has been increased to 1%, 10%, and 12% for the replacement of 5.0%, 7.5% and 10% respectively. The ASR tests showed the expansion values are within 2 to 3 mm. SEM analyses showed the gel is less porous and denser in nature. The gel is composed of crystals as CSH and CH in layers. Ettringite was observed. As in [12], waste liquid crystal glass rich in silica was used as partial replacement of natural sand by 0%, 10%, 20% and 30%. It has been observed that on replacement of cement with 10% glass, the mortar observed to be compact and resist sulphates. SEM images showed the presence of C-S-H low density gel and CH crystals. ASR tests performed on the mortars and observed that upto 10% replacement of glass with sand, the ASR reaction is negligible and above 10% shows the presence of ASR [6, 9]. In [5, 11, 13] the natural sand is replaced by waste glass and observed that the compressive strength at 90 days was marginally reduced at rate of 4% to 4.84% to the control mix. The glass is treated with nitric acid to reduce the effect of residual lead which could inhibit the hydration process thereby reducing the compressive strength. As per [1] the glass was used as replacement of sand in the self compacting concrete and showed that the compressive strength decreased to 24% at replacement ratio of 50%. SEM images showed the poor homogeneity of mix. Cracks are observed at the higher percentage replacement of glass.

II. RESARCH SIGNIFICANCE

The objective of the research was to make sure the utilization of waste material in cement mortar at desired proportion. The waste generated during the resizing of marble, polishing the statues, broken window panes can be re-used in the constructional activities. The morphological effect of utilizing waste marble dust along with waste crushed glass. Specimens were prepared in two stages only with waste marble dust and then with waste marble dust and waste crushed glass. The replacement ratios studied were 0%, 5%, 10%, 15% and 20%.

III. MATERIALS AND METHOD

A. Materials

Cement: In this study ordinary Portland cement of make ACC 43 grade was used conforming to IS 8112-1989.

Sand: The natural river sand locally available was used.

Waste marble dust: Waste marble dust is been taken from the marble shop available in Jalandhar, Punjab where cutting and desire size of the marble is done. The waste generated from these operations was collected and processed to grinding as shown in Fig. 1. The waste marble dust has been sieved from IS Sieve 150 microns. Morphology of waste marble dust is shown in Fig. 2. Image shows the size of the particles varies from 2 µm to 200 µm. the chemical composition of waste marble dust is given in Table 1.

Waste Crushed glass: The waste glass has been taken from the broken window panes having white color glass which were further processed and crushed. The waste crushed glass used is used in partial replacement with sand in stage 2 and is sieved from 850 microns as shown in fig. 3. The morphology of the crushed glass is shown in Fig 4. Image showed that the particles are angular in nature. The elemental composition is given in Table 1.

Figure 1. Waste marble dust.

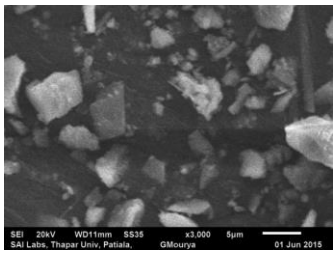

Figure 2. Morphology of waste marble dust.

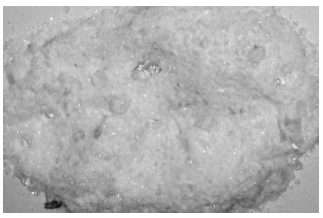

Figure 3. Waste crushed glass.

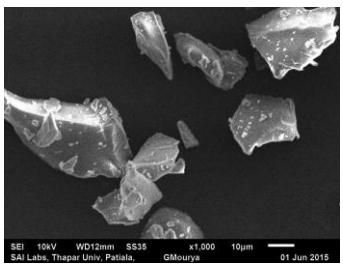

Figure 4. Morphology of waste crushed glass.

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Table 1. Chemical properties of waste materials

Chemical oxides	Chemical Composition (%)	
	Marble dust	Crushed glass
CaO	5.52	3.60
SiO_2	42.24	70.70
Na_2O	4.94	19.72
MgO	1.86	5.97
Al_2O_3	17.59	--
Fe_2O_3	1.02	--

SEM- EDS was carried out at SAI labs, Thapar technology campus, Patiala, Punjab.

B. *Method and Experimental structure*

In this study, experimental structure was divided in two stages. In stage 1, the cement was replaced with waste marble dust at ratio of 0%, 5%, 10%, 15% and 20%. In stage 2, the cement was replaced with waste marble dust for the optimized ratio of 10% and sand is replaced with waste crushed glass at the ratio of 0%, 5%, 10%, 15% and 20%. Water to binder ratio used was 0.50. All the cement mortar cubes were casted and cured till date of testing in water. The mechanical property i.e. by compressive strength has been studied and micro structure has been analyzed for both the stages. The mixing ratio is given in Table 2 and Table 3.

Table 2 Mix constituents for stage 1

Mix	Cement	Marble Dust
R0	100 %	0 %
R5	95%	5%
R10	90%	10%
R15	85%	15%
R20	80%	20%

Table 3 Mix constituents for stage 2

Mix	Marble Dust	Cement	crushed glass	Sand
WG0	10%	90%	0 %	100%
WG5	10%	90%	5%	95%
WG10	10%	90%	10%	90%
WG15	10%	90%	15%	85%
WG20	10%	90%	20%	80%

IV. RESULTS AND DISCUSSION

A. *Cement mortar with waste marble dust:*

1) Compressive strength of cement mortars: As shown in Fig. 5, it has been observed that the compressive strength for the replacement of 5%, 10% has been increased to 7.10%, 10.53%respectively and there was considerable decrease in compressive strength to 20.24%, 31.59% for 15% and 20% partial replacement respectively. The decrease in compressive strength might be due to CaO compound which is decreasing on further addition of waste marble dust. Compressive strength loss might be due to reduction in C_3S and C_2S cementing material. 10% replacement ratio can be considered as optimum percentage above which the compressive strength decreases. The increase in compressive strength is due to the pozzolanic action of marble dust.

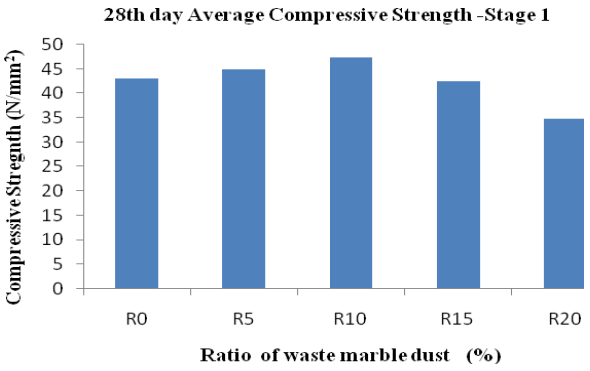

Figure 5, Compressive strength of waste marble dust

2) Morphology of marble dust modified cement mortar: A number of scanning electronic microscope graphs are studied for various magnifications for the (optimized ratio of 10% waste marble dust) cement modified cement mortar at 28 th day. These micrographs are shown in Fig 6. Fig. 6 (b) shows the presence of C-S-H gel and CH crystals, Ettringites are present in the pores which are needle like strctures. Fig 6 (a) and Fig. 6 (c) shows the uniformly distribution of C-S-H gel and shows the mortar is less porous and more denser.

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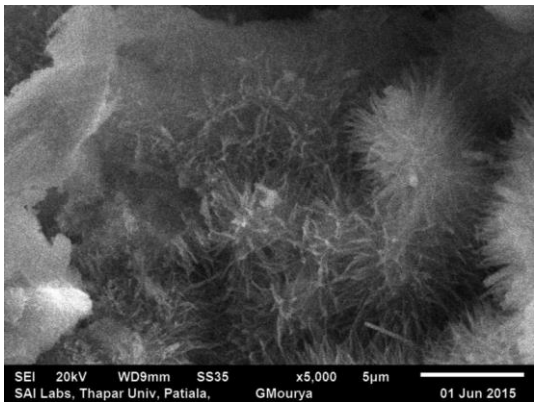
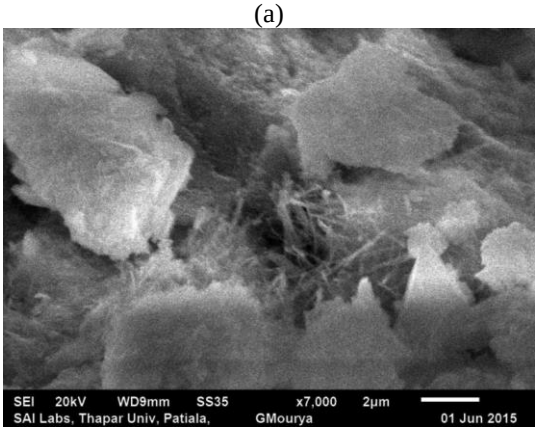
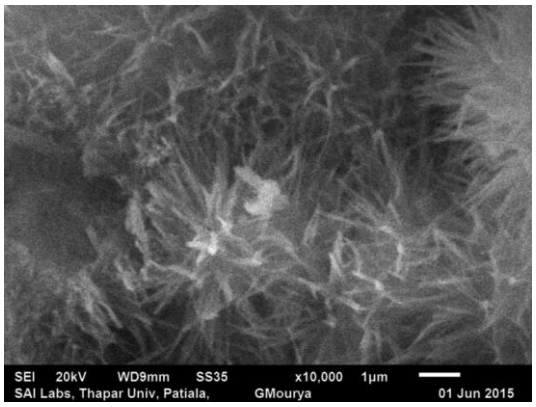


(a)



(b)



(c)

Figure 6, SEM of 10% marble dust modified cement mortar (a) at x5000 (b) at x7000 (c) at x10000 magnification.

B. Cement mortar with waste marble dust and waste crushed glass:

1) Cement mortar with crushed glass and binder: the compressive stregnth of waste marble dust modified cement mortar along with sand replacement with waste crushed glass has been shown in Fig. 7. It has been observed that the compressive strength was increased by 31.67 % at 20%. The increase in strength is due to the compactness and interlocking of angular size of crushed glass in mortar and with the increase in ratio of waste crushed glass the compactness increases and results in increased compressive strength as compared to controlled mix. At 5% partial replacement, the compressive strength decreases to 44.62%, this might be due to weak adhesion between cement paste and lesser amount of glass particles. The compressive strength was increasing for the ratio of 10% and 15% from the reference of 5% replacement of waste glass. This can be addressed due to the angular sized crushed glass interlocking which is resulting in homogeniety of mix.

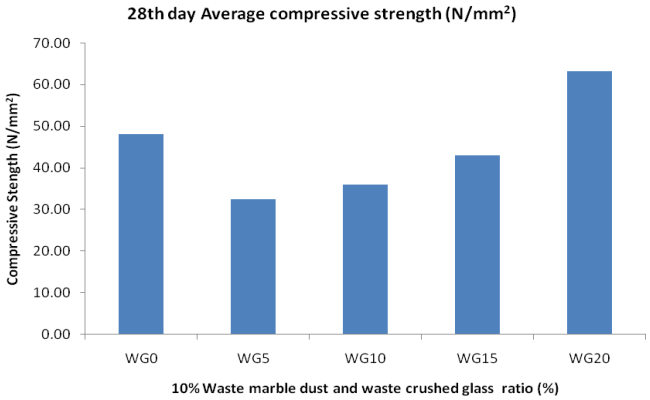


Figure 7 Compression strength of Blend material

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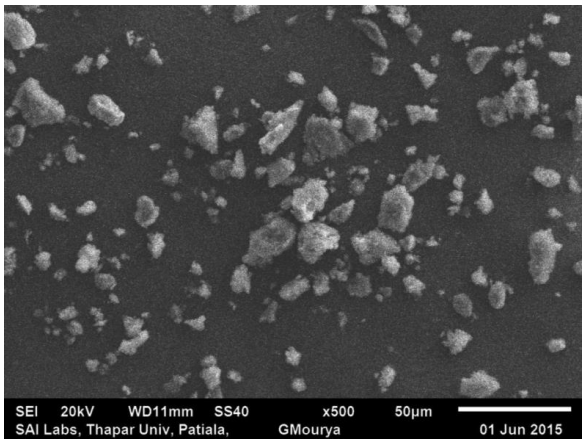
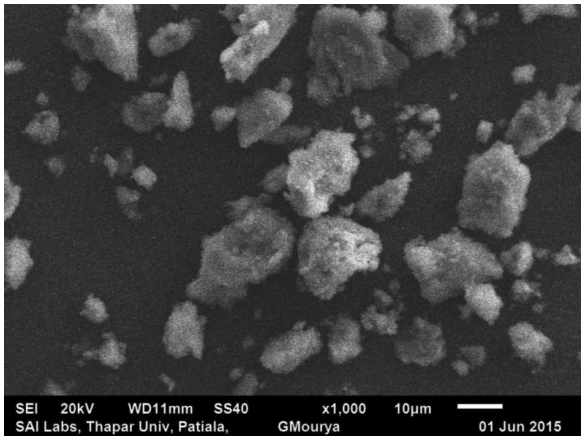
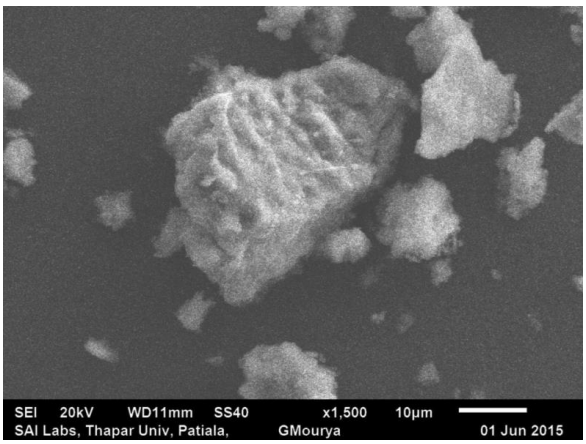
2) Morphology of optimum waste material blended with crushed glass in replacement of sand: Micro study is carried out with SEM and the microscopic graphs of the cement mortar at 28 th day are shown in Fig. 8. The images (a) and (c) show uniform distribution of gel paste. Image (b) shows the crystal formation.



(a)



(b)



(c)

Figure 8, SEM of 10% marble dust modified cement mortar along with crushed glass as replcement of sand (a) at x500 (b) at x1000 (c) at x1500 magnification.

3) Cost analysis of samples: The cost analysis of the cement mortar was carried out. Some factors which can affect the total cost of the finished material such as transportation, placement, handling, quality control, has not been taken into account. The material cost was only the parameter worked per cubic meter. The total costs are shown in Table 4. The cost of material for controlled sample, 15% (WG15), 20% (WG20) waste crushed glass along with 10% marble dust are Rs. 4976, Rs. 5050 and Rs. 5167. It has seen that the cost of the controlled sample is less than the blended one. WG15 is having 1.5 % and WG20 is having 3.84 % more than the controlled sample material cost. At the same time to dispose these materials, landfills and other recycling methods increases the management cost which should be considered lower in comparison to this increase in cost. Moreover the usage of glass reduces its disposal sites for the solid waste management and provides eco-friendly solution.

Future Scope: SEM morphology of cement mortar shows the presence of C-S-H gel and in denser nature along with pores containing Ettringite, compressive strength increases from 5% for further addition of waste crushed glass till 20%. There is a scope of increasing the percentage of crushed glass more than 20% substitution with sand and sequential investigation is needed from time to time to check the changes happening as per the variation of material ratio.

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