ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 9, September 2014

Comparative Study of Physical and Mechanical Behavior of Mortar Containing Fly ash and Waste Glass Powder

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ABSTRACT: This paper analyzing the behavior of blended past and mortar when cement is replaced by glass powder and fly ash at 0, 10, and 20 %by mass of cement. The test results in terms of fresh and hardened stages are evaluated. The comparison of the results based on the observe value of fresh property signifying that fineness, morphology and chemical composition of glass powder and fly ash playing vital role at this stage. However the hardened stage property of blended mortar of glass powder and fly ash showing the strength development at later stage defining the pozzolanic behavior of the same.

KEYWORDS: fine waste glass powder, compressive strength, economical, environmental friendly

I. INTRODUCTION

Fly ash is a fine powder which is a byproduct of burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement. The fly ash produced by coal-fired power plants provides excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others. Fly ash can be an expensive replacement for Portland cement in concrete although using it improves strength, segregation, and ease of pumping concrete. Nonetheless, the amount of fine aggregate should be reduced to accommodate fly ash additional volume. Fly ash is a commonly used Supplementary Cementing Material (SCM) which enhances the fresh properties of concrete including increased workability (Mindess, Young et al. 2003; Malhotra 2006; Mehta 2009). High volume fly ash contents are now replacing cement because (1) this results in lower consumption of cement, hence reducing the energy required to produce cement and also reducing the associated green house gas emissions, (2) production of many self consolidating mixes require high contents of fly ash, and (3) this results in cost-savings and is a more sustainable process since an industrial by-product (fly ash) is now being utilized which otherwise would end-up in a landfill. However, addition of fly ash can decrease the rate of the hydration reaction, negatively impacting the construction process as the stripping of forms may be delayed. The effect of using fly ash in concrete on the maturity of concrete was studied in this project. During the hydration reaction, heat is generated and released to the surroundings; the rate of the reaction is proportional to the heat generated. The dissipation of this heat of hydration to the environment will depend on the type of forming material used, thickness of the concrete mass, and use of insulation (Khan, Cook et al. 1998; Wang, Zhi et al. 2006).

Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75μm (Federio.L.M and Chidiac S.E, 2001, Jin.W, Meyer.C, and Baxter.S, 2000). Studies have shown that finely ground glass does not contribute to alkali – silica reaction. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete production as a part of green house management. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica – rich glass particle and the alkali in pore solution of concrete, which is called Alkali – Silicate reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. ASR can be prevented or reduced by adding mineral admixtures in the concrete mixture, common mineral admixtures used to minimize ASR are pulverized fuel ash (PFA), silica fume(SF) and metkaolin (MK).A number of studies have proven the suppressing ability of these materials on ASR. A high amount of waste glass as aggregate is known to decrease the

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concrete unit weight (Christopher cheeseman, 2011, Mageswari.L.M and B.Vidivelli, 2010). The fact that glass has high silica content has led to laboratory studies on its feasibility as a raw material in cement manufacture. The use of finely divided glass powder as a cement replacement material has yielded positive results (Malek Batayneh, Iqbal Marie, Ibrahim Asi, 2007), Optimal dosage range of this glass powder is chosen based on cement paste studies.

II. RESEARCH SIGNIFICANCE

In the research reported in this study, fine waste glass powder obtained from the grinding process is used as a cement replacement material while fly ash is obtained in dust form from the electric power generation plant used in concrete. The ultimate focus of this work is to ascertain the performance of concrete containing fine glass powder, fly ash and compare it with the plain concrete. This is expected to provide:-

- To partially replace cement content in concrete & mortar as it directly influences economy in construction.
- Environmental friendly disposal of waste glass and fly ash.
- Contribution in strength development & durability of concrete.
- To enhance the use of such non-conventional materials which are typically of local or regional origin.

III. MATERIAL CHARACTERISTICS AND TEST METHODS

Ordinary Portland cement confirming to I.S 269-1976 [18] was used for this study. The fine glass powder had a particle size such that 80 % finer than 45 micron is used in this study. The chemical compositions of these materials are given in Table 1. The glass powder has higher silica content than the cement, while having the least alumina content.

Table 1. Chemical Composition of Cement, Glass Powder and Fly Ash used in this study

Composition (% by mass)	Cement O.P.C 43 GRADE BIRLA GOLD	Glass Powder	Fly Ash
Silica (SiO_2)	20.6	72.20	62.4
Alumina ($Al2O_3$)	5.2	1.54	18.7
Iron Oxide (Fe_2O_3)	2.9	0.48	12.5
Calcium Oxide (CaO)	64.5	11.42	5.4
Magnesium Oxide (MgO)	2.7	0.79	3.2
Sodium Oxide (Na_2O)	0.21	12.85	1.6
Potassium Oxide (K_2O)	0.92	0.43	0.6
Sulfur Trioxide (SO_3)	1.8	0.09	0.06
Fineness % Passing 45 micron	97	80	80
Density (Kg/m^3)	3150	2480	2294

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IV. EXPERIMENTAL PROGRAM

In this section the procedure and testing program is prepared to find out the properties of blended paste and mortar of fly ash and glass powder. In this connection Table 3 provides the information about the sample.

Table 1
Testing environment and sample information

Sample information	Temperature and Humidity	Test and Equipment
Mould of size 60x70x40 mm	27 ±2°C, 65 ± 5 percent	Normal consistency, Initial & Final setting time using vicate apparatus
Mould of size 70.6 mm x 70.6 mm x 70.6 mm	27 ±2°C, 65 ± 5 percent	Compressive strength using Compression testing machine
Mould of size 70.6 mm x 70.6 mm x 70.6 mm	27 ±2°C, 65 ± 5 percent	Water absorption

Normal Consistency and setting time of Paste: The quantity of water required to produce the paste of standard consistency was find out in light of IS 4031(Part 4):1988 [17] . The Vicat apparatus with plunger is used so that the penetration of 5 to 7 mm measured from the bottom of the mould for given cement paste is the % normal consistency by weight of cement. Meanwhile to prepare the paste a weighted quantity of cement is mixed with potable water by taking care that time of gauging not exceeding 5 minutes. The Vicate mould is placed on non porous plate then the paste is filled up to the top of mould and to expelled air from the paste the mould was gently shaken off. In addition to that setting time was also measured as per IS 4031 (Part 5):1988 [18] with the Vicate apparatus. In this case instead of plunger the needle was affixed with movable rod, after that the cement paste is mixed with water (the water added is 0.85 times the normal consistency) and the same process was repeated for paste preparation & testing except there is now stopwatch to note down the time.

Analysis of Mechanical strength of Mortar: The mortar was prepared as per the procedure laid down in IS:4031(Part 6):1988[20] and IS:1727:1967[21]. The cement: standard sand ratio of 1:3 and water (%{ Normal consistency /4 + 3}) is added in given mix then the mix was placed in mould and by using plate vibrator the entrapped air is removed. After that the cube moulds are placed in moist room for 24 hours and finally they were submerged in water tank for curing. The SAI index was determined using the compressive strength results as per ASTM C-618[22] depicting that it is ratio of compressive strength of blended test mixture over the control mixture at respective days expressed in percentage.

V. RESULTS & DISCUSSION

Fresh Properties of Paste:

Normal Consistency:

The normal consistency of paste as shown in figure as determined as per IS **IS 4031(Part 4):1988.** From the figure it is clear that as the % glass powder increases the water requirement is also increases for glass powder blended paste. However for fly ash blended paste the water requirement is going to decrease when % fly ash was increased. This may be due to the difference in morphology among the paste. Moreover the particle size is also influencing the consistency as shown in figure. At the instance GP_{63} blended paste of glass powder required more amount of water as compare to GP_{75} whereas for fly ash blended paste inverse of that is observe.

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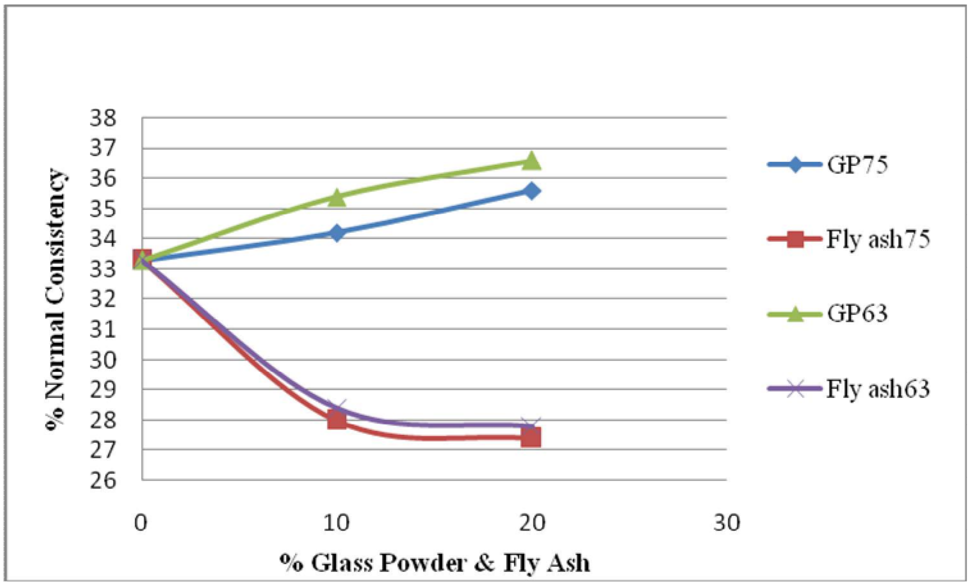

Fig.1. % Normal consistency verses % Glass powder & Fly ash

Setting Time:

The initial and final setting time as find out according to the **IS 4031 (Part 5):1988.**The results are drawn in figure suggesting that glass powder enable paste was acclerating the both timings as compare to control whereas for flyash enabled paste the retarding in setting time was observed.This may be due to the lesser amount of cement in case of glass powder paste and for flyash its chemical composition and latent hydraulic action could be the cause.Moreover the same particle size effect was observe as found in Normal consistency.

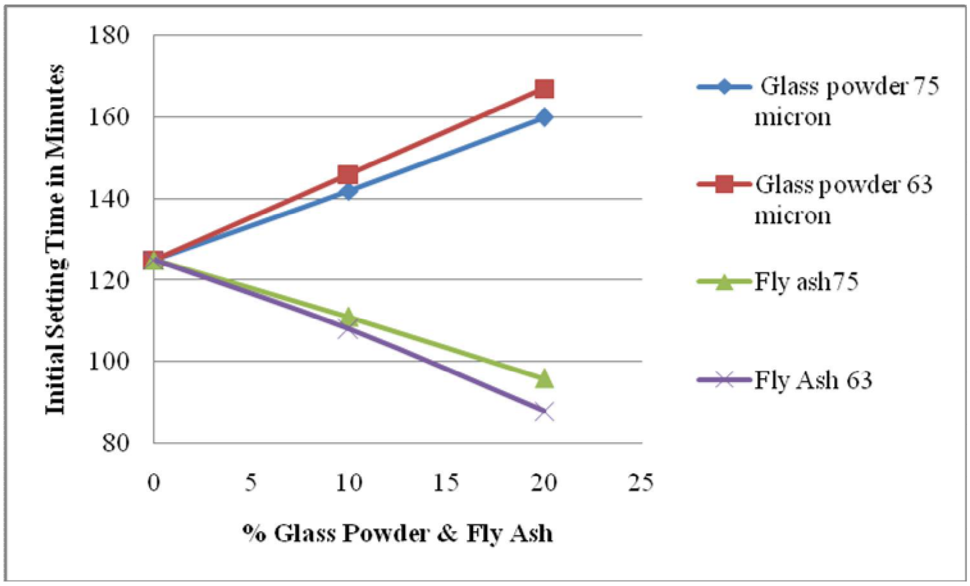

Fig.2. Initial setting time verses % Glass powder & Fly ash

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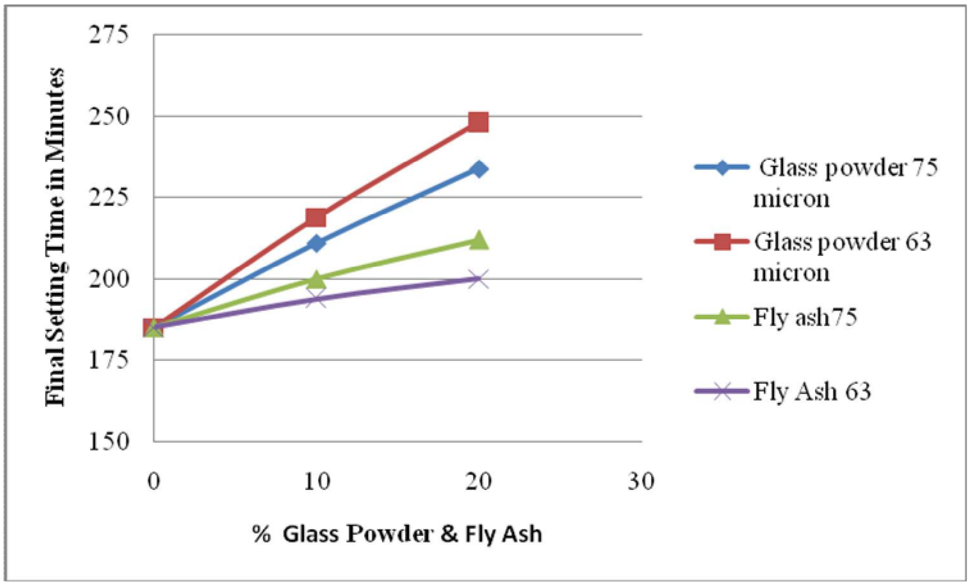

Fig.3. Final setting time verses % Glass powder & Fly ash

Mechanical Strength of Mortar:

The compressive strength of mortar is determined according to IS:4031(Part 6):1988[20] and IS:1727:1967[21] .The observed results are plotted in figure signifying that at initial curing days(7 days) the compressive strength of GP_{75} ,GP_{63}, Fly ash_{75} and Fly ash_{63} was decreasing as the % replacement increased. However the effect of fineness of the particle signifying that coarser particle blended powder showing more strength as compare to finer blended powder. This may be due to the confinement of particle packing which improves density. At 28 days the same pattern of strength was observed but the strength is not decreased rapidly, as shown in graph which is now flat. Moreover as the replacement increased the rate of gain in strength is improved for all the series.

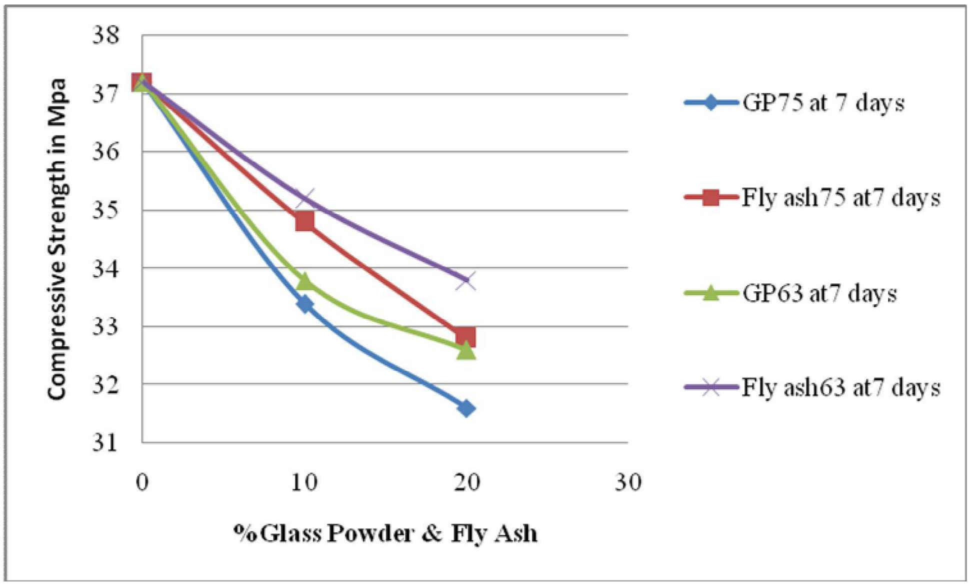

Fig.4. Compressive strength verses % Glass powder & Fly ash at 7 days

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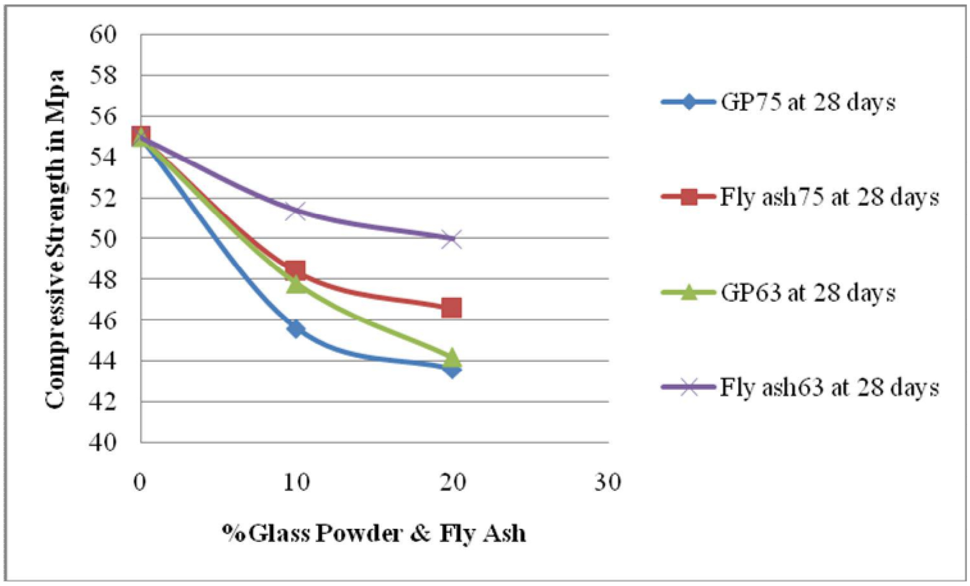

Fig.5. Compressive strength verses % Glass powder & Fly ash at 28 days

VI. SUMMARY & CONCLUSION

The following conclusion can be drawn from this study.

I. Figure 4 and 5 depict that, the replacement of cement by glass powder and fly ash in concrete generally decreases the ultimate strength of concrete.

II. The % decrease in 28 days strength of concrete by replacement of cement with 20 % glass powder is only about 10 % where as for fly ash blended mortar it was 5% (the strength variation is shown in Fig 4 & 5)

III. It is clear that about 15 % of cement replacement by fine glass powder provide the most optimal strength results because with this replacement the decrease in strength is less than 5 %and for fly ash blended mortar this replacement value improved to 20%.

Image 1. Compression testing machine with modified concrete cube

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