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Impact of Waste Materials as Binder and Filler In Cement Mortar

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Abstract

Shortage of post-consumer disposal waste has become a necessary issue and immediate attention is required. Waste materials such as broken or unused glass, marble dustetc. has the huge potential to be used in the civil engineering and landfills can be saved. The research was focused on the utilization of waste materials as glass and marble dust in place of proportion with cement and crushed unused glass in proportion to fine aggregates in mortar. There were two phases where phase 1 consists of cement mortar from replacement of waste marble dust and the optimum ratio of waste marble dust was carried out in respect to compressive strength and phase 2 utilized the optimum ratio of waste marble dust and the substitution of unused crushed glass in replacement of natural sand. Compressive strength, morphology and cost analysis has beenexperimented. It has been observed that compressive strength was on higher side and the optimized ratio of waste marble experimented was 10%. Morphology witnessed the reasons. Cost analysis was taken into account for the material cost.

1. Introduction

Now a days developing country are facing shortage of site for post-consumer disposal waste and it has become very serious problem. The materials such as 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 and aggregates, usage of natural resources is increasing day by day. To resolve such situations some alternatives materials should be tested and

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can be used for the production of cement and aggregates. Also, the rising prices of these raw materials are a concern.

Concrete is a boon as construction material to the construction industry wherein several desirable properties like considerable compressive strength, flexure strength and at the same time workability is there under normal environmental conditions.

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 remain at the shops after cutting of marble and from making of marble statues, tuned into heaves and these 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. Millions of tons of waste marble dust are being generated while cutting the marble. The disposal of this material is a challenge. Various studies have shown the strength of the mortar has been increased. D.Sepra et.al (2013) studied [10] on Portuguese recycled glass material as replacement in cement-based mortars. The efficiency to be used as pozzolanas or even as aggregates is related with the replacement ratios. In this study it is shown that 100 % replacement slowdown the reaction towards alkali. Even cracks were there at 28 days. When replacement is done for natural sand, there is slight increase of expansion observed at 28- days. It has been observed that on partial replacement with cement (grain size < 125 µm) alkali silica reaction (ASR) expansion decreases. Glass can be used till 20

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percent safely. Finely ground glass can be used as mineral additive. Author studied the use of marble unused in proportion to cement. Marble dust showed a filler effect in the concrete.Compressive strength of mortar has been on higher side.

No research has been stipulated for proportioning of mortarusing marble dust and unused or waste glass.

The engineering significance of researchwas

- ✓ Reuse and conservation of natural resources.
- ✓ Cost saving over traditional materials.
- ✓ Use of unused or broken glass as building material.
- ✓ Replacement of cement with waste material (marble dust) in constructional activities.

2. Background

Waste glass on reaction with cement has Alkali silica reaction which forms gel paste when used as coarser aggregates. This gel paste is porous in nature and swells on absorbance of water which in turn change the desirable properties in terms of strength. The waste glass shows pozzolanas behavior. It has been observed that the waste glass when used in the crushed form having size less than 1.18mm, shows no alkali silica reaction and thus can potentially be used in the concrete and save the natural resources as well.

Various investigations in the laboratory have evident that the broken glass and marble powder can be utilized in the mortar.

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has reviewed studies of various tests and experiments carried out by different researchers. The review paper has emphasized on the glass reuse and has highlighted the environmental issues related to the non-biodegradable nature of glass. The reviewed studies witnessed glass powder utilization in mortar. The author insisted upon the need of careful investigation for optimization the % of glass in lieu of aggregate.

Yahya Jani and William Hogland**(2014) and** Ali A. Aliabdo et. al **(2014)** carried out the experimental work for the waste and observed that there is no considerable change in water requirement when specimen is prepared with blended marble dust cement.Also no change has been shown in case of Initial and final setting times when the partial replacement of marble dust is done up to 15%. Thermo gravimetric analysis (TGA)test is performed on the specimen having $CA(OH)_2$. The weight loss is seen than the initial weight which is due to the decomposition of calcium hydroxide. XRD analysis shows no noticeable difference between control paste and the blendedone. SEM micrographs shows that the paste is less porous and denser than the controlled.The gel consists of CSH and crystals. Ettringite needles also present in the pores. In the second section, increases marble dust covers the volume in the mortar [1] [2]. Her-Yung Wang et. al**(2013)**carriedexperiment on the mortar having proportion from 10 to 50 percent of waste LCD as replacement for cement and also used replacement of natural sand by 0%, 10%, 20% and 30%. The waste glass used in the study is silica rich. The chemical composition of glass used is CaO – 2.70%, SiO_2-

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62.48%, traces of Al_2O_3, Fe_2O_3, MgO, SO_3, Na_2O compounds.Water content was reduced for higher proportions because of low water absorption rate on the glass surface. Compressive strength of cement mortar showed the slow growth and also compressive strength decreases with the increase in replacement ratio of glass.Calcium silicate hydrate gel is present in all mortars on the 28th day. SEM analysis showed that the alkali originally contained in the glass was bound in the paste and the crystalline materials are present which were resulted from the pozzolanic reaction of liquid crystal glass powder [11].

Diego Romero et. al**(2013)**[9] carried out experimental work on the cathode ray tube proportion of fine aggregates. The composition of glass is having silica content. Five cathode ray glass-based mortars are prepared for each ratio and tested for ASRThe optimum replacement was 10% above which ASR reaction is observed. As far as environmental problems are concerned, test has been conducted which shows environmental leaching shows that lead concentrations in the mix is lower than the drinking water and it depends upon the percentage replacement of the cathode ray tube along with the biopolymers.

Authorobserved [13] that fly ash has the role to reduce alkali reaction expansion and crushed treated CRT funnel tube glass sand having fineness modulus of 3.22 against fineness modulus of 2.15 of sand was used to replace the natural sand by 0%, 25%, 50% and 75% in the high density concrete. Nitric acid is used to remove the lead oxide present on the surface of the crushed funnel glass. On this sample of crushed funnel glass, the toxicity characteristic leaching procedure has been adopted and found the limit within the permissible limits of 5 mg/L as per the requirement. It has been shown by adding the crushed funnel glass sand, the mechanical properties are improved and also the alkali silica reaction is within the specified limits of 0.1%. total of 4 high density concrete mixtures are prepared. The study has shown that the CRT funnel glass can be treated, processed and reutilized for the production of high-density concrete. The segregation and bleeding reduce and the values of the slump increases. With the increase of curing period the compressive strength increases.The reduction in compressive strength at 28 days is 8.65%, 14.54%, 18.70% for the ratio of 25%, 50% and 75% respectively. At the age of 90 days, the reductions in compressive strength were 4.05%, 4.49%, 4.84% for the ratio of 25%, 50% and 75% respectively. The reason for this can be due to two factors, one is due to incomplete adhesion between smooth surface of crushed glass sand and cement paste and secondly with the increase of more percentages of crushed funnel glass, the more residual lead contained in the crushed funnel glass is being added to the concrete which lowers the hydration reaction and inhibit cement hydration product formation. Alkali silica reaction expansion of the mortar is studied which shows addition of 15% fly ash mitigates the alkali silica reaction expansion within the limit of 0.1% as specified.

Zhao Hui and Wei Sun **(2011)**carried out work on cathode ray tube (CRT) of discarded computer monitors and televisions were used in lieu of aggregates in mortars. Various tests were performed. In this fly ash and ground granulated blast furnace slag is used as 25% replacement of cement.Slump flow values are more than controlled by 173% of the initial slump. The compressive strength obtained on the higher sides in case of slump flow diameter values. When fly ash is used as mineral admixture, the compression strength at 28 days was higher as 119% of the controlled. The same behaviour is exhibited with the GGBS. Expansion values of alkali silica reaction with fly ash as mineral admixture lies within the 0.1% at 14 days while with ground granulated blast furnace is 0.147%. This shows the alkali silica reaction using fly ash has effectively reduced [13].

Her-Yung Wang et.al has done research on the mortar with 0.485 w/c and 10%, 20%, 30%, 40%, and 50% partial replacement of TFT-LCD discarded glass by cement [11]. It has been observed that the setting time drops with more ratio and the compressive strength gradually reduces.The compressive strength at 10% is shown as same as that of controlled group. Durability of concrete at 10% substitution showed the best result. SEM analysis shows the presence of calcium silicate hydrate and calcium hydroxide crystals. The mortar structure is denser in nature.It is shown that the mortar having 10% substitution with TFT-LCD glass has the same microscopic structure as that of controlled group. At this substitution, it is shown from EDS that the silicon content increases and calcium content decreases [11].

Huseyin Yilmaz Aruntas et. al **(2010)** studied the mineral additive to be used in partial replacement of cement at amount of 2.5%, 5%, 7.5% and 10% by

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weight.The chemical composition of the waste marble dust studied was SiO_2- 0.67%, CaO- 54.43%, Na_2O and K_2O -0.14%, Al_2O_3 and Fe_2O_3 – 0.20%, MgO – 0.59%.The work is carried with respect to Portland cement and Portland composite cement. Amount of 5% gypsum was in the clinker to mitigate the ASR. Mortar samples of size 40 x 40 160 mm have been prepared. It has been pointed out the specific gravity of waste marble dust is less than the specific gravity of cement. The need of water requirement is less as compared to control specimen. The setting times were not so affected. Due to less content of Al_2O_3 in the waste marble, the setting times does not considerably changed. It has been seen that the adding the ratio of waste marble dust decreases the CaO content in the sample. The compressive strength of the blended cement mortar sample is more than the Portland composite cement and less than the Portland cement with respect to controlled sample. The compressive strength decreases at the rate of 20%, 17%, 19%, 16% from the controlled specimen at the ratio 2.5%, 5%, 7.5% and 10% respectively and is higher than Portland composite cement at the rate of 23%, 28%, 25% and 30% for the respective ratios on 7 days whereas for 28 days, the compressive strength was equal to the controlled specimen at ratio of 2.5 , 5.0 % and decreases at the rate of 10% and 14% for ratio of 7.5 and 10% respectively. The compressive strength for 90 days is found to be higher than Portland cement controlled specimen at the rate of 2%, 5% for ratio of 2.5%, 5.0% and decreases at the rate of 3% and 4% for the ratio of 7.5% and 10% respectively. The higher strength is contributed due to the PC content being higher than PCC content. More addition of the waste marble dust in the cement

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affects the compressive strength on the negative side. Unused waste marble dust can be utilized till 10 percent safely. The compressive strength is on higher side than the compressive strength of controlled specimen in case of Portland composite cement than the Portland cement [3].

Hebhoub reported**(2010)**experimental work withunused marble dust proportionate toaggregates. The natural sand and aggregate were replaced by waste marble dust in ratio of 25%, 50%, 75% and 100%.It has been observed that the substitution till 75% can be utilized in the concrete which shows better results in respect to controlled specimen [4].

Zainab Z. Ismail et.al**(2009)** observed crushed waste glass used in the mortar as partial replacement of fine aggregates at ratio of 10%, 15%, 20%. ASR tests and strength properties have been studied. The chemical composition of the waste crushed glass powder was SiO_2- 67.72%, CaO- 6.9%, Na_2O and K_2O -10.75%, Al_2O_3 and Fe_2O_3 – 3.4%, MgO – 6%. Test showed that the finely grounded waste glass used in the mortar reduces the expansion by 66%. The tests shows decrease in slump from 75mm for 0% replacement to 50mm for 20% replacement. This is due to poor geometry of the waste glass which is acting as hindrance in flow of mix.Compressive strength increases from 44 N/mm^2 at 0% to 45.9 N/mm^2 for 20% replacement. At 20%, the increase is at rate of 4.23% with respect to controlled one. It has been observed the marginal decrease at the 14 days might be due to poor bonding inter-surficial. Later this decrease has been improved on 28 days. The reason could be the pozzolanic reaction appears at

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later stage and make the remarkable improvement over the strength of the concrete. The optimum ratio for the replacement can be taken as 20% [6].

Seung observed**(2004)t**he broken glass in proportioned with natural sand at the ratio of 30%, 50% and 70%. The compressive strength decreases with increased content of crushed glass. The expansion rate increases for the increase in crushed glass content [8].

3. Problem identification and methodology

As far as past studies are concerned for the waste crushed glass and waste marble dust, it has been observed that waste glass powder and waste marble dust proved to be useful in proportion with cement and fine aggregates when used standalone. Results obtained for the work carried out in the past are on the higher side.

Intensive experiments are the need of hour with waste materials as discussed. Research was focused for investigate the effect of unused glass crushed and marble dust in mortar. During phase one, cement mortars was prepared using crushed marble dustwith desired percentage along with cementfor the optimized percentage of marble dust. Phase two comprises of cement mortar cubes withoptimized ratio experiments during phase one and unused glass as filler material with natural fine aggregates.Morphology and compressive strength parameter were carried out.

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Methodology/ Planning of work:

The study will be carried out as follows

1. To optimize the unused marble in the mortar 1:3 from 0% to 20%.
2. To find the compressive strength of the cubes casted with waste glass powder as a partial replacement with fine aggregates for the ratio of 0%, 5%, 10%, 15% and 20% with optimized blended cement
3. Cost analysis of blended cement and partial replacement of sand with waste glass powder over traditional materials.

The experimental program was in phases, First phase, the unused marble has been used as partial replacement of cement in the amount of 0%, 5%, 10%, 15% and 20% by weight to know the optimized replacement ratio. After the optimized ratio from phase one, the same optimized ratio was carried to phase two with the cement is being partially replaced with this ratio and the waste crushed glass is used as partial replacement of waste crushed glass in the amount of 0%, 5%, 10%, 15% and 20% by weight. For both the stages, the cement mortar cube of size 70.7 mm has been prepared for each ratio. Compressive strength was tested at the age of 7th and 28th day to understand the impact of powder from marble in the beginning and at the 28th days of curing. The FTIR analysis of sample is done and also the SEM analysis is done on the material sample and finished mortar sample. The both stages are represented as below

For stage-1 Composition of cement with partial replacement of waste marble dust

Ratio (%)	Waste Marble Dust	Cement	Total

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

For stage-2 composition of waste marble dust and waste crushed glass

Ratio (%)	Waste Marble Dust	Cement	Waste 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%

The cost analysis of the mortar was studied, in this study, the material cost is only considered. There are factors whose cost has not been considered such as handling, placing, transportation etc.

4. Waste Materials characterization-

Standard cement grade of 43 and standard sand has been taken for experimentation and waste materials chemical composition has been addressed herein.

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Waste marble dust: Waste marble dust is been taken from the marble shop where cutting and desire size of the marble is done. The waste generated from these operations is collected. The waste marble dust has been sieved from IS Sieve 150 microns. The specific gravity of the waste marble dust is 2.67. unused marble powder was taken in Phase one as figure 4.1. The chemical composition is shown in table 4.3. morphology of the sample used is shown in figure 4.2 wherein it is seen that the particles are denser in nature. From the morphology, it is clearly shown that the particle size varies as small as 2 µm and as large as 200 µm. Also the percentage elemental variation is there in the sample. CaO varies from 1.42 – 5.73%, SiO_2 varies from 32.52 – 58.09%, Al_2O_3 varies from 15.04 – 17.59%. It can be seen that the particles are uniformly distributed throughout.

Figure 4.1 Waste marble dust.

Table 4.3 Chemical composition of waste marble dust

Characterization of elmentsCompound	Proportion (%)
CaO	5.52

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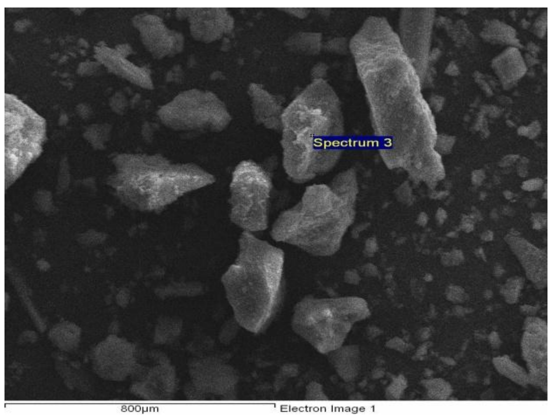
SiO_2	42.24
Na_2O	4.94
MgO	1.86
Al_2O_3	17.59
Fe_2O_3	1.0



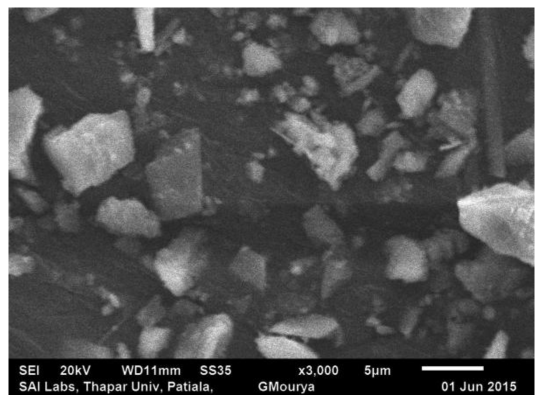


Figure 4.2 Morphology of waste marble dust

Waste crushed glass: The waste glass has been taken from the broken window panes having clear glass of 4mm size which are 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. The particles are angular in nature. Homogenous in nature.

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Figure 4.3 Waste crushed glass.

Table 4.4: Chemical composition of waste crushed glass

Compound	Percentage (%)
CaO	3.60
SiO_2	70.70
Na_2O	19.72
MgO	5.97

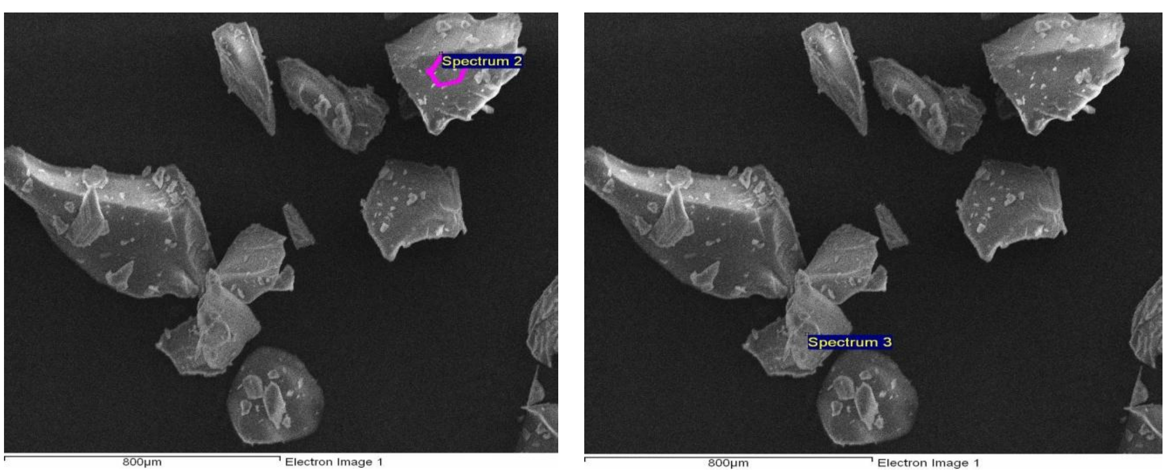

Figure 4.4 Morphology of waste crushed glass

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FTIR spectroscopy of materials: Fourier transformation infrared spectroscopy of the materials is done and explained. From figure FTIR of cement shows peaks and phases. C_3S phase at 522 cm^{-1} frequency, C_2S phase at 489, 875, 920 cm^{-1} , water bands are shown at 3308 cm^{-1}

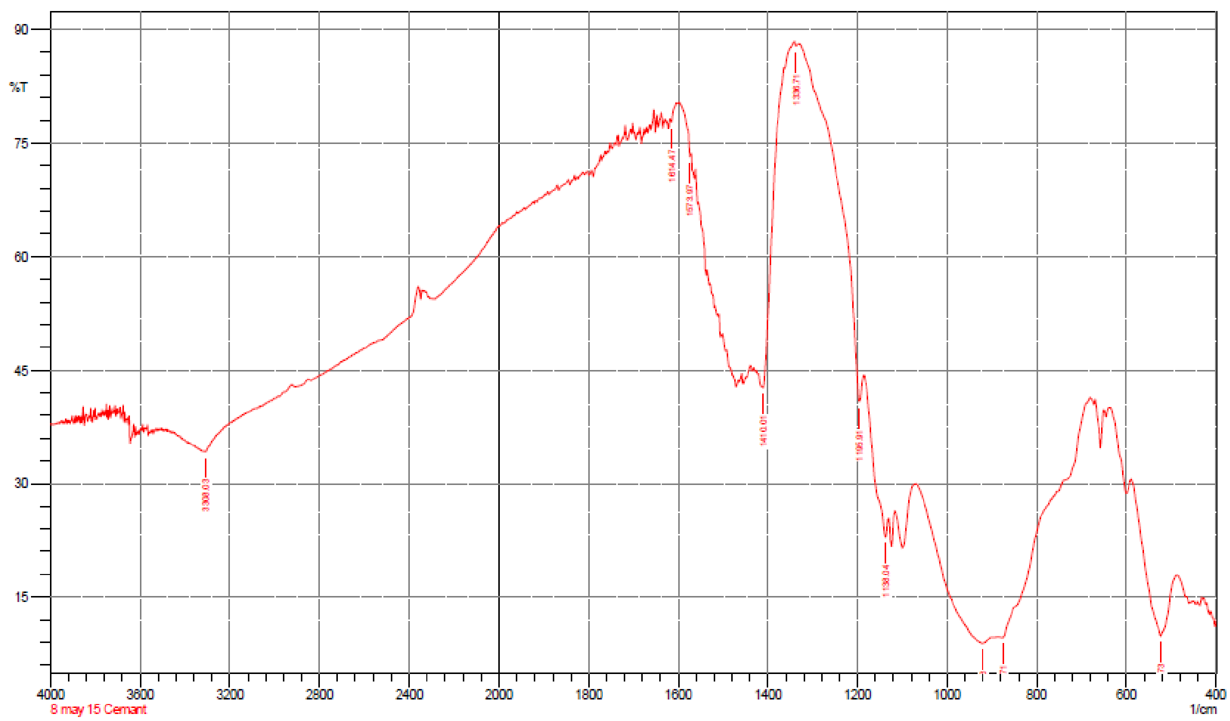

Figure 4.5: FTIR of OPC cement grade 43

From figure FTIR of waste marble dust shows peaks and phases that are in accordance with the cement phases. C_3S phase at 464 cm^{-1} frequency, C_2S phase at 464, 877, 925 cm^{-1}, water bands are shown at 3055, 3672 cm^{-1}

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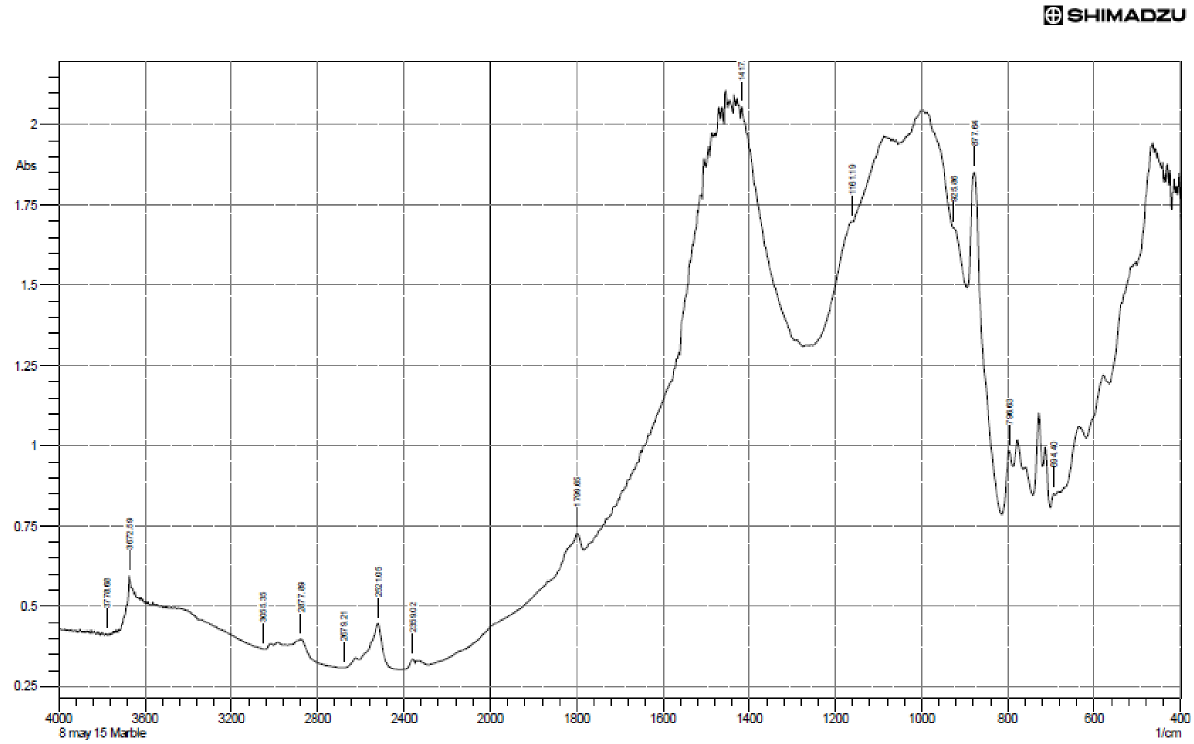

Figure 4.6: FTIR of waste marble dust

From figure FTIR of waste crushed glass shows peaks and phases, C_3S phase at 462 cm^{-1} frequency, C_2S phase at 462, 630, 771 cm^{-1}, water bands are shown at 2885 cm^{-1}

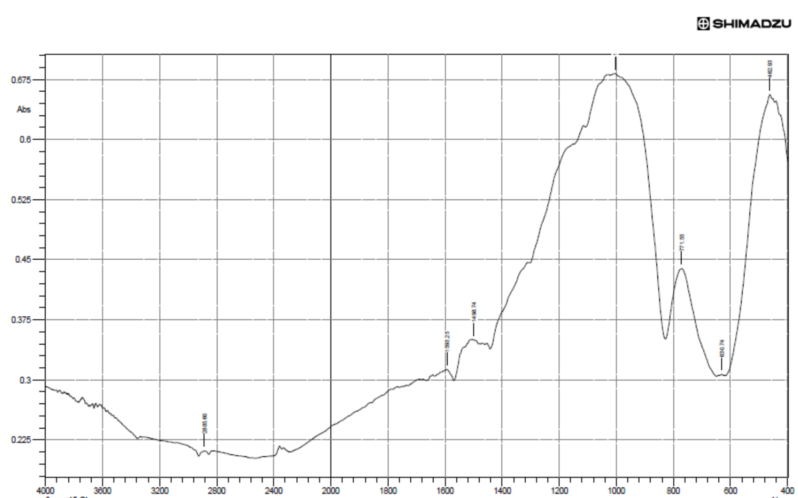

Figure 4.7: FTIR of waste crushed glass

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5. Discussion and Conclusion

Impact of waste materials through experimented research has been on the higher side First phase showsthatcompressive strength was more than controlled due to the increase of CaO at earlier replacements whereas more proportion leads to decreases the CaO content in the cementmix due to which the strength further gets decreases. The results are as under

Phase one Compressive strength impact: From the experimental study, it has been observed that the compressive strength for the partial replacement of 10% has been still increasing to 10.53%, also the increase in compressive strength has been seen at 5% partial replacement. But for 15% and 20% partial replacement, there was considerable reduction in strength. This might be due to CaO compound which is decreasing on further addition of waste marble dust, due to reduction in CaO content, the compressive strength decreases. The average compressive strength is presented in figure 2.

Table 5.1 Average Compressive strength test at 28th day - Stage 1

Ratio of WMD	Average compressive strength	Percent Increase in Strength	Percent Decrease in Strength
(%)	(N/mm^2)	(%)	(%)
R0	43.13		
R5	44.87	7.10	
R10	47.45	10.53	
R15	42.49		-20.24
R20	34.75		-31.59

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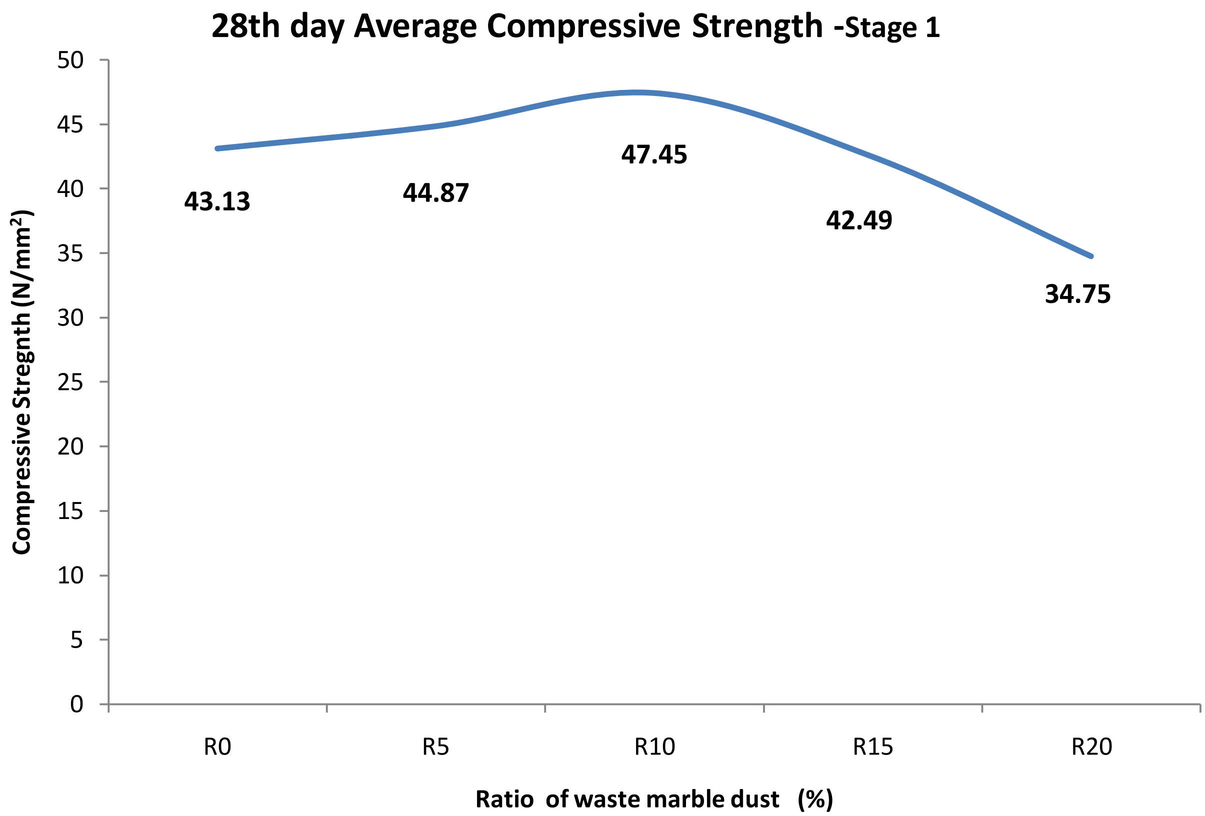

Figure 5.1 Compressive strength of stage 1 at 28th day.

Phase two: In phase 2, The average compressive strength at 28th day is shown in the table 4.2. It has been observed that the strength is increased by 31.67 % at 20%. The same is presented in figure 2. The increase in strength relates to compactnessand angularity in mortar and the ASR reaction is not possible as the size of the crushed glass is less than 1.18mm. With the increase in ratio of waste crushed glass the compactness increases and results in increased compressive strength as compared to controlled mix.

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Table 5.2 Average Compressive strength test at 28th day -Stage 2

Ratio	28th day Average compressive strength	Percent Increase in Strength	Percent Decrease in Strength
(%)	(N/mm2)	(%)	(%)
WG0	48.01		
WG5	32.41		-44.62
WG10	36.01		-25.00
WG15	42.93		-10.58
WG20	63.22	31.67	

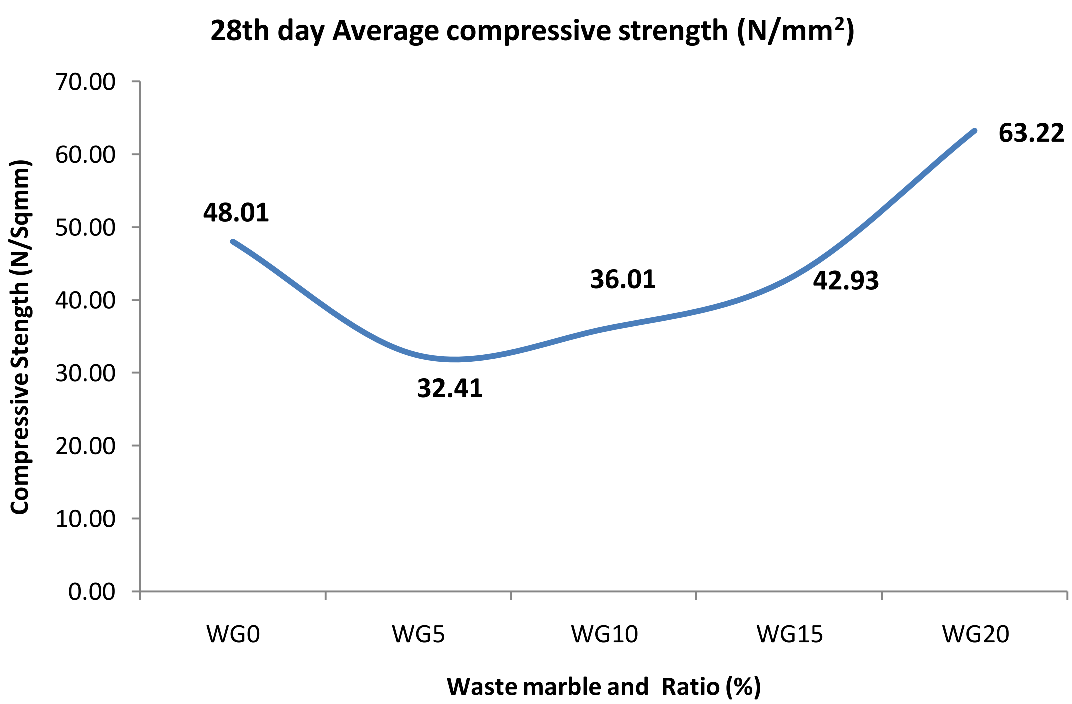

Figure 5.2 Compressive strength of stage 2 at 28th day.

5.1 Morphological analysis of Phase one: The morphology is shown in the figure 5.3, this shows the presence of CSH gel and crystals. The gel is denser in nature

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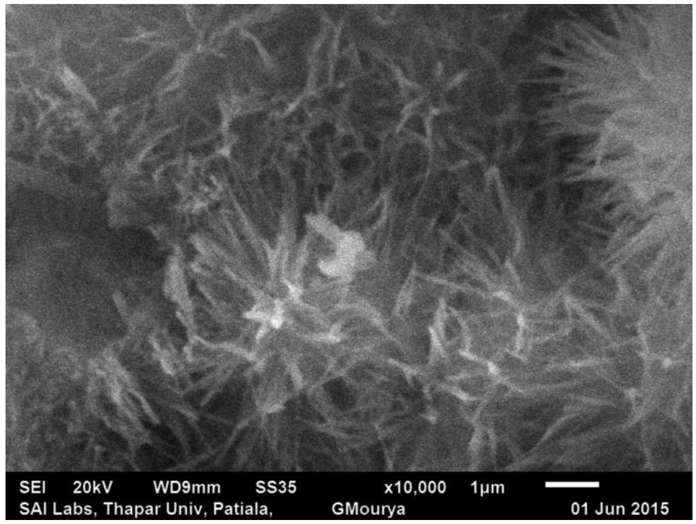
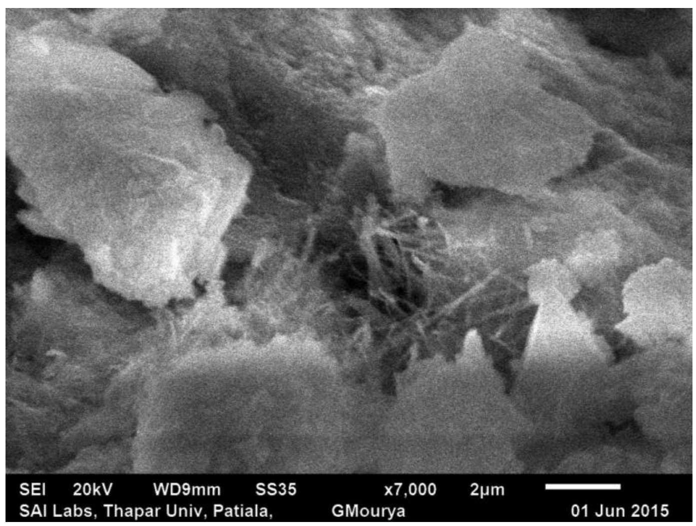
and uniform throughout. Image shows the structure is less porous. In pores, Ettringite needles are seen in the images.





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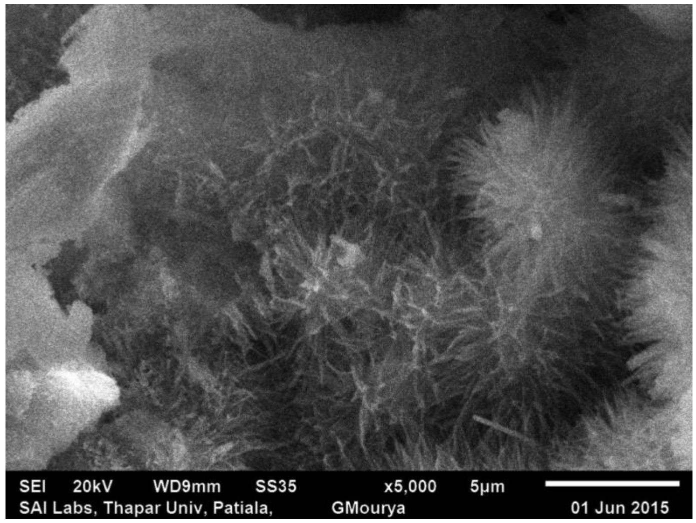
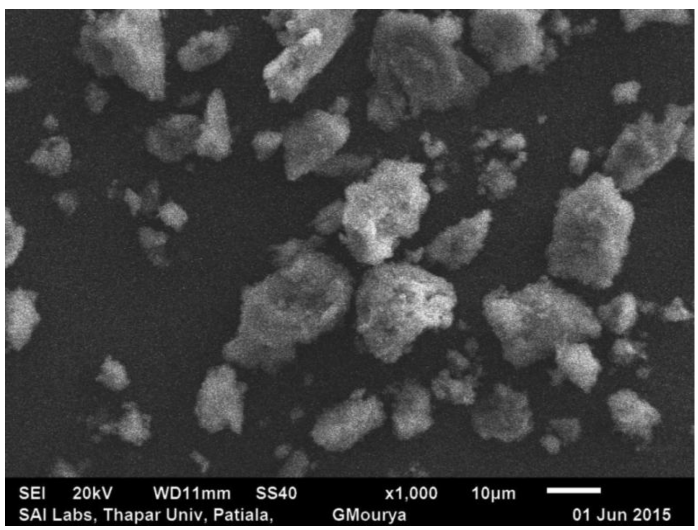


Figure 5.3 Morphology of Cement mortar at 10% waste marble dust.

Morphological analysis of Phase two:. The images show uniform distribution of gel paste.



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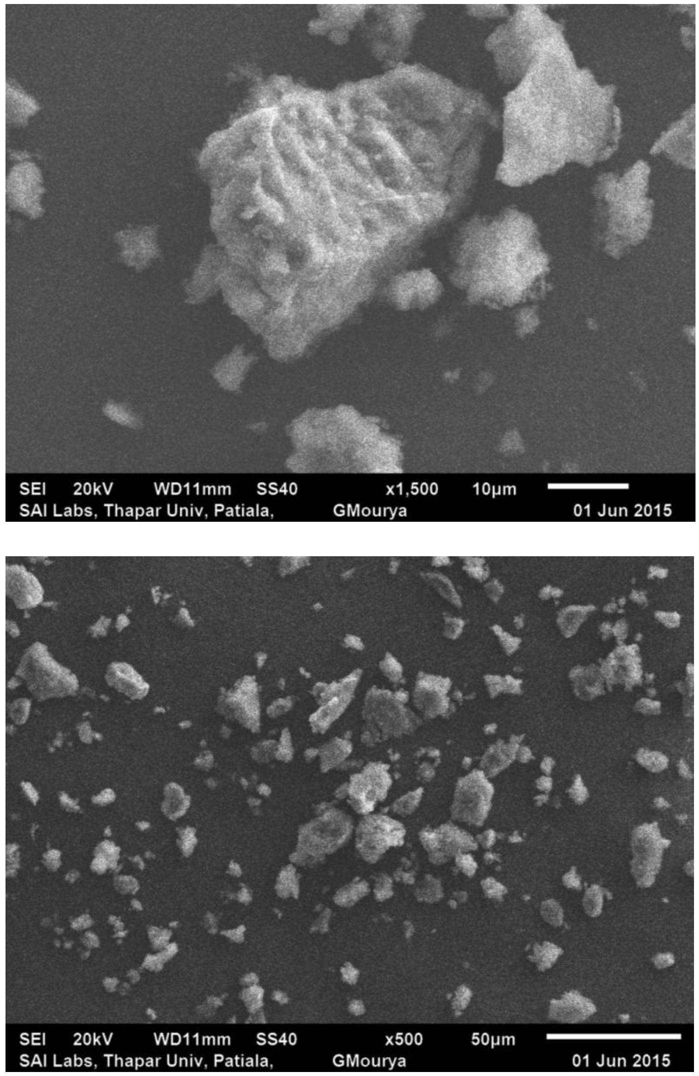

Figure 5.4 Morphology of Cement mortar at 10% waste marble dust and 10% crushed glass

Cost analysis of cement mortar: The cost analysis of the cement mortarwere calculated in table 5.3. the cost of material for control, 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 control material is less than the other blended

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one. WG15 is having 1.5 % and WG20 is having 3.84 % more than the controlled 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 concern and eco friendly solution.

Table 5.3 The Material Cost in Rupee of Cement Mortar (1:3) per m^3

Sample	Material Cost per m^3					Total material Cost (Rs.)
	Cement	Fine Aggregates	Waste Marble Dust	Glass Powder	Water	
Control	3876	1098	0	0	1.9	**4976**
WG15	3488	933	114	513	1.9	**5050**
WG20	3488	878	114	684	1.9	**5167**

CONCLUSION

On account of experimental study, the conclusions are as under

- The waste materials like waste marble dust upto 10% in proportion to cement and crushed glass upto 20% in proportion to sand can be utilized.
- Both the materials act as filler and binder for the proportion experimented.

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- Cost analysis showed that the costs of the samples are more than control specimen by 1.5 to 3.84%. The increased cost can be offset by the cost involved in arranging landfills for such hazardous waste.
- The morphology of the sample prepared showed the formation of CSH gel and crystals as Ettringite like needles.

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