



## An experimental investigation on performance of ternary Concrete in strength and durability aspects

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### **Abstract:**

*In the investigation,  $M_{20}$  Grade concrete mix was designed with different percentages of cementitious materials ( 5%, 7.5%, 10% & 12.5% ) and tests were conducted for compressive strength, split tensile strength and Flexural strengths at 7, 28 and 56 days of curing period. Durability studies were also carried out in the same combination of ternary concrete (OPC, silica fume and fly ash ) immersed in Sulphuric acid ( $H_2SO_4$  ) and Hydrochloric acid (HCl), Potassium Sulphide ( $K_2SO_4$ ) solutions and Sea water. The results obtained from the experimentation are compared with the results of reference mix made with regular cement. Test results indicate that the replacement of cement by 10% had attained a maximum strength in  $M_{25}$  Grade concrete. The results obtained thus are encouraging for partial replacement.*

*Key words: Grade, concrete, field, construction*

### **Introduction:**

The usage of cement in the field of construction has been increased rapidly. Some of the pozzolanic industrial by products such as Fly ash and Silica Fume are playing a vital role in enhancing the strengths of the cement concrete mixes and also reduces the adverse environmental effects and cost. The construction sector absorbs the majority of such materials by incorporating them in hydraulic binders as supplementary cementing materials. For so many reasons, the concrete construction industry is not sustainable; it consumes huge or heavy quantities of materials currently around 5 million cubic meters of concrete is produced per annum. Roberto advocates the use of silica fume

and fly ash as a supplementary cementitious materials in the manufacture of concrete. In recent years, it has been reported that ternary blended cement could substantially improve the performance of concrete compared with the conventional binary blended cement of regular Portland cement. Roland Bleszynski (1998) studied seven concrete mixtures, including three ternary concrete mixtures consisting of various combinations of various combinations of silica fume, blast-furnace slag and Portland cement. Significant expansion due to alkali-silica reaction has occurred in the concrete made with high-alkali Portland cement used as a control but has not been observed in any of the ternary blend mixtures. Ternary concrete mixtures include three different



cementitious materials. This addresses those combinations of Portland cement, slag cement, and a third cementitious material. The third component is often fly ash and silica fume, three-way mixes have been utilized in the past, but typically for specialty high strength concrete where higher reactivity silica fume have been combined with either fly ash or slag to generate very high early strengths. Ternary blended cement consisting of Portland cement, Granulated blast furnace slag and fly ash was developed in Japan for mass concrete construction due to its very low heat of hydration. This can be treated as slag cement incorporating fly ash, the addition of fly ash can increase workability and reduce bleeding in slag cement concrete. The strength development of this system is relatively slower at early age. Ternary cement concrete has many useful applications in the use of construction of simple buildings to high range buildings and massive dam. Since the phenomenon of early deterioration of concrete structure has become a matter of global concern, the topic of strength and durability has gained considerable interest throughout the world. Hence there is need for definitive information and guidance on the performance of concrete structures during their full service life.

### **Experimental Study:**

#### **Materials Used:**

**Cement:** Ordinary portland cement used in this investigation is Priya Cement (43 Grade) conforming to Bureau of Indian Standards (IS 8112:1989). The cement is fresh and of uniform colour, consistency and free from lumps and foreign matter. The cement was tested for various properties as per IS: 8112-1989.

**Silica fume:** In the present work the Silica Fume was obtained from Forsook Chemicals. Silica Fume is a mineral admixture made up of very fine, solid, glassy spheres and amorphous solids of silicon dioxide. It is a by-product obtained during the production of metallic silicon or Ferro silicon alloys in electric arc furnaces. The silica content is as high as 98%.

**Fly ash:** Fly ash used in the experimental work was obtained from Simhadri thermal power plant (STPP), NTPC, and Visakhapatnam. They are generally finer than cement and consist mainly of glassy-spherical particles as well as residues of hematite and magnetite, char and some crystalline phase formed during cooling. Fly ash is known to enhance the flow ability of concrete and is expected to be effectively used for ternary concrete.

**Super plasticizer:** Sulphonated Naphthalene Formaldehyde condensate (CONPLAST SP-430) was used as admixture in this study to increase the workability of concrete. Super plasticizer



CONPLAST SP-4320 A2 from FORSOC chemical was used as water reducing agent to achieve required workability.

**Concrete Mix Design:** The grade of concrete used in this investigation is M25 with different percentages (5%, 7.5%, 10% and 12.5% ) of both silica fume and fly ash. The mix design procedure is adopted according to IS 10262 – 2009 & IS 456 –2000.

The experiments were conducted as per IS code. The strength tests like Compressive strength, Split tensile strength and Flexural strength were performed. The cubes, Prisms and cylinders were casted for various curing periods like 7, 28 and 56 days. All cubes were tested for various Durability aspects like Acid effect, Sulphide effect, Sulphate effect and Marine effect. The experimental findings are as follows

**Results and Discussions:**

Table 1: Variation in compressive strengths with different percentage Replacement of cementitious material

Compressive strength	7 Days strength (Mpa)	28 Days strength (Mpa)	56 Days Strength (Mpa)
CC	27.30	40.60	45.5
TC-5%(FA and SF)	46.60	57.20	60.31
TC-7.5%(FA and SF)	48.72	59.06	60.91
TC-10%(FA and SF)	66.99	68.96	68.40
TC-12.5%(FA and SF)	62.04	63.20	64.24

From table 1, it is observed that the 7days cube compressive strength varies from 46.60 to 66.99 MPa, the 28days cube compressive strength is about 57.20 to 68.96 MPa and also the 56days cube compressive strength is about 60.31 to 68.40 MPa respectively with replacement

of ordinary Portland cement with both fly ash and silica fume in the range of 5% to 12.5%. As the dosage of admixture increases the strength has been increased up to 10% later on a decreased trend was observed.

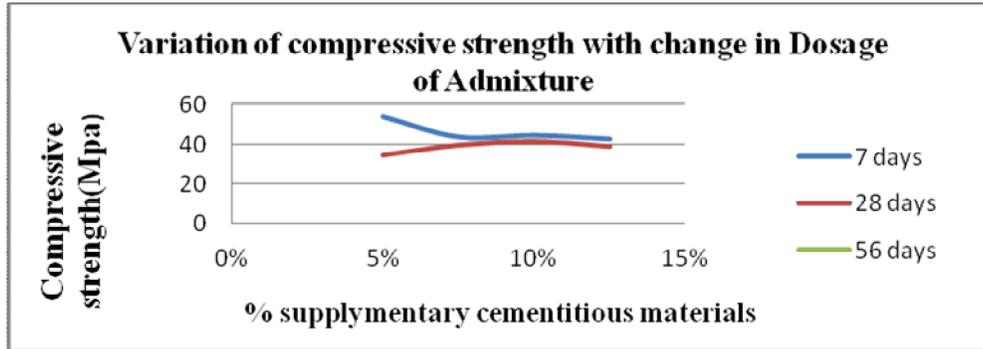


Figure : 1

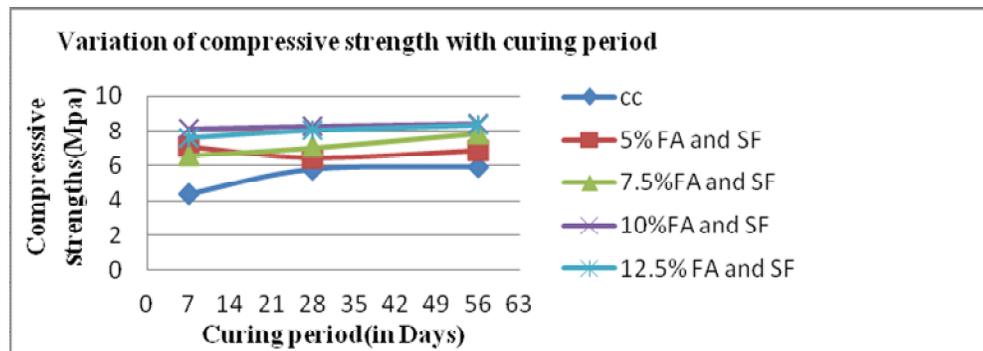


Figure : 2

From Figures 1 and 2 it can be known that the max % increase of 7 days compressive strength obtained for 10% replacement of SCM is higher than conventional concrete mix and other percent replacements. The max % increase of 28 days compressive strength for 10% replacement of SCM is 59% and 43% at 56 days which is lesser compared to % increase in strength at the age of 28 days for all ternary mixes. The target mean compressive strength of ternary concrete is reached easily. It can be noted

that the % increase is marginal at the age of 56 days when compared to 28 days.

**Split Tensile Strength:**

The split tensile strength test was conducted on cylindrical specimens made with replacement of both fly ash and silica fume for different percentages (5%, 7.5%, 10%, 12.5%). The results of split tensile strength at 7, 28 and 56 days for the Mix M25 with various replacements are tabulated in table 2 and figures 3 and 4 which include the average values of three cylinders for each mix.



Table 2:  
 Variation of Split tensile strength with different percentage Replacement of cementitious material

Split tensile strength	7 Days strength (MPa)	28 Days strength (MPa)	56 Days strength (MPa)
CC	2.82	3.56	3.96
TC-5%(FA and SF)	2.44	3.02	3.8
TC-7.5%(FA and SF)	3.85	3.953	4.04
TC-10%(FA and SF)	4.11	4.28	4.42
TC-12.5%(FA and SF)	3.80	3.96	4.24

It is observed from Figures 3 and 4 that the percentage increase in tensile strength with the age is observed to be higher when compared to conventional cement concrete as the percentage replacement of cement by SCM's increase.

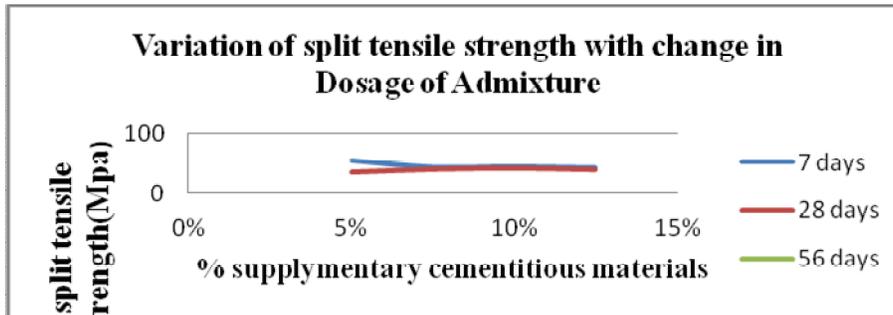


Figure : 3

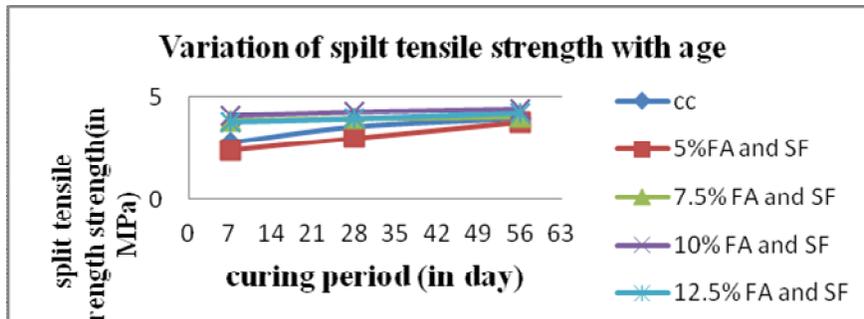


Figure : 4



The increase in strengths observed to be very nominal at the same age with different percent replacement of cement by SCM's. The maximum percentage increase of 7 days tensile strength is 45% obtained for 10% replacement of cement by SCM's. When compared with reference mix, the ternary concrete mix has shown higher value of tensile strength about 4.219 MPa at 28 days with 10% replacement and the maximum percentage increase of 56 days tensile strength is 10% obtained for 10%

replacement by SCM's. The decrease in tensile strength at the age of 56 days with 12.5% replacement of cement by SCM's is marginal.

**Flexural strength:**

The values of Flexural strength obtained from the test for ternary concrete prisms with different percentage of replacements were presented in table 3 and the results were plotted in figures 5 and 6.

**Table 3: variation of Flexural strength with different Percentage replacement of SCM's**

Flexural tensile strength	7 Days strength (MPa)	28 Days strength (MPa)	56 Days strength (MPa)
CC	4.40	5.80	5.94
TC-5%(FA and SF)	7.05	6.45	6.85
TC-7.5%(FA and SF)	6.60	7.05	7.85
TC-10%(FA and SF)	8.08	8.24	8.40
TC-12.5%(FA and SF)	7.60	8.04	8.3

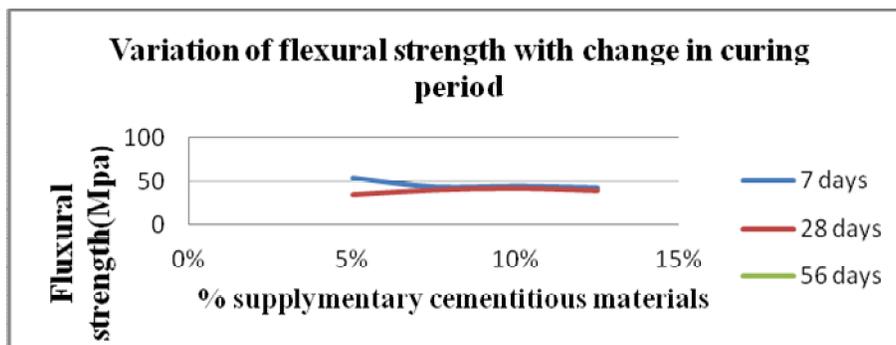


Figure : 5

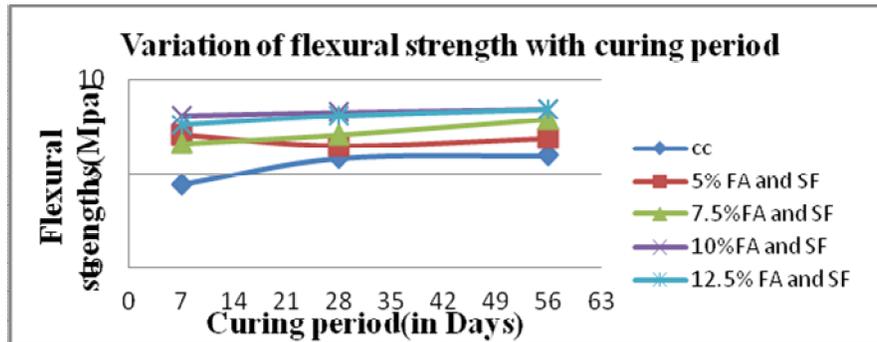


Figure : 6

From the table 3, it is observed that the 7-days flexural strength is about 7.05 to 7.60 MPa, the 28 days Flexural strength is about 6.45 to 8.04 MPa and also the 56-days Flexural strength is about 6.85 to 8.04 MPa respectively with replacement of ordinary Portland cement with both fly and silica fume in the range of 5% to 12.5%. As the percentage of replacement increases the strength also increases up to 10% and further slightly decreases for 12.5% replacement for M25. The results indicate that the strength variation in all the grades is very marginal.

**Acid attack:** The compressive strength test of concrete was conducted on cube test specimens of standard size 100mm\* 100mm for concrete mixes made with

Table 4 variation of compressive strength with different percentage replacement of SCM's Immersed in HCL solution

different percentages of replacement with both fly ash and silica fume. The values of compressive strength obtained from the test for conventional aggregates concrete and concrete made with different percentage replacements were presented in table 4 and results were plotted in fig 7 to 10

The test was conducted on test specimens after subjecting them to 5% hydrochloric acid (HCL) solution and one day air drying. The specimens were cured for 28 days in water and air dried for one day before they are subjected to HCL solution for 28 days and 56 days. The variation in the results were shown in fig 7.

Compressive tensile strength(Hcl)	28 Days	56 Days
CC	38.0	46.08
TC-5%(FA and SF)	38.0	36.60
TC-7.5%(FA and SF)	40.02	36.06
TC-10%(FA and SF)	43.80	38.70
TC-12.5%(FA and SF)	40.8	35.05

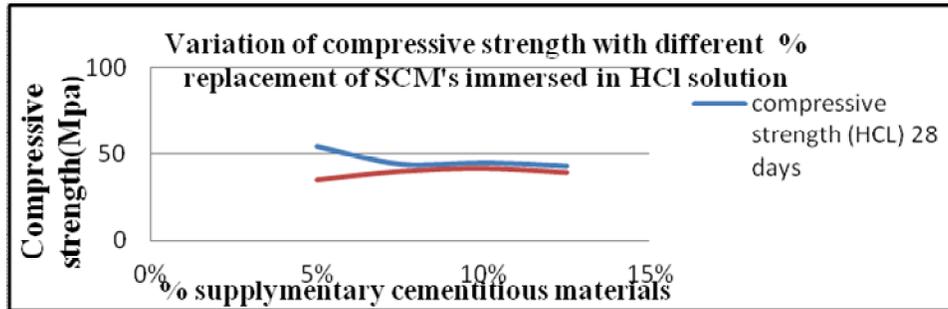


Figure : 7

**Sulphate attack ( $H_2SO_4$ ):**The test was conducted on test specimens after subjecting them to 5% concentration Sulphate solution and one day air drying. The specimens were cured for 28days in tap water and air dried for one day before they are subjected to Sulphate solution for 28days and 56days.The compressive strength values for the test specimens were presented in table 5 and results were plotted in Fig 8.

Table 5: Variation of compressive strength with different percentagereplacement of SCM's immersed in  $H_2SO_4$  solution

Compressive strength ( $H_2SO_4$ )	28 Days	56 Days
CC	38.0	46.08
TC-5%(FA and SF)	19.0	14.6
TC-7.5%(FA and SF)	24.0	17.0
TC-10%(FA and SF)	26.66	19.9
TC-12.5%(FA and SF)	22.0	18.93

Form the table 5 we know that compressive strengths of all ternary mixes are decreased for sulphate attack at all ages. The more strength loss is obtained for 10% replacement of both FA and SF at the age of 28days.

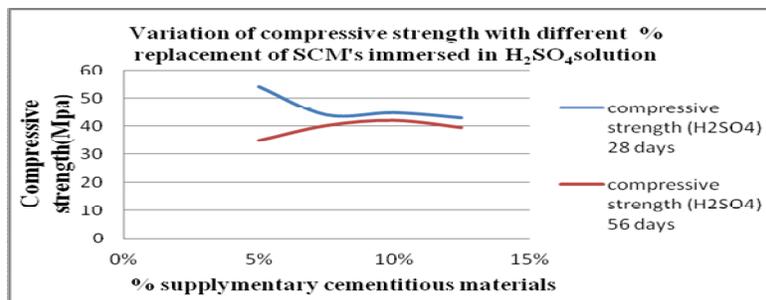


Figure : 8



**Sulphide attack ( $K_2SO_4$ ):**The test was conducted on test specimens after subjecting them to 5% concentration Sulphide solution and one day air drying. The specimens were cured for 28days and 56days. The compressive strengths for the test specimens were presented in table 6 and results were plotted in Fig 9.

Table 6: Variation of compressive strength with different percentage replacement of SCM's immersed in  $K_2SO_4$  solution

Compressive strength ( $K_2SO_4$ )	28 Days	56 Days
CC	38.0	46.08
TC-5%(FA and SF)	39.0	34.95
TC-7.5%(FA and SF)	45.95	36.9
TC-10%(FA and SF)	54.4	45.56
TC-12.5%(FA and SF)	52.8	40.83

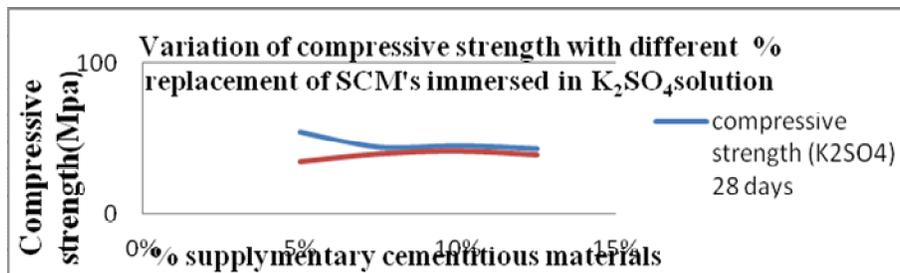


Figure : 9

**Marine effect:**The test was conducted on test specimens after subjecting the specimen to marine water attack and one day air drying. The specimens were cured for 28days in tap water and air dried for one day before they are subjected to marine water attack for 28days and 56days. The compressive strength values for the test specimens were presented in table 7 and results were plotted in fig 10.

Table 7: Variation of compressive strength with different percentage replacement of SCM's immersed in Sea water

Compressive strength (sea water)	28 Days	56 Days
CC	38.0	46.08
TC-5%(FA and SF)	54.0	34.8



TC-7.5%(FA and SF)	44.05	40.06
TC-10%(FA and SF)	44.8	41.88
TC-12.5%(FA and SF)	43.02	39.36

Form table 7 it is observed that the loss of strength in Conventional Concrete is more at 10% replacement of cement by SCM's at all ages when compare to ternary concrete. The maximum percentage weight loss in ternary concrete mixes is observed to be 7% at all the ages when compared to Conventional Concrete.

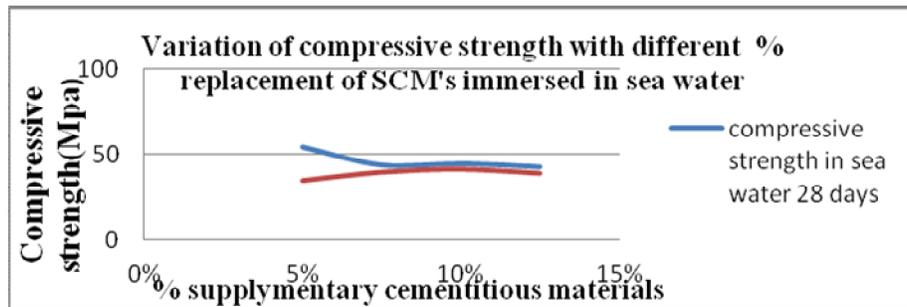


Figure : 10

**Conclusions:**

The addition 10 percentage of admixture has shown optimum strength values for all curing periods. The 28 days curing was decided as best period for compressive strength criteria because it has shown maximum strengths. The curing period of 56 days was considered as optimum for tensile and flexural strengths which has given higher values of strengths. A decrease in compressive strengths for 28 Days curing period up to 5% addition was observed later on a constant trend was obtained. An increase in compressive strengths up to 5% addition was observed for 56 Days curing

period, after that constant trend was shown up to 12%.

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