Effect of Ternary Material on Strength and Durability Parameters of Concrete

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Abstract

Today, Concrete is widely used material in the construction. Portland cement is the most important ingredient of concrete. The production of the cement has been greatly increased in recent years. As we all knows that this higher production of cement is resulting in the emission of CO_2 gas and increasing a lot of environmental pollution. Subtitues Supplementary cementitious materials are the materials which are finely ground solid materials and used in partial replace of cement. This paper reviews work carried out on the use of combinations of silica fume and metakaoline mix as a partially pozzolanic replacement for cement in M30 grade concrete. Metakaoline and silica fume content of 75% and 25% used respectively as a replacement. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 days. Durability test was also studied in which percentage of weight loss is compared with normal concrete. From the resent research work using SF and MK, it is evident that it is a very effective pozzolanic material and it effectively enhance the strength parameters of concrete.
Keywords: Silica Fume, Metakaoline, Durability, Compressive Strength, Flexural Strength, Split Tensile Strength

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I. INTRODUCTION

In civil engineering structures, Concrete is the most important construction materials which affect the cost of the whole building. Concrete plays a key role in national development of all countries around the world. Globally concrete comes next to the water for the most consuming substance with an estimated consumption over 6-billion-meter cube per year. During the last 50 years, there will be so many methods to improve the strength of the concrete. Supplementary cementitious materials like silica fume, Metakaolin, Fly ash would be the best option for the replacement of the cement. The use of SCM results in the increment the various properties of concrete like durability, strength and workability. Manufacturing of cement product will affect the environment because emission of CO2 gas. So finding for this type material, which can be used as an alternative solution for replace the cement content. This material should also decrease the overall cost of the construction. In the recent years the materials replace the cement as a partially or fully, they are Fly ash, GGBS, Silica Fume, Metakaolin and other powder form materials should be the best suited. Silica Fume with the other SCM like Metakaolin and Fly ash are the best option for the Ternary cement materials. From the records, we know that the addition of silica fume definitely increases the mechanical and durability properties of concrete. When the concrete containing fine pozzolanic materials, material generate a large number of the precipitations of the hydrogen products and therefore make the paste more homogeneous. The reason behind this is that, there will be the cement hydration reactions between the amorphous silica of the SCM and calcium hydroxide. The main reason of using the SCM as a replacement of the cement is that they allow dense packing with the cement and reduce the wall effect in the transition zone between the cement paste and aggregate.

Silica fume is a by-product of the smelting process in the silicon and ferrosilicon industry. Silica fume is also known as the micro silica, condensed silica fume, volatized silica pr silica dust. It should be grey or premium white in colour. Particle size of the silica fume are between 13,000 and 30,000 m^2/kg and for this reason Characteristics of the transition zone between the aggregate particles and cement paste plays a significant role in the cement aggregate bond. Addition of silica fume influence the thickness of transition phase in mortars and the degree of the orientation of the CH crystals in it.

Metakaoline is a pozzolanic material which is manufactured from selected kaolin, after refinement and Calcinations under specific Conditions. Metakaolin is a highly effective pozzolanic material and rapidly reacts with the excess calcium hydroxide which is coming from the hydration cement, to produce calcium alumina silicate hydrates and calcium silicate hydrates. Metakaoline is produced by heating kaolin which is one of the most natural clay minerals at a temperature of 650 to 900-degree C. kaolin structure should be break down under the heat treatment or calcinations. In metakaolin, hydroxyl ions are removed and resulting that alumina and silica layers yields a highly reactive and amorphous materials with pozzolanic for the use in form of cementing application.

II. EXPERIMENTAL INVESTIGATION

A. *Materials*

1) Cement
Ordinary Portland Cement of Tata brand of 53 grade confirming to IS: 12269-1987(9) was used in the present study. Cement used in practical having specific gravity 3.15, initial and final setting time was 47 and 260 minutes respectively.
2) Fine Aggregate
Natural sand as per IS: 383-1987 was used. Locally available River sand was used having specific gravity 2.67, fineness modulus 3.00 and zone of grading II.
3) Coarse Aggregate
Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm of specific gravity 2.78 and Elongation Index and Flakiness Index value in % is 11.96 and 12.74 respectively.
4) Silica Fume
Silica fume used was supplied by "AMGEEN MINERALS". The Silica fume is used as a partial replacement of cement. The properties silica fume Having specific gravity 2.2, Bulk density 576 (Kg/m^3) Containing SiO_2 of 90-96% and Al_2O_3 of 0.5-0.8% as per manufacturers manual.
5) Metkaoline
Metakaoline used was supplied by "AMGEEN MINERALS". The properties of Metakaoline containing 62% of SiO_2 and 28.63% Al_2O_3 as per manufacturers manual.

B. *Mix Proportioning*

M30 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-1982. Quantity for 1 m^3 of concrete contain 382 kg cement, 648 kg F.A, 1166 kg C.A and 186 kg of water.

C. *Experimental Procedure*

The specimen of standard cube of (150mm x 150mm x 150mm) standard cylinders of (300mm x150mm) And Beam of (700 mm x 150mm x 150mm) were used to determine the compressive strength, split Tensile strength and flexural strength of concrete. Three specimens were tested for 7 & 28 days with each proportion of combination of silica fume and Metakaolin replacement. Totally 42 cubes, 84 cylinders and 42 Beams were cast for the strength parameters. W/C ratio is constant for all the mix was 0.50. The constituents were weighed and the materials were mixed by mixture. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive, split tensile and flexural strength as per Indian Standards.

III. TEST RESULT AND DISCUSSIONS

A. *Fresh Concrete Test Result*

Results of fresh concrete with partial replacement of silicafume and Metakaolin are discussed in comparison with those of normal concrete. Workability is carried out by conducting the slump test and compaction factor test. As per I.S. 1199-1959 on ordinary concrete and concrete containing combination of silica fume and metakaoline.

From the result of slump Test and Compaction Factor test, it was noticed that the slump value increase as the increase the replacement level of cement with SF+MK. Workability of concrete increased with the increase the replacement of cement.
1) Slump Test Result
The result of slump test was presented in Table 1. Slump test is the most commonly used test for measuring consistency of concrete. The apparatus for slump test consists of a metallic mould in the form of a frustrum of a cone with bottom diameter of 200 mm, top diameter of 100 mm and height of 300 mm. For tamping the concrete, a steel tamping rod of 16 mm diameter, 600 mm length with bullet end is used. The thickness of the metallic sheet for the mould should not be less than 1.6 mm. The mould is provided with suitable guides for lifting vertically up.

Table - 1
Slump Test Result

SR NO.	MIX	PROPERTIES		SLUMP(mm)
		CEMENT	SF+MK	
1	NORMAL	100%	0%	37
2	2.5%	97.5%	2.5%	45
3	3%	97%	3%	45
4	4%	96%	4%	45
5	5%	95%	5%	47

6	7.5%	92.5%	7.5%	50
7	10%	90%	10%	58

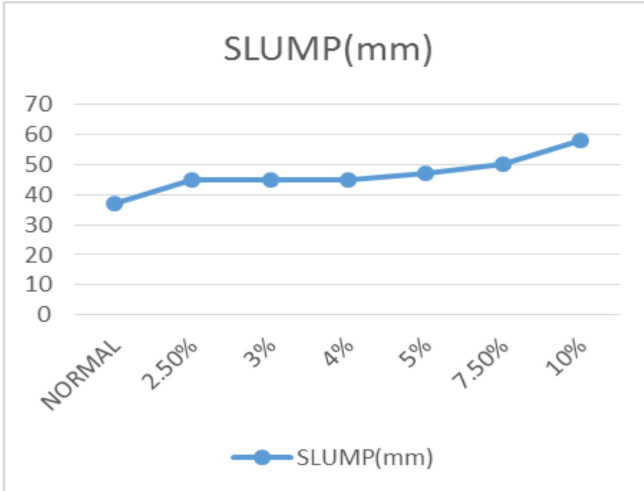

Fig. 1: Slump Test Result

2) Compaction Factor Test Result

A compaction factor test apparatus as per IS: 5515-1983 was used. Compaction test consists of 3 layer. Upper hopper consists of top internal diameter of 250 mm, bottom internal diameter of 125 mm and height of 275 mm. Upper hopper consists of top internal diameter of 225 mm, bottom internal diameter of 125 mm and height of 225 mm. Bottom cylinder having internal diameter of 150 mm and height of 285 mm. distance between all this apparatus should be 200 mm.

Table - 2
Compaction Factor Result

SR NO.	*MIX*	*PROPERTIES*		*COMPACTION FACTOR*
		CEMENT	*SF+MK*	
1	*NORMAL*	*100%*	*0%*	*0.889*
2	*2.5%*	*97.5%*	*2.5%*	*0.87*
3	*3%*	*97%*	*3%*	*0.86*
4	*4%*	*96%*	*4%*	*0.858*
5	*5%*	*95%*	*5%*	*0.849*
6	*7.5%*	*92.5%*	*7.5%*	*0.8321*
7	*10%*	*90%*	*10%*	*0.801*

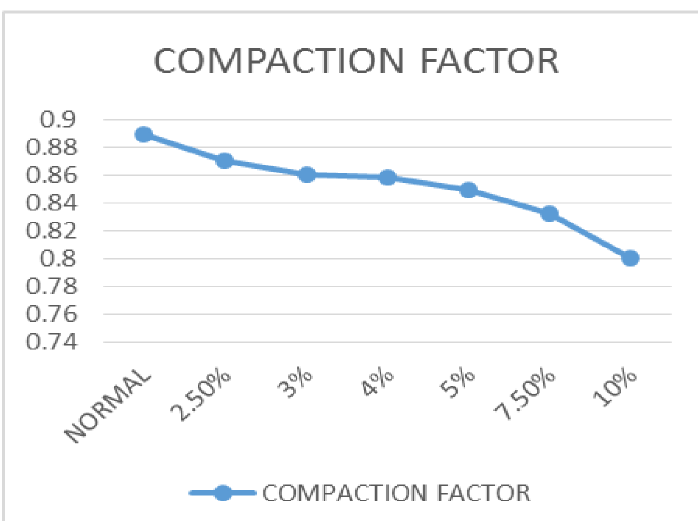

Fig. 2: Compaction Factor Result

B. Hardened Concrete Test Results

1) Compressive Strength

The results of compressive strength were presented in Table 8. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000Kn. From Fig 3,4 the compressive strength is up to 30.07 N/mm^2 and 43.03 N/mm^2 at 7 and 28 days. The maximum compressive strength is observed at3% replacement of silica fume+ Metakaolin. The maximum Compressive strength of cylinder at 7 days and 28 days are found to be 23.02 N/mm^2 and 29.62 N/mm^2 respectively when cement is replaced by the combination of silica fume and metakaolin.

Table - 3
Compressive Strength Result of Cube

SR NO.	MIX	PROPERTIES		Cube	
		CEMENT	SF+MK	7 Days	28 Days
1	NORMAL	100%	0%	24.88	36.66
2	2.5%	97.5%	2.5%	28.74	39.18
3	3%	97%	3%	30.07	43.03
4	4%	96%	4%	27.25	40.07
5	5%	95%	5%	24.37	34.81
6	7.5%	92.5%	7.5%	24.07	29.85
7	10%	90%	10%	22.74	28.88

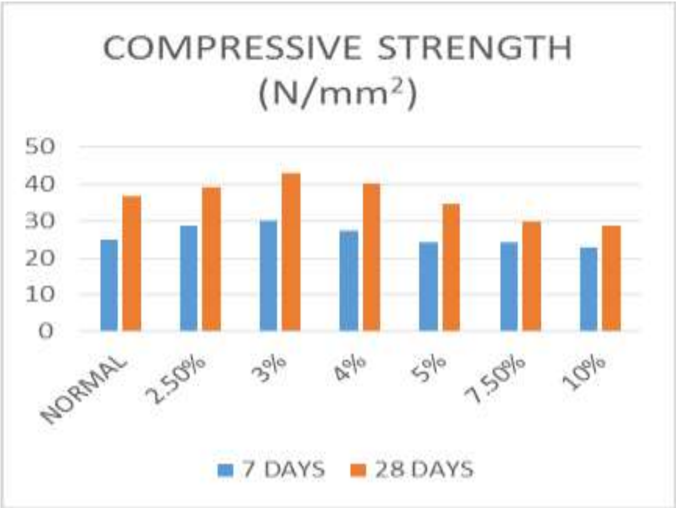

Fig. 3: Compressive Strength of Cube

2) Split Tensile Strength

The results of Split Tensile strength were presented in Table 9. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000Kn.From Fig 5 the increase in strength is 3.20 N/mm^2 and 4.15 N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength is observed at 3% replacement of silica fume. Figure also shows that the split tensile strength of concrete containing silica fume and metakaolin decrease as the increase in the replacement beyond 3%.

Table - 1
Split Tensile Strength Result

SR NO.	MIX	PROPERTIES		Cylinder	
		CEMENT	SF+MK	7 Days	28 Days
1	NORMAL	100%	0%	2.35	3.30
2	2.5%	97.5%	2.5%	2.78	3.56
3	3%	97%	3%	3.20	4.15
4	4%	96%	4%	2.52	3.98
5	5%	95%	5%	1.88	3.13
6	7.5%	92.5%	7.5%	1.79	2.878
7	10%	90%	10%	1.5	2.64

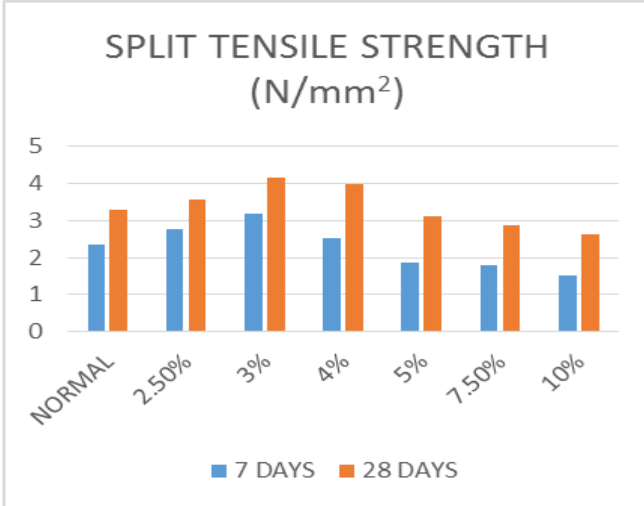

Fig. 4: Split Tensile Strength Result

3) Flexural Strength

The results of flexural strength of normal concrete and silica fume + Metakaolin replaced concrete were presented in Table 10. The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 7 and 28 days. The cubes were tested using Flexure Testing Machine (FTM). From Fig 6 the maximum increase in flexural strength is observed as 4.68 N/mm^2 and 5.71 N/mm^2 at 7 and 28 days when silica fume+ Metakaolin is replaced by 3% to that of cement.

The flexure strength at the age of 7 days and 28 days of concrete containing silica fume and metakaolin continuously decrease with respect to conventional concrete after the replacement beyond the 3%.

Table - 2
Flexure Strength Result

SR NO.	*MIX*	*PROPERTIES*		*Beam*	
		CEMENT	*SF+MK*	*7 Days*	*28 Days*
1	*NORMAL*	*100%*	*0%*	*3.14*	*4.80*
2	*2.5%*	*97.5%*	*2.5%*	*4.20*	*4.85*
3	*3%*	*97%*	*3%*	*4.68*	*5.71*
4	*4%*	*96%*	*4%*	*4.0*	*5.36*
5	*5%*	*95%*	*5%*	*3.34*	*4.65*
6	*7.5%*	*92.5%*	*7.5%*	*2.90*	*4.08*
7	*10%*	*90%*	*10%*	*2.25*	*3.70*

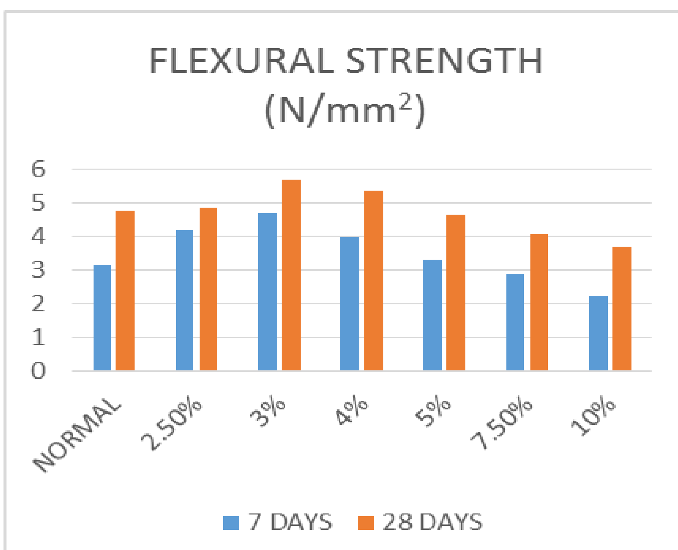

Fig. 1: Flexure Strength Result

IV. CONCLUSION

- From the above study we conclude that the compressive strength, split tensile strength and flexural gradually increase up to addition of 3% of silica fume + metakiolin.
- With increase in replacement of silica fume + Metakaolin with cement beyond the 3%, gradually compressive strength, split tensile strength and flexural strength were decreasing.
- Compressive strength of concrete is increased by 20% and 17% at 7 days and 28 days for 3% replacement of silica fume + Metakaolin.
- Split tensile and flexural strength of concrete is respectively increased by 36%, 49% and 25%, 19% at 7 days and 28 days for 3% replacement of silica fume + Metakaolin.
- Workability of concrete containing silica fume and metakiolin is increased as increase in the replacement level.

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