Mechanical Properties of Concrete Modified with Silica Fume and Integral Waterproof and Comparison with Waste Glass Aggregate Concrete

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Abstract: This study includes the effect of using different dosages of integral waterproof Admixture and silica fume on some mechanical properties of concrete. Concrete improved by using different ratios of integral water proof admixture(IWP admixture) to increase strength and durability, this admixture used as percentages from cement weight in each mix ranged from 0.0% to 2% (0.0%, 1.0%, 1.2%, 1.4%, 1.6%, 1.8%, and 2%) , compressive strength test done for cubes with (10*10*10) cm for each mix .The flexural strength test was done by (10*10*40) cm beams and tested after 28 days of curing. comparison study was made between silica fume mixes properties and mixes without silica fume. Adding IWP admixture leads to increase mechanical properties of ordinary concrete, the reference mix shows compressive strength equal to 26.38 MPa ,while mixes with 2% IWP gives 38.8 MPa in this study .The study also includes the effect of using 2 main dosages of silica fume to the mixes that contain IWP, the new concrete with two admixtures show better values of compressive , tensile and flexural strength comparing with mixes with only IWP, the compressive strength increased from 38.8 MPa for ordinary IWP mixes to 52.3 MPa for 10% silica fume concrete mixes , and also the flexural strength increased from 4.8 MPa for mixes with only IWP to 7.3 MPa for mixes modified with 10 % silica fume .Study include also using waste glass as fine aggregate in mixes contain IWP and 10% silica fume and that show more increment in mechanical properties also.

Key words: Silica fume, integral waterproof, compressive strength, tensile strength, flexural strength.
1. Introduction

Admixtures in concrete are widely used in concrete production to improve the mechanical properties of concrete such as compressive strength, tensile strength, flexural strength, and the static modulus of elasticity, and also to make concrete more durable to severe conditions such as sulfate attack due to groundwater or exposure to freeze-thaw conditions. The use of integral water proof liquid admixture in concrete can improve the mechanical properties of concrete and also decreasing absorption of concrete [1,2] that lead to more durable concrete, silica fume is a relatively new powder material and called sometimes micro silica can be used in concrete to increase strength silica fume reacts with calcium hydroxide that liberates from cement hydration [3, 4], and that operation leads to form more cement gel that blocks the pores inside the concrete and make concrete with higher strength and durability [5]. Silica fume is an important material used in concrete production to improve mechanical properties of concrete and also the production of high strength concrete especially when used with super-plasticizer, silica fume mainly consists of micro silica particles at least of 85% of SiO2 with particles size distribution finer than cement particles and this property allow the silica fume to refine the pore structure of cement paste [6]. Using integral waterproof admixture gives more durable concrete with higher strength comparing with ordinary concrete [7]. Another advantage of using integral waterproofing admixture done by Geetha, A., and Perumal, P., [8] they state that using integral waterproofing admixture in concrete reduces permeability and improve the corrosion resistance in reinforced concrete. Using waste aggregate concrete leads to several benefits especially decreasing environmental pollution and also lead to less cost of concrete production and finally increase some of the mechanical properties of concrete.

This study aims to use both silica fume and integral waterproofing admixtures on some of the mechanical properties of ordinary concrete and also include using waste glass as fine aggregate and comparison between two types.

2. Experimental program

Materials used: A constant mix proportions were used in all mixes in this study with 450 kg for each cubic meter concrete as shown in table 1, but with different percentages of water/cement ratio and different integral waterproof admixture. Portland cement type I was used in all mixes, fine aggregate zone 2 is used and 16 mm maximum size of coarse aggregate and confirming with Indian standards 383 [9] as shown in tables 2 and 3. Integral water proof used as percentages of the weight of cement with different ratios, silica fume used as the replacement from cement weight with ratios of 5% and 10% in this study. Waste glass used with mixes containing 10% silica fume and IWP admixture as a replacement with 50% and 100 % from normal sand.

Specimens and tests: Using steel molds with dimensions of 10 *10*10 cm for compression test and the specimens tested after 28 days, 3 specimens were used for each mix and taking the average value after testing. Figure 1 shows concrete specimen under compression test. Tensile strength is done by using cylinders with 10 cm*20 cm and tested for splitting tensile test according to equation number 1:

\[ F_{\text{tens}} = 2P/\pi DL \]

Where:
\( F_{\text{tens}} \) : is the Tensile strength value for cylinder.
\( P \) : is the peak load from testing machine.
\( D \) : is the diameter of concrete cylinder.
\( L \) : is the length of the cylinder.

Flexural strength done according to British Standards B-S: 1881 [10] by using the Third Point loading according to equation 2:

\[ F_{\text{flex}} = P/L BD \]

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Where:
- $F_{\text{flex}}$: is the Flexural Strength value.
- $P$: is the maximum load from flexure test machine.
- $L$: length between supports that hold the beam.
- $b$ and $d$: is the width and depth of the beam respectively.

Flexural strength done by using 10*10*40 cm beams, as shown in figure 2. Three beams were tested for each mix and taking the average value.

![Figure 1](image1.png)

**Fig. 1.** Compressive strength test for 10% silica fume concrete specimen.

![Figure 2](image2.png)

**Fig. 2** Compressive strength test for 10% silica fume concrete specimen.

**Table 1.** Concrete used for mixes preparations

| Mix type       | Water/cement ratio | Integral water proof admixture | cement | Fine aggregate | Coarse aggregate |
|----------------|--------------------|--------------------------------|--------|----------------|------------------|
| M1 Reference ordinary | 0.45               | 0.0                            | 450    | 750            | 900              |
| M2             | 0.37               | 1.0 liter/100 kg cement        | 450    | 750            | 900              |
| M3 Modified    | 0.37               | 1.2 liter/100 kg cement        | 450    | 750            | 900              |
| M4 Modified    | 0.37               | 1.4 liter/100 kg cement        | 450    | 750            | 900              |
| M5 Modified    | 0.35               | 1.6 liter/100 kg cement        | 450    | 750            | 900              |
| M6             | 0.30               | 1.8 liter/100 kg cement        | 450    | 750            | 900              |
### Table 2. Concrete used for mixes preparations

| SIEVE SIZE MM | % Passing by weight | Indian specifications for 16 mm |
|---------------|---------------------|-------------------------------|
| 20 MM         | 100                 | 100%                          |
| 16 MM         | 92.4                | 90-100%                       |
| 10 MM         | 54.7                | 30 – 70 %                     |
| 4.75 MM       | 8.9                 | 0 – 10 %                      |

### Table 3. The Grading of The - Fine Aggregate- Zone 2

| Sieve Dimension, mm , micron | % Pass by weight | Indian specifications for zone 2 |
|------------------------------|------------------|---------------------------------|
| 10 mm                        | 100              | 100                             |
| 4.75                         | 100              | 90-100%                         |
| 2.36                         | 80.5             | 75-100%                         |
| 1.18                         | 72.3             | 55-90%                          |
| 600                          | 41.2             | 35-59%                          |
| 300                          | 18.7             | 8-30                            |
| 150                          | 1.2              | 0-10                            |

### 3. Results and discussion

Table 4 shows some of the mechanical properties of reference mix and mixes modified with integral waterproof only, compressive strength was increased from 26.3 MPa to 38.8 MPa by using 2 liters for each 100 kg cement and that can be attributed to double action of this type of admixture that it reduces w/c ratio and also polymer particles action that reduce voids inside cement paste [9,10], also tensile strength increased from 1.58 to 3.36 MPa, and flexural strength increased from 2.8 to 4.8 MPa.

Table 5 shows all mixes used in table 4 but modified with 5% silica fume powder by weight of cement, table 5 shows increment in compressive, tensile and flexural strength of concrete, table 6 shows all mixes with a higher percentage of silica fume (10%) , the compressive strength increased from 38.8 MPa for mix without silica fume to 42.8 MPa for mixes with 5% silica fume and then increased to 52.3 MPa for mixes with 10% silica fume and that can be attributed to the action of silica fume that reacts with Ca(OH)2 that liberates from the operation of cement hydration and forming an additional gel that increases strength and decreases voids inside concrete [11,12], also the flexural strength increased from 4.8 for mixes with maximum integral waterproof to 7.3 MPa for the mixes with 10% silica fume. Figures 3,4 and 5 show the relationship between integral water proof admixture dosage and compressive strength, tensile strength and flexural strength respectively. figures 6,7 and 8 show a comparison between concretes with 0%,5%, and 10% silica fume content for compressive, tensile and flexural strength, it can be seen that concrete with a higher dosage of silica fume and maximum dosage of IWP give the maximum mechanical properties values. Tables 7 and 8 show modified concrete mixes (which contains IWP and 10% silica fume ) but with replacing normal sand with 50% and 100 % waste glass, the compressive, tensile and flexural strength increased by using waste glass and that can be attributed to the sharp edges of particles of waste glass which gave excellent bond with cement paste.
Table 4. Properties for ordinary mixes modified with integral water proof only

| Mix type       | Compressive Strength, MPa | Tensile Strength, MPa | Flexural Strength, MPa |
|----------------|---------------------------|-----------------------|------------------------|
| M1 Reference   | 26.38                     | 1.58                  | 2.84                   |
| M2 Modified    | 31.67                     | 2.25                  | 3.92                   |
| M3 modified    | 33.89                     | 2.47                  | 4.14                   |
| M4 Modified    | 34.75                     | 2.71                  | 4.33                   |
| M5 Modified    | 35.90                     | 2.88                  | 4.60                   |
| M6 Modified    | 37.22                     | 3.07                  | 4.73                   |
| M7 Modified    | 38.86                     | 3.36                  | 4.81                   |

Table 5. Properties for ordinary mixes modified with integral water proof and 5% of silica fume

| Mix type                                                   | Compressive Strength (MPa) | Tensile Strength, (MPa) | Flexural Strength, (MPa) |
|------------------------------------------------------------|-----------------------------|-------------------------|--------------------------|
| M1 Reference with 5% silica fume                           | 30.70                       | 2.34                    | 3.17                     |
| M2 Modified – with 5% silica fume                          | 34.85                       | 2.81                    | 4.36                     |
| M3 modified- with 5% silica fume                           | 36.10                       | 3.05                    | 4.73                     |
| M4 Modified -with 5% silica fume                           | 38.06                       | 3.39                    | 4.92                     |
| M5 Modified -with 5% silica fume                           | 39.44                       | 3.61                    | 5.18                     |
| M6 Modified- with 5% silica fume                           | 41.38                       | 3.90                    | 5.50                     |
| M7 Modified -with 5% silica fume                           | 42.85                       | 3.98                    | 5.93                     |

Table 6. Properties for ordinary mixes modified with integral water proof and 10% of silica fume

| Mix type                                                   | Compressive Strength (MPa) | Tensile Strength, MPa | Flexural Strength, MPa |
|------------------------------------------------------------|-----------------------------|-----------------------|------------------------|
| M1 Reference with 10% silica fume                          | 32.83                       | 2.80                  | 4.02                   |
| M2 Modified – with 10% silica fume                         | 38.90                       | 3.47                  | 5.10                   |
| M3 modified- with 10% silica fume                          | 41.54                       | 3.92                  | 5.69                   |
| M4 Modified -with 10% silica fume                          | 43.80                       | 4.45                  | 6.14                   |
| M5 Modified -with 10% silica fume                          | 47.72                       | 4.70                  | 6.85                   |
Table 7. Modified concrete with 50% replacement of waste glass as fine aggregate

| Mix type | Compressive Strength, MPa | Tensile Strength, MPa | Flexural Strength, MPa |
|----------|----------------------------|-----------------------|------------------------|
| M1       | 36.15                      | 3.12                  | 4.81                   |
| M2       | 42.34                      | 3.67                  | 5.62                   |
| M3       | 45.91                      | 4.22                  | 5.98                   |
| M4       | 48.55                      | 4.65                  | 6.52                   |
| M5       | 51.92                      | 4.93                  | 7.11                   |
| M6       | 55.40                      | 5.10                  | 7.80                   |
| M7       | 57.88                      | 5.31                  | 8.04                   |

Table 8. Modified concrete with 100% replacement of waste glass as fine aggregate

| Mix type | Compressive Strength, MPa | Tensile Strength, MPa | Flexural Strength, MPa |
|----------|----------------------------|-----------------------|------------------------|
| M1       | 38.71                      | 3.60                  | 5.12                   |
| M2       | 43.82                      | 3.93                  | 5.94                   |
| M3       | 46.93                      | 4.55                  | 6.60                   |
| M4       | 49.38                      | 4.80                  | 7.21                   |
| M5       | 53.70                      | 5.29                  | 7.84                   |
| M6       | 56.09                      | 5.41                  | 8.23                   |
| M7       | 58.64                      | 5.81                  | 8.65                   |

Fig. 3 Relationship between % IWP and compressive strength without silica fume.
Fig. 4 Relationship between % IWP and tensile strength without silica fume.

Fig. 5 Relationship between % IWP and flexural strength without silica fume.

Fig. 6 Comparison between concrete with 0%, 5%, and 10% silica fume content (10% for upper curve)-compressive strength test.

Fig. 7 Comparison between concrete with 0%, 5%, and 10% silica fume content (10% for upper curve)-tensile strength test.
Fig. 8 Comparison between concrete with 0% , 5% , and 10% silica fume content (10% for upper curve) - flexural strength test.

4. Conclusions

1- The compressive strength, tensile strength and also flexural strength of concrete increased due to the use of IWP admixture only and by using silica fume in addition of adding IWP, more increment achieved in mechanical properties.

2- More increment in mechanical properties achieved by using waste glass as fine aggregates.

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