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Comparative Study of Waste Glass Powder as Pozzolanic Material in Concrete

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ABSTRACT

Glass is utilized in numerous structures in everyday life. It has restricted life expectancy and after use it is either stock heaped or sent to landfills. Since glass is non-biodegradable, landfills don't give a situation neighborly arrangement. Consequently, there is solid need to use waste glasses. Numerous endeavors have been made to utilize waste glass in solid industry as a replacement of coarse aggregate, fine aggregate and cement. Its execution as a coarse aggregate replacement has been observed to be non-acceptable in light of solidarity relapse and development because of alkali-silica reaction. The examination demonstrates that there is quality misfortune because of fine aggregate substitution moreover.

The point of the present work was to utilize glass powder as a replacement of cement to survey the pozzolanic action offine glass powder in cement and contrast its execution and other pozzolanic materials like silica smoke and fly fiery debris.

A progression of tests were led to study the impact of 15% and 30% replacement of cement by silica smolder, fly fiery remains and glass powder on compressive quality and solidness as hairlike ingestion. The molecule estimate impact was assessed by utilizing glass powder of size150µm-100µm and glass powder of size under 100µm.

The present study demonstrates that waste glass, if ground better than 100µm demonstrates a pozzolanic behavior. It responds with lime at beginning time of hydration shaping additional CSH gel along these lines framing denser cement matrix. The early utilization of alkalis by glass particles mitigate alkali-silica reaction henceforth increment toughness of cement.

Keywords : pozzolona, glass powder, silica, fly ash,

INTRODUCTION:

Concrete is a mix of cement, sand, coarse aggregate and water. The key factor that increases the value of concrete is that it very well may be intended to withstand harshest situations huge job. Today an Earth-wide temperature boost and natural pulverization have turned out to be show hurts as of late, worry about ecological issues, and a change over from the mass-waste, mass-utilization, large scale manufacturing society of the pasttoazero-manation society is currently seen as critical. Typically glass does not hurt the earth at all since it doesn't emit toxins, however it can hurt people and in addition creatures, if not managed cautiously and it is less benevolent to condition since it is non-biodegradable. Accordingly, the advancement of new advances has been required. The term glass

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contains a few synthetic assorted varieties including soft drink lime silicate glass, alkali-silicate glass and boro-silicate glass. To date, these sorts of glasses glass powder have been broadly utilized augmentation and aggregate blend as pozzolana for civil works. The presentation of waste glass augmentation will build the alkali content in the cement. It additionally help in blocks and clay fabricate and it jelly crude materials, diminishes vitality utilization and volume of waste sent to landfill. As valuable reused materials, glasses and glass powder are for the most part utilized in fields identified with civil engineering, for instance ,in cement, as pozzolana (strengthening cementitious materials),and coarse aggregate. Their reuse ingratiois near 100%, and it is alsousedin concrete without antagonistic impacts in concrete toughness.

As of late, Glasses and its powder has been utilized as a development material to diminish natural issues. The coarse and fine glass aggregates could cause ASR(alkali-silica reaction)in concrete ,however the glass powder could smother their ASR propensity, an impact like advantageous cementations materials(SCMs). In this way, glass is utilized as are placement of beneficial cementitious materials.

This exploration work has the accompanying objective:

- To assess there cyclability of powdered waste glass as a pozzolana(SCM) as incomplete replacement of cement in the concrete.
- To study the near impacts of expansion of powder glass, fly fiery debris and silica exhaust in concrete as pozzolana to mitigate alkali aggregate reaction.
- A near investigations of various blends at minuscule dimension were made with the assistance of EDS and SEM analysis of themixes.

Trial Program Materials

The materials utilized in this present work are glass powder, Ordinary Portland cement(43□ review), fly fiery debris, silica exhaust, coarse aggregates and fine aggregates.

Glass Powder

The glass powder utilized in the present study is brought from Hyderabad advertise. This material replaces the cement in blend extent. Molecule estimate dissemination diagram and XRD analysis of glass powder was done and appeared in Fig.3.1 and Fig.3.2
individually.

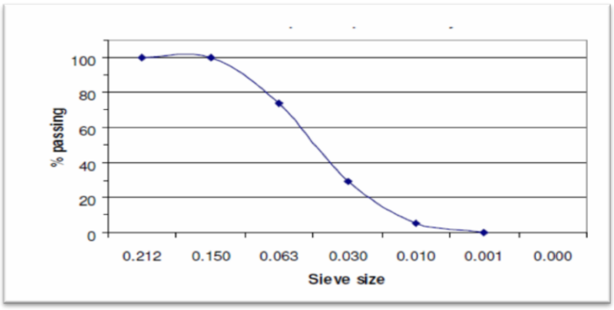
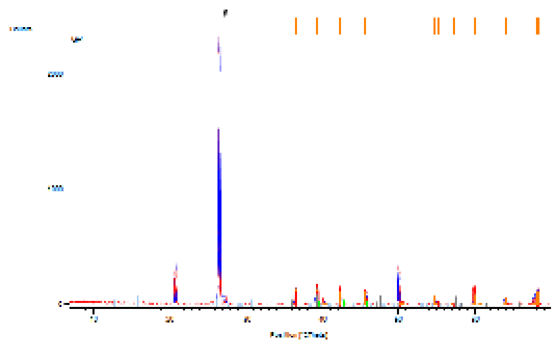


Fig.3.1



Silica Fumes The silica rage utilized in the present work is provided by Structural Laboratory of Department of Civil Engineering, NIT Rourkela. Silica rage is very receptive pozzolanic material and is a side-effect from the production of silicon or ferro-silicon metal. It is formed from the pipe gases from electric bend heaters. Silica

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rage is fine powder, with particles about 100th times minor than normal cement grain. It is accessible in a water slurry shape. It is utilized at 5% to 12% by mass of beneficial cementitious materials for concrete structures that requires high quality. The XRD analysis of silica smolder is appeared in Fig.3.3 and the analysis is given in table 3.1.

Chemical Properties of silica fume as supplied by the supplier

Silica fume	ASTM-C-1240	Actual Analysis
SiO_2	85% min	86.7%
LOI	6% max	2.5%
Moisture	3%	0.7%
Pozz Activity Index	105% min	129%
Sp Surface Area	>15 m2/gm	22 m2/gm
Bulk Density	550 to 700	600
+45	10% max	0.7%

Table 3.1

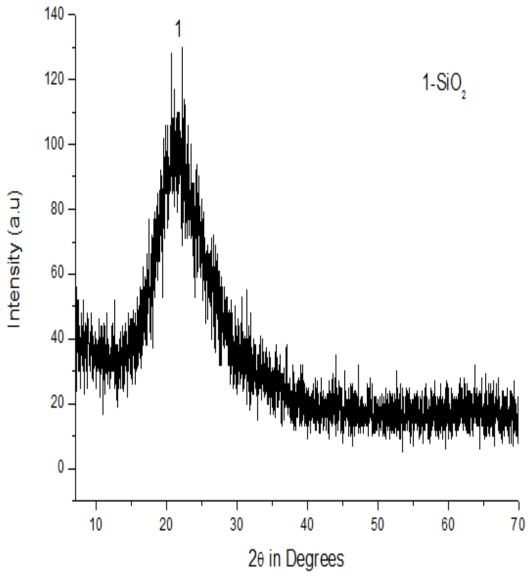
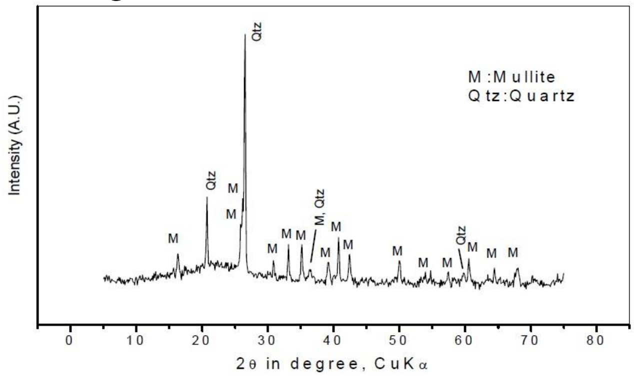


Fig.3.3

Fly Ash The fly ash used in the present work is supplied by CPP2 of Rourkela steel plant. Fly ash is largely made up of calcium oxide and silicon dioxide can be used as a substitute or as a supplent for Portland cement. Fly ash is also known as Green concrete. . The XRD analysis of silica fume is shown in Fig.3.4 and the sieve analysis is given in Fig. 3.5.



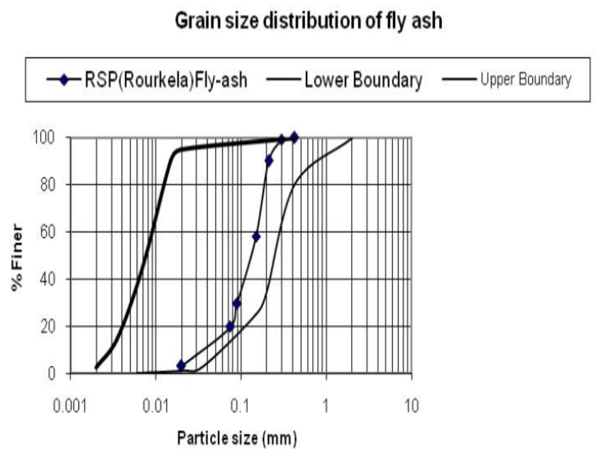


Fig.3.7 XRD

Fine Aggregate

Naturally available sand from Koel river bed is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. Hence used as a fine aggregate in concrete. The

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sieve analysis of sand is shown in table 3.2. As per IS383 the sand falls under zone 4.

Sieve size(mm)	Aggregate wt. retained(Kg)	% wt. retained	Cumulative % wt. retained	100 – cumulative % passing
4.25	.039	3.9	3.9	96.1
2.36	0.27	2.7	6.6	93.4
1.18	.088	8.8	15.4	84.6
.6	.176	17.6	33	67
.3	.416	41.6	74.6	25.4
.15	.234	23.4	98	2
Pan	.014	1.4	99.4	.6

Table 3.2

Sieve analysis of fine aggregate

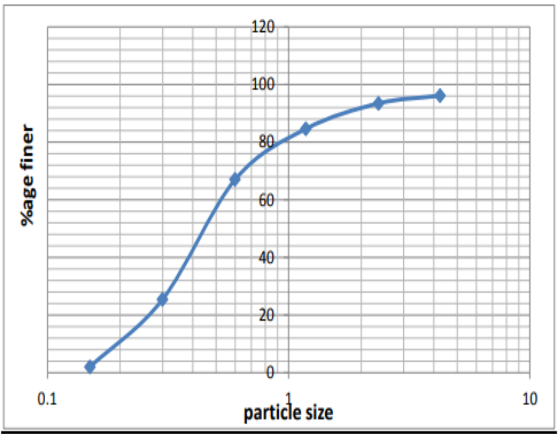

Fig. 3.8

Coarse Aggregate The coarse aggregate available in structural engineering lab of civil engineering department. The sieve analysis of 20mm and 10mm down size is shown in table 3.3 & 3.4 and sieve analysis in Fig.3.8 respectively. Sieve analysis of coarse aggregate

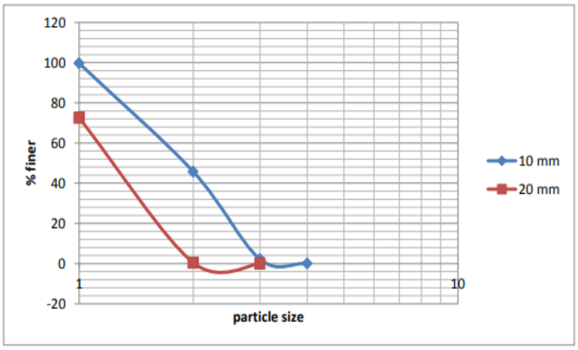

Fig.3.9

Sieve size(mm)	Aggregate wt. retained(Kg)	% wt. retained	Cumulative % wt. retained	100 – cumulative % passing
20	1.374	27.48	27.48	72.52
10	3.604	72.08	99.56	.44
4.75	.022	.44	100	0

Table 3.3(20 mm)

Sieve size(mm)	Aggregate wt. retained(Kg)	% wt. retained	Cumulative % wt. retained	100 – cumulative % passing
20	.016	.32	.32	99.68
10	2.696	53.92	54.24	45.76
4.75	2.178	43.56	97.8	2.2
Pan	.108	2.16	99.96	.04

Table 3.4 (10 mm)

Physical characteristics of materials were given below

Description	Spe
Cement (OPC)	
Silica fume	
Fly ash	
Glass powder	
Coarseaggregate	2.9
Fine aggregate	
Water	1

3.2 Methodology:

A nominal mix of concrete of proportion 1:2:4 was embraced for the present study. The main blend MC1 is control blend having just cement as cover. The MCF arrangement had fly slag as replacement of cement. The MCS and MCG arrangement had silica smoke and glass powder as replacement of cement. The compressive quality test were led to screen the quality advancement of concrte containing 15% and 30% of these pozzolana as cement replacement. The molecule estimate impact of glass powder contemplated by utilizing glass powder of size (150-100)µ and (50-100)µ. Slim ingestion test is directed to study the impact of alkali aggregate reaction. The EDS analysis and SEM analysis of the blends were done to study the adjustment in the morphological qualities of concrete blends • The tests were led in two arrangement. • In first Series 30 % of pozzolana were utilized as fractional replacement of cement. • In second arrangement 15% of pozzolana were utilized as halfway replacement of cement. • Eleven quantities of standard 3D shapes (150x150x150 mm) were cast to gauge the compressive quality after 28days and 52 days. Two 3D square were held to gauge narrow retention following 28 days and 52 days separately.

• The EDS analysis and SEM analysis of the blends were done following 28 days and 52 days to study the adjustment in the morphological attributes of concrete blends. To study the attributes following tests were led: Normal consistency Normal consistency of various folio blends controlled by utilizing the technique alluding to IS 4031: section 4 (1988) : • 300 gram of test coarser than 150µ strainer is taken. • Approximate level of water added to test and blended systematically for 2-3 minutes.

Fig 3.10

In the wake of applying oil to the surface of shape, glue was filled in the vicat's form and was set under the needle of vicat's contraption.

• Release rapidly the needle enabling it to soak in the glue and note down the infiltration perusing when the needle winds up stable.

• If the entrance perusing is under 5 to 7 mm, set up the glue again with more water and rehash the above method until the point that the needle enter to a profundity of 5 to 7 mm. • The level of the water with which the above circumstance is fulfilled is called ordinary consistency.

Compressive Strength Test For every arrangement five set were cast to decide compressive quality. Each set includes eleven standard solid shapes out of which nine 3D shapes were cast to quantify the compressive quality after 28days and 52 days. The extent of the 3D square is according to the IS code 10086 – 1982.

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Fig.3.11

Capillary absorption Test Out of eleven standard cubes two cubes were retained to measure capillary absorption coefficients after 28 days and 52 days curing respectively. This test is conducted to measure the capillary absorption which indirectly measures the durability.

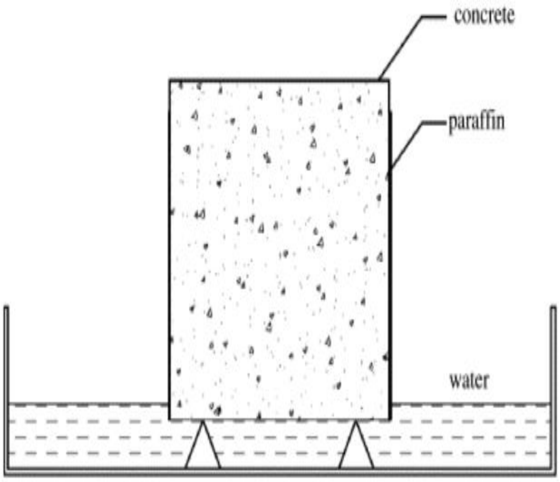

Fig. 3.12

Procedure: The sample was dried in oven at 105ºC until constant mass was obtained

- Sample was cool down to room temperature for 6hr
- The side of the sample was coated with paraffin to attain unidirectional flow
- The sample was exposed to water on one side by placing it on a pan filled with the water.
- The water in the pan was kept about 5mm above the base of the specimen as shown in• the figure below.
- The weight of the sample was measured at 15 and 30 minutes intervals

The capillary absorption coefficient (k) was calculated by using formula:

$$k= Q/A* \text{sqrt} (t)$$

where, Q= amount of water absorbed

A = cross sectional area in contact with water
t = time

Fig. 3.13

RESULTS& DISCUSSION

RESULTS AND DISCUSSIONS Normal consistency of binder mixes were tabulated below:

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Mix	Description	Cement(g)	Silica fume(g)	Fly ash(g)	Glass powder(g)	Consistency(%)
MC	CEMENT	300	0	0	0	31.2
MCS	MC with 15% SF	255	45	0	0	36.67
MCF	MC with 15% FA	255	0	45	0	38.3
MCG 1	MC with 15% GP	255	0	0	45	37.2
MCG 2	MC with 30% GP	210	0	0	90	38.5

Table 4.1

Where, MC= pure cement, SF= silica fume, FA= fly ash, GP= glass powder Compressive Strength The results of compressive strength testing of laboratory-cured cubes are presented in Table 4.2. and Table 4.3 for First series with 30% cement replacement and Second series with 15% cement replacement respectively.

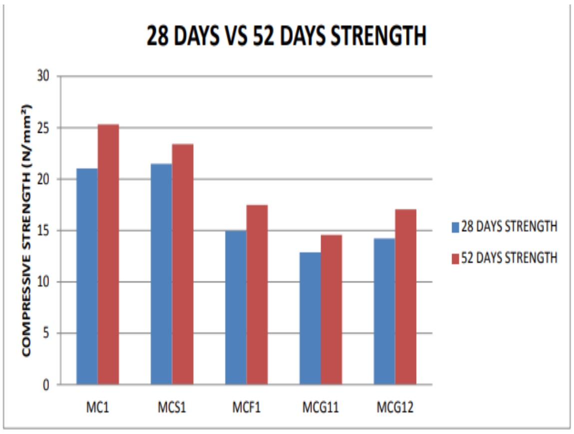
The strength values reported are the average of three test results. Fig. and Fig. are graphical representation of strength development of concrete cubes of various mixes for the First series and second series respectively. Compressive Strength of series after 28 days and 52 days were tabulated below:

First Series

DESIGN MIX	28 days (N/mm²)	52 days (N/mm²)
MC1	21.03	25.33
MCS1	21.48	23.41
MCF1	14.96	17.48
MCG11	12.88	14.57
MCG12	14.22	17.05

Table 4.2

Table 4.2 Where, Where, Mix MC1= Only OPC cement
Mix MCS1= cement + 30% silica fume
Mix MCF1= cement + 30% fly ash
Mix MCG11= cement+ 30% glass powder (150-100) micron
Mix MCG12= cement + 30% glass powder (<100) Microns



Compressive Strength of mixes with 30% replacement of cement. Fig. 4.1a Second Series

Second Series

DESIGN MIX	28 days (N/mm²)	52 days (N/mm²)
MC2	21.03	25.33
MCS2	22.88	24.88
MCF2	15.556	18.815
MCG21	13.77	14.67
MCG22	15.11	19.57

Table 4.3

Where, Mix MC2= Only PPC cement
Mix MCS2= cement + 15% silica fume
Mix MCF2= cement + 15% fly ash MixMCG21= cement+ 15% glass powder (150-100) micron Mix MCG22= cement + 15% glass powder (100-50) micron

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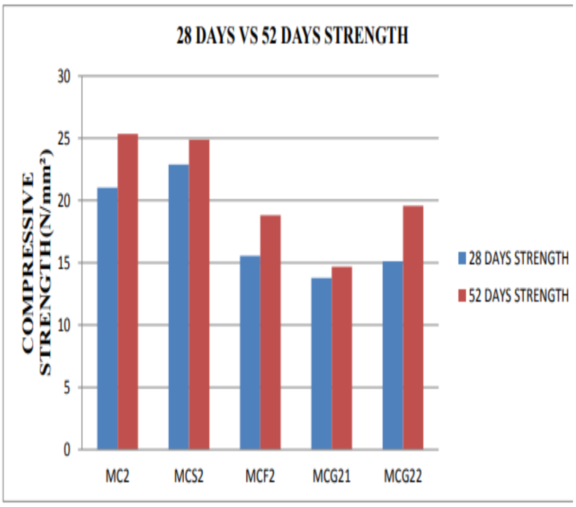

Compressive Strength of mixes with 15% replacement of cement

Fig. 4.1b

The results indicate that silica fume replacement produces higher strength than the glass powder and fly ash replacement. The strength development of concrete mix with glass powder of size

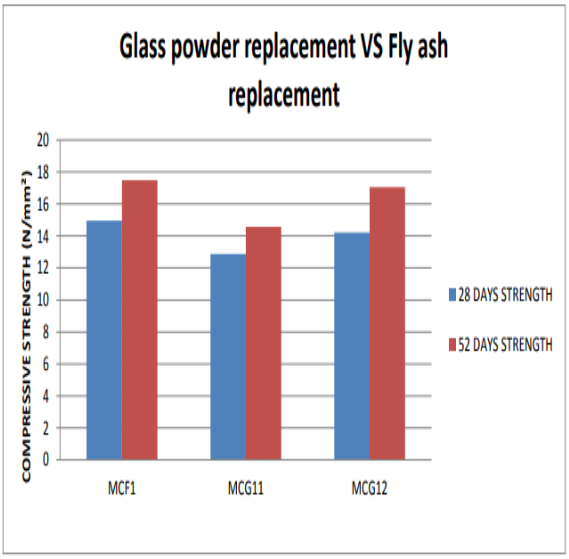

Fig. 4.2

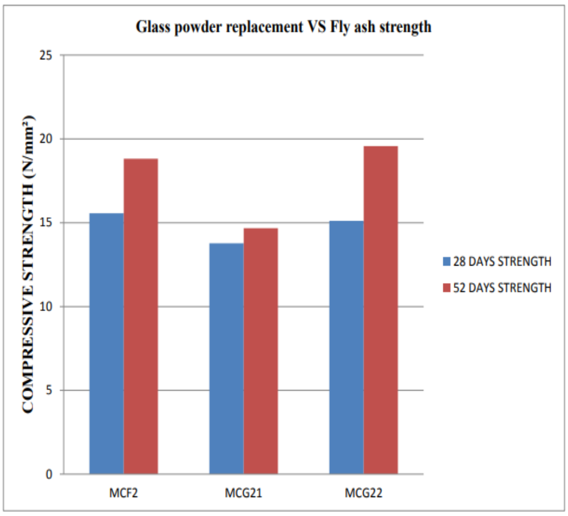

Fig. 4.3

Coefficients of capillary absorption of series after 28 days and 52 days were tabulated below:

DESIGN MIX	28 days($k*10^{-3}$ cm/s)	52 days($k*10^{-3}$ cm/s)
MC1	3.02	2.98
MCS1	1.65	1.57
MCF1	1.52	1.82
MCG11	2.85	3.14
MCG12	1.73	1.59

Table 4.4

The data shows that capillary absorption reduces due to addition of SCMS because they act like fillers and pozzolanic reactions form extra gel which makes cement matrix denser .The k value is lowest for silica fume concrete.The glass powder concrete MCG12 also has lower k value ,indicating denser matrix formation . The mix MCG11 has highest k value probably due to bond failure because of alkali-silica reaction.The fly ash concrete shows better performance than the control mix MC1.

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MICROSTRUCTURAL EXAMINATION OF CONCRETE CORES Scanning electron microscopy (SEM) and energy-dispersive X-ray (EDX) analysis were used to examine the nature of the hydrated binder and the binder-aggregate interfacial zones. The EDX analyses are also conducted . Note that the peak height in the EDX spectra is proportional to the amount of element present. A brief summary of SEM/EDX analysis is given below. Figure below shows the typical composition of hydrated paste in Mix MC1(control mix) and its interface with the aggregate.

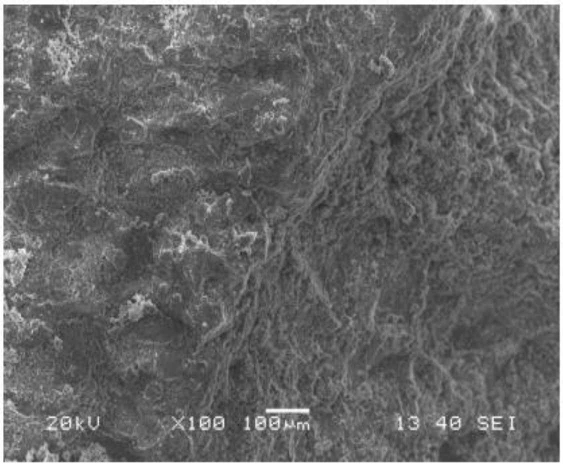
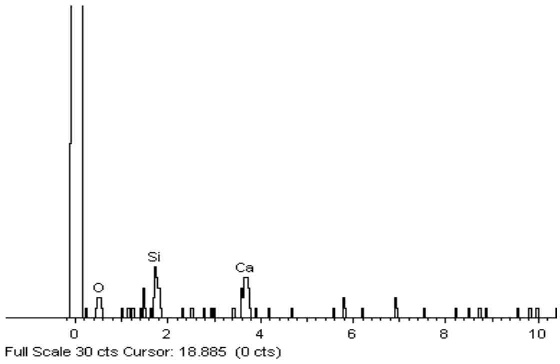


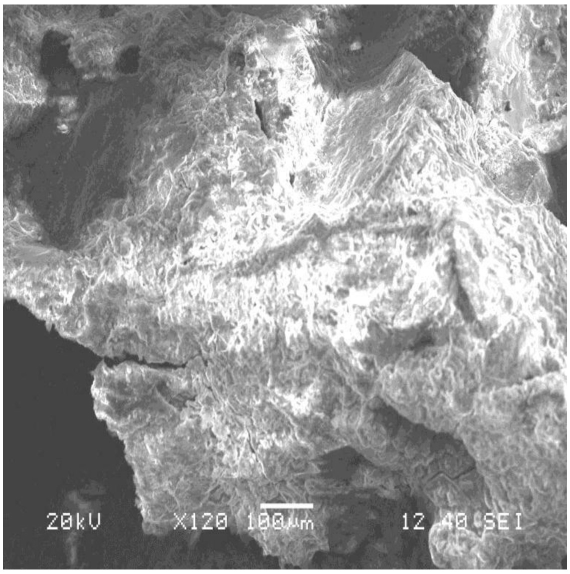
Fig4.4 (mc1)

Figure below shows the typical composition of hydrated paste in Mix MC1(control mix) and its interface with the aggregate.

Element	App Conc.	Intensity Corrn.	Weight%	Weight% Sigma	Atomic%
O K	23.96	0.4956	55.48	28.78	72.89
Si K	13.11	0.8961	16.79	12.76	12.57
Ca K	24.07	0.9965	27.73	19.79	14.54
Totals			100.00		

Table 4.5





The paste in Mix 2, which contained silica fume was found to have been enriched with silica.The reaction product had small amounts of Na and large amounts of Ca and silica. The compositions may reflect the

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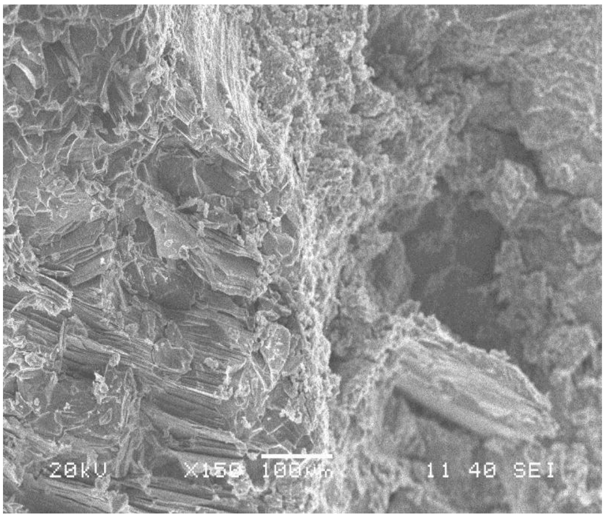
composition of the pozzolanic reaction product

Element	App	Intensity	Weight%	Weight%	Atomic%
	Conc.	Corrn.		Sigma	
O K	61.61	0.6107	60.05	1.62	75.62
Na K	0.15	0.7054	0.13	0.40	0.11
Al K	3.25	0.8057	2.40	0.38	1.79
Si K	24.92	0.8698	17.06	0.88	12.23
K K	1.01	1.0638	0.57	0.25	0.29
Ca K	32.67	0.9823	19.80	1.00	9.95
Totals			100.00		



The SEM view of MCF shows a denser cement matrix having voids. The matrix is enriched with silica and Ca.

Element	App	Intensity	Weight%	Weight%	Atomic%
	Conc.	Corrn.		Sigma	
O K	69.37	0.7963	64.35	14.62	77.81
Al K	10.34	0.8148	9.37	7.10	6.72
Si K	14.63	0.7986	13.53	8.04	9.32
Ca K	16.84	0.9757	12.75	10.42	6.15
Totals			100.00		

Table 4.7

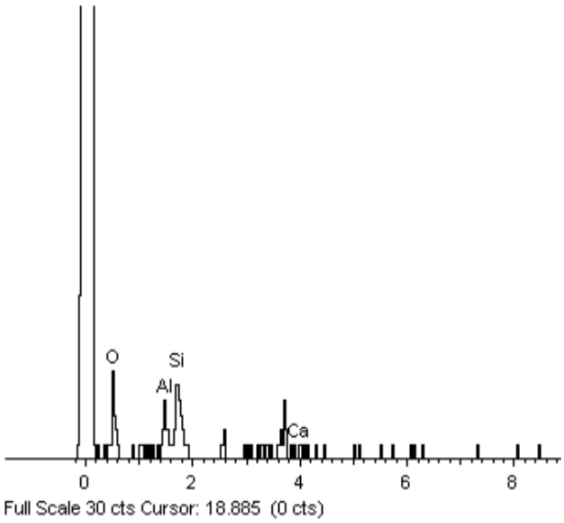


Fig.4..9

Glass powder

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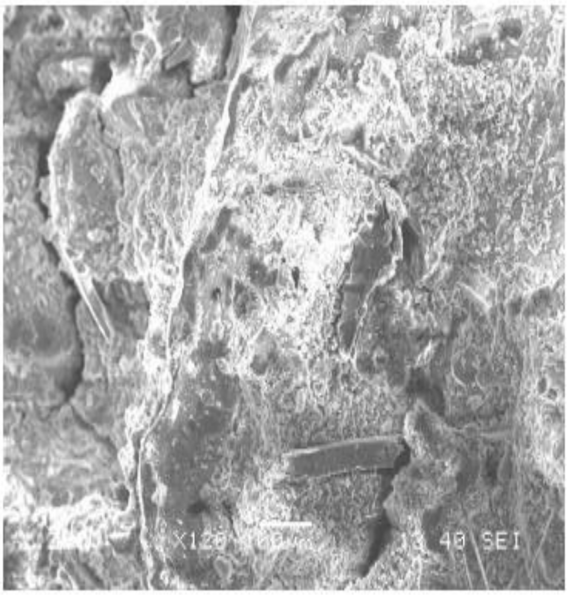
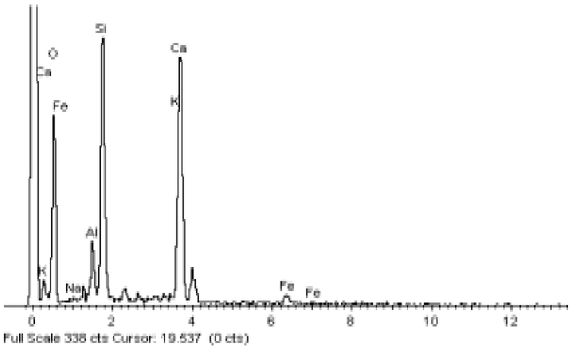
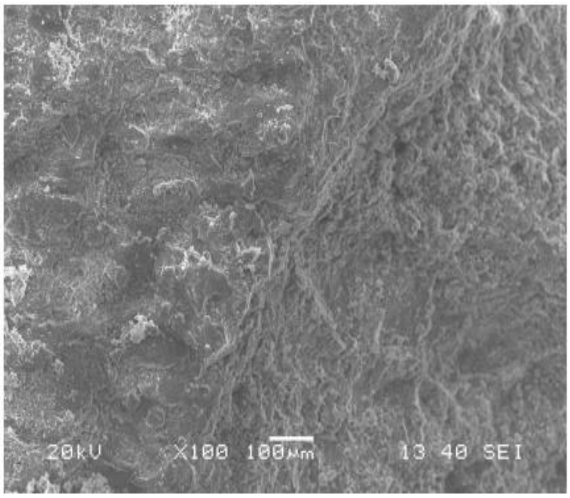


The SEM view and EDX composition of the reacted surface of a GLP particle in Mix MCG11.Flakier glass particals are visible in the view. Near a glass particle (lower right) the fine needle-shaped crystals in the paste are probably ettringite. The analysis shows a presence of Na and interfacial bond failure is clearly visible.

Element	App	Intensity	Weight%	Weight%	Atomic%
	Conc.	Corrn.		Sigma	
O K	60.47	0.6016	58.71	1.68	75.01
Na K	0.36	0.6901	0.31	0.36	0.27
Al K	3.89	0.7925	2.87	0.41	2.17
Si K	22.42	0.8552	15.32	0.83	11.15
K K	0.42	1.0731	0.23	0.25	0.12
Ca K	35.51	0.9899	20.96	1.03	10.69
Fe K	2.24	0.8120	1.61	0.55	0.59
Totals			100.00		



MCG2



The SEM view and EDX composition of the reacted surface showed enrichment in silica, and incorporation of fine glass particles into the paste was clearly noted

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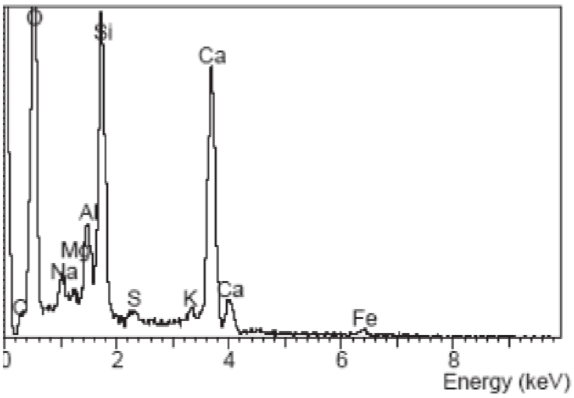

Fig. 4.13

CONCLUSION

1. Waste glass, if ground better than 100μm demonstrates a pozzolanic behavior.
2. The littler molecule size of the glass powder has higher action with lime bringing about higher compressive quality in the concrete blend.
3. Contrasted with fly cinder concrete, better glass powder concrete had marginally higher early quality and also late quality.
4. Small scale structural examination demonstrates that glass powder delivers a denser matrix which enhances the strength property of concrete.
5. The coefficient of fine assimilation test likewise demonstrates that fuse of better glass powder enhances solidness.
6. Glass powder of size 150μm - 100μm display inception of alkali aggregate reaction. The nearness of ettringite affirms this.
7. The information exhibited in this study demonstrates that silica rage is best SCM. It gives most noteworthy compressive quality as a result of its littler grain measure and circular shapes.
8. The outcomes acquired from the present study demonstrates that there is extraordinary potential for the usage of best glass powder in concrete as replacement of cement.
9. The fine glass powder can be utilized as a replacement for costly materials like silica smoke and fly fiery remains.
10. It very well may be presumed that 30% of glass powder of size under 100μm could be incorporated as cement replacement in concrete with no troublesome impact.

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