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# Study of Physical and Mechanical Behavior of Mortar Containing Silica Fume and Waste Glass Powder

**Dhirendra Patel**
*Lecturer*
*Department Civil Engineering*
Kalaniketan Polytechnic College
Jabalpur (M.P.) [INDIA]
*Email:dheerupatel4@gmail.com*

***Abstract*—***This paper analyzing the behavior of blended past and mortar when cement is replaced by glass powder and silica fume 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 silica fume playing vital role at this stage. Moreover due to extreme fineness of silica fume its behavior is close to reference mix. However the hardened stage property of blended mortar of glass powder and Silica fume showing the strength development at later stage defining the pozzolanic behavior of the same.*

***Keywords:—*** *Silica fume; fine waste glass powder, compressive strength, economical, environmental friendly.*

## 1. INTRODUCTION

Silica fume is an industrial by-product mainly from ferrosilicon producing companies. Silica fume is a very fine amorphous material and is used in concrete as a mineral admixture. However, it is relatively new as a mineral admixture compared to natural pozzolan, fly ash and blast furnace slag. According to the RILEM TC 73 classification, silica fume is a highly active pozzolan. The earliest studies have been conducted in the North European countries including Norway, one of the primary countries producing silica fume. Silica fume has been used as a cement replacement material in the beginning. The earliest example is the use of 15% silica fume to replace cement in the construction of a tunnel in Oslo in 1952 [2]. Later, additional research was done in Scandinavia. Work representative of these studies has been reported by the following: Fascia et al., 1971 [3],Traetteberg 1977 [4], Asgeirsson & Gudmundsson 1979 [5], Jahr 1981 [6] Loland 1981 [7], and Gjorv and Loland 1982 [8].Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75µm [9,10]. 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 concrete unit weight [11, 12]. 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 [13].Optimal dosage range of this glass powder is chosen based on cement paste studies.

## 3. 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 silica fume is obtained in dust form from the ferrosilicon producing companies plant used in concrete. The ultimate focus of this work is to ascertain the performance of concrete containing fine glass powder, silica fume 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 Silica fume.
- Contribution in strength development & durability of concrete.

### *Material Characteristics and Test Methods*

Ordinary Portland cement confirming to I.S 269-1976 [14] 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 Silica fume used in this study**

| Composition (% by mass ) | Cement O.P.C 43 GRADE BIRLA GOLD | Glass Pow-der | me |
|---|---|---|---|
| Silica ($SiO_2$ ) | 20.6 | 72.20 | 93 |
| Alumina ($Al2O_3$ ) | 5.2 | 1.54 | 0.5 |
| Iron Oxide ($Fe_2O_3$ ) | 2.9 | 0.48 | 0.3 |
| Calcium Oxide (CaO ) | 64.5 | 11.42 | 0.2 |
| Magnesium Oxide (MgO ) | 2.7 | 0.79 | 0.9 |
| Sodium Ox-ide ($Na_2O$) | 0.21 | 12.85 | 0.6 |
| Potassium Oxide ($K_2O$) | 0.92 | 0.43 | 1.3 |
| Sulfur Tri-oxide ($SO_3$ ) | 1.8 | 0.09 | 0.5 |
| Fineness % Passing 45 micron | 97 | 80 | 100 |
| Density (Kg/ $m^3$ ) | 3150 | 2480 | 2200 |

## 4. EXPERIMENTAL PROGRAM

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

**Table 3 :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 [15] . 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 [16] 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 [17] and IS:1727:1967[18]. 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.

## 6. 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 Silica fume blended paste the water requirement is increasing more sharply when % Silica fume was increased. This may be due to the difference in morphology among the paste. Moreover the particle size is also influencing the consistency as the silica fume is finer as compare to glass as shown in figure 1.

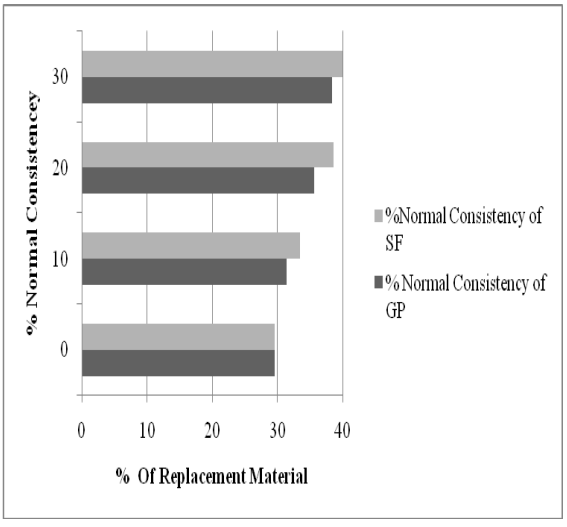


*Figure 1: % Normal consistency verses % Glass powder & Silica fume*

### *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 2 suggesting that glass powder enable paste was acclerating the both timings as compare to

control whereas for silica fume 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 silica fume its chemical composition and latent hydraulic action could be the cause. Moreover the same particle size effect was observe as found in Normal consistency.

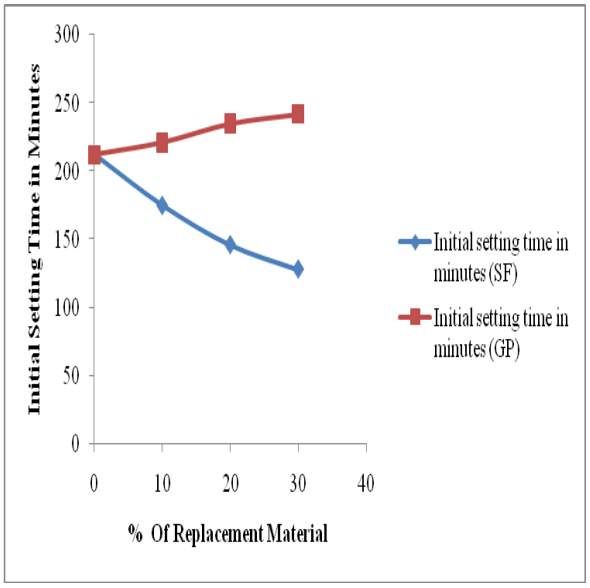


*Figure 2: Initial setting time verses % Glass powder & Silica fume*

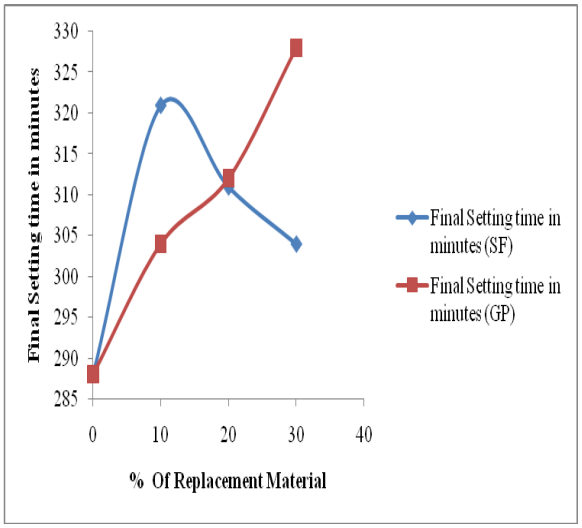


*Figure 3: Final setting time verses % Glass powder & Silica fume*

### *Mechanical Strength of Mortar:*

The compressive strength of mortar is determined according to IS:4031(Part 6):1988 and IS:1727:1967 .The observed results are plotted in figure 4 signifying that at initial curing days(7 days) the compressive strength of GP, was decreasing as the % replacement increased. But in case of silica fume there was lesser decrease in compressive strength However, the effect of fineness of the particle signifying that silica fume blended powder showing more strength as compare to glass 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 5 which is now flat. Moreover as the replacement increased the rate of gain in strength is improved for all the series.

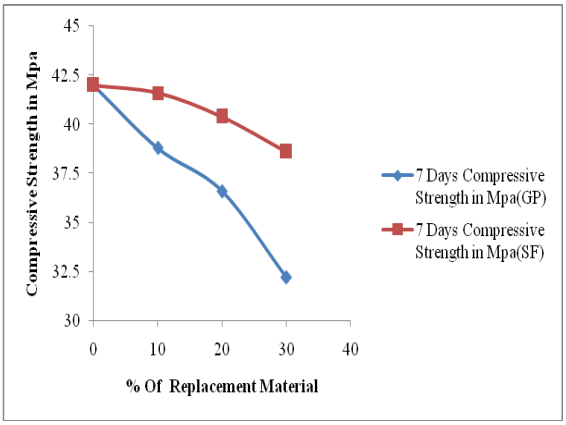


*Figure 4: Compressive strength verses % Glass powder & Silica fume at 7 days*

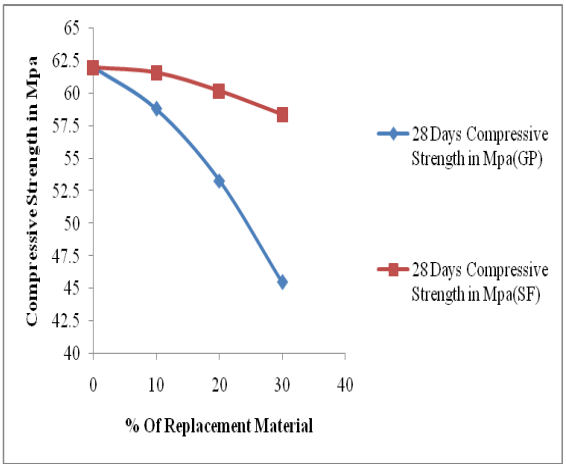


*Figure 5: Compressive strength verses % Glass powder & Silica fume at 28 days*

## 7. SUMMARY & CONCLUSION

The following conclusion can be drawn from this study.

Figure 4 and 5 depict that, the replacement of cement by glass powder and Silica fume in mortar generally decreases the ultimate strength of concrete.

The % decrease in 28 days strength of concrete by replacement of cement with 30 % glass powder is only about 12 % where as for Silica fume blended mortar it was 5% (the strength variation is shown in Figure 4 & 5)

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 Silica fume blended mortar this replacement value improved to 25%.

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