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Experimental Study on High Strength Concrete with Fly Ash and Condensed Silica Fume

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ABSTRACT:- *Concrete, is one of the key construction materials having good compressive &, flexural strengths and durable properties among others. With comparative low cost made from some of the most widely available elements, it has found wide usage. It is mouldable, adaptable and relatively fire resistant. The fact that it is an engineered material which satisfy almost any reasonable set of performance specifications, more than any other material currently available has made it immensely popular construction material. In fact, every year more than 1 m3 of concrete is produced per person (more than 10 billion tonnes) worldwide.As our project title suggests, the objective of our project is to find out the strength parameters, in specific, the compressive and flexural strengths of fibre reinforced triple blended high strength concrete and compare the same with that of ordinary concrete. In turn, our project is aimed towards experimentally proving the advantages of fibre reinforced triple blended concrete over ordinary concrete and thus fostering its usage for not only greater strength and durability but also in view of the economic and environmental considerations previously mentioned. More specifically, the aim of this study is:*

- *To prepare the concrete cubes & beams using cement partly replaced by silica fume and fly ash.*
- *To determine compressive strength of hardened concrete at 28 days of curing &compare various mixes.*
- *To determine flexural strength at 28 days of curing & compare various mixes*

In the process of testing, compressive and flexure tests specifications as per IS:516-1959 have been adhered to.

I. INTRODUCTION

Strength (load bearing capacity) and durability (its resistance to deteriorating agencies) of concrete structures are the most important parameters to be considered while discussing concrete. The deteriorating agencies may be chemical – sulphates, chlorides, CO_2, acids etc. or mechanical causes like abrasion, impact, temperature etc. The steps to ensure durable and strong concrete encompass structural design and detailing, mix proportion and workmanship, adequate quality control at the site and choice of appropriate ingredients of concrete. Type of cement is one such factor. In this paper, the significance and effect of the type of cement on strength and durability of its corresponding concrete is focused on. Depending upon the service environment in which it is to operate, a concrete structure may have to encounter different load and exposure regimes. In order to satisfy the performance requirements, cements of different strength and durability characteristics will be required.

So far, the development can be divided into four stages. Viz; normal strength concrete (NSC) which is composed of only four primary components (cement, water, fine aggregates & coarse aggregates). Increase in housing needs in the form of high rise buildings; long

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span bridges, etc.,needed higher compressive strength. Thus, the next stage was that of developing a cement type with an inherent higher compressive strength i.e. the development of high strength concrete (HSC). However, with time, it was realized that high compressive strength was not the only important factor to be considered in the design of concrete mixes. Other parameters such as high durability, low permeability, high workability etc. were also learnt to be equally quintessential. Thus, high performance concrete (HPC) was proposed and widely studied at the end of the last century. The last stage involved the maximization of all these properties to the highest extent possible in an economical and environment friendly way. Here, comes into picture, the concept of triple blended concretes.

In simple words, triple blended cement is characterised by part replacement of cement with mineral admixtures/additives such as pozzolanic admixtures (fly ash, silica fume, granulated slag etc.) or inert fillers. The corresponding concrete is termed as triple blended concrete. These admixtures are found to enhance the physical, chemical and mechanical properties of the concrete i.e. in terms of its strength parameters (compressive and flexural) as well as durability parameters.

II. LITERATURE REVIEW

R.V Balendran, T.M Rana, T. Masqood and W.C Tsong (2002) studied on "strength and durability performance of High Performance incorporating pozzolanas at elevated temperatures". The inclusion of pozzolanas like fly ash and silica fume enhances the properties of concrete both in fresh and hardened states. In the case of high performance concrete (HPC), their role in enhancing the workability, strength and durability is extremely significant.

OzkanSengul and Mehmet Ali Tasdemir (2009), have concluded that for the improvement of strength, the pozzolanas were more effective in the low water/binder ratio i.e. for high strength concrete.

Jon M. Rouse and Sarah L. Billington (2007) "creep and shrinkage of high performance fibre reinforced cementitious composites" describes a class of high performance fibre reinforced cementitious composites, referred to as engineered cementitious composites that were studied for its time dependant properties. The material exhibits a pseudo strain-hardening response with multiple fine cracking in uniaxial tension. A series of experiments on Fibre reinforced concrete specimens were conducted to provide information about the shrinkage, basic creep, dying creep and shrinkage of concrete were made.

The study of mechanical behaviour of fibre reinforced concrete was conducted by **Swamy and Hannat.** As a consequence of the above investigation it has been observed that compared to plain concrete there is a substantial increase in the tensile strength, the first crack, flexural strength and ultimate flexural strength of fibre reinforced concrete.

III. MIX DESIGN

The selection of mix materials and their required proportion is done through a process called mix design. There are number of methods for determining concrete mix design. The method that we have adopted is called the D.O.E Method which is in compliance to the British Standards. The objective of concrete mix is to find the proportion in which concrete ingredients-cement water fine aggregate and coarse aggregate should be combined in order to provide the specified strength workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2000.

The DOE method was first published in 1975 and then was revised in 1988, as per the BS code 1988 year. The DOE method is applicable to concrete for most purposes. The method can be used for concrete using fly ash.

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Since DOE method presently is the standard British method of concrete mix design, the procedure and steps involved in this method is described below.

MATERIALS:

Cement : OPC 53 grade

Coarse aggregate: crushed stone

Fine aggregate : natural river sand

PARAMETERS:

Assume standard deviation = 5 N/mm^2

Assume slump of concrete = 75 mm

Step 1: Find the target mean strength from the specified characteristic strength

Target mean strength = specified characteristic strength + standard deviation x risk factor.

Step 2: Calculate the water/cement ratio. Using table and figure shown below.

Table gives approximate compressive strength of concrete made with a free w/c ratio of 0.50. Using this table find 28 days strength for the approximate type of cement and types of C.A. mark a point on the Y-axis in fig equal to the compressive strength read from the table which is at a W/C ratio of 0.50. Through this intersection point, draw a parallel doted curve nearest to the intersection point. Using the new curve we read of W/C ratio as against target mean strength.

Step 3: Decide water content water require workability express in terms of slump or vee-bee time taking into consideration the size of aggregate and its type.

Step 4: Find the cement content knowing the W/C ratio and the water content.

Step 5: Find out the total aggregate content and find out wet density of fully compacted aggregates. The value of specific gravity of 2.7 for crushed aggregate can be taken. The aggregate content is obtain by subtracting the weight of cement and water content from weight of fresh concrete.

Step 6: Proportion of fine aggregate is determine in the total aggregate. Maximum size of C.A the level of workability, W/C ratio, and the %age of fine passing 600µ sieve. Once the proportion of FA is obtained multiplying by the weight of total aggregate gives the weight if fine aggregate. Then the weight of the CA can be found out

Cement	= 629.03 kg
Fine aggregate	= 598.86 kg
Coarse aggregate	= 977.28 kg
Water	= 195 kg

The ratio comes out to be 1:0.95:1.55

IV. EXPERIMENTAL METHOD

A. Compressive strength results:

Table 1: Variation of compressive strength at 28 days with addition of 0% fibre by volume of concrete and with various % of Silica Fume and Fly ash

S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	76.24		
2	5	0	77.89	2.16	2.16
3	10	0	78.94	3.54	1.34
4	15	0	78.42	2.85	-0.65
5	0	20	77.59	1.77	-1.05
6	5	20	78.50	2.96	1.17
7	10	20	79.48	4.24	1.24
8	15	20	79.25	3.94	-0.28
9	0	40	77.12	1.15	-2.68
10	5	40	78.26	2.64	1.47
11	10	40	79.19	3.86	1.18
12	15	40	78.75	3.29	-0.55

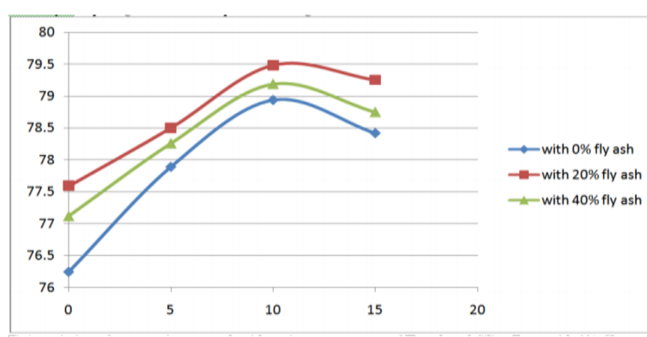

Fig 1: Variation of compressive strength at 28 days with addition of 0% fibre by volume of concrete and with various % of Silica Fume and Fly ash

Table 2: Variation of compressive strength at 28 days with addition of 0.5% fibre by volume of concrete and with various % of Silica Fume and Fly ash

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S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	77.21		
2	5	0	78.94	2.24	2.24
3	10	0	79.47	2.92	0.67
4	15	0	79.15	2.51	-0.40
5	0	20	78.14	1.20	-1.27
6	5	20	79.59	3.08	1.85
7	10	20	79.96	3.56	0.46
8	15	20	79.56	3.04	-0.50
9	0	40	77.83	0.80	-2.17
10	5	40	79.18	2.55	1.73
11	10	40	79.62	3.12	0.55
12	15	40	79.38	2.81	-0.30

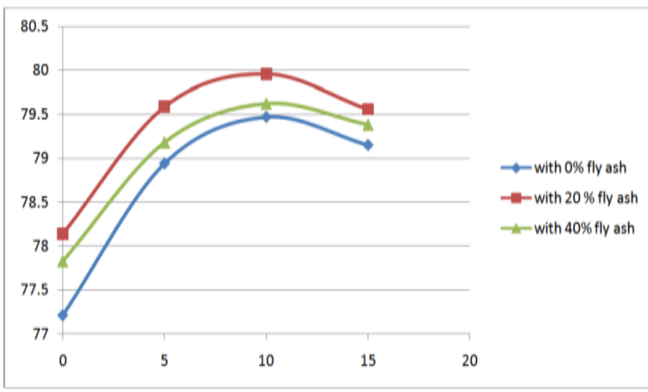

Fig 2: Variation of compressive strength at 28 days with addition of 0.5% fibre by volume of concrete and with various % of Silica Fume and Fly ash

Table 3: Variation of compressive strength at 28 days with addition of 1% fibre by volume of concrete and with various % of Silica Fume and Fly ash

S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	79.69		
2	5	0	80.23	0.67	0.67
3	10	0	80.68	1.24	0.56
4	15	0	80.29	0.75	-0.48
5	0	20	80.17	0.60	-0.14
6	5	20	80.78	1.36	0.76
7	10	20	81.20	1.89	0.51
8	15	20	80.64	1.19	-0.68
9	0	40	79.98	0.36	-0.81
10	5	40	80.51	1.02	0.66
11	10	40	80.82	1.41	0.38
12	15	40	80.40	0.89	-0.51

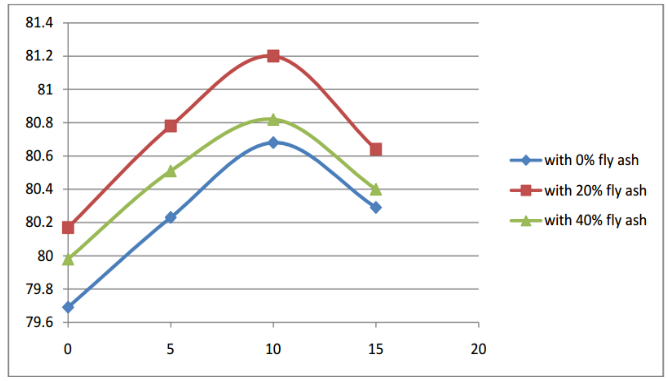

Fig 3: Variation of compressive strength at 28 days with addition of 1% fibre by volume of concrete and with various % of Silica Fume and Fly ash

The compressive strength results (tables.1, 2,.3) are given for 3 fibre percentages and various percentages of silica fume and fly ash considered. In general it is found that compressive strength is getting reduced with fly ash replacement and getting increased with silica fume replacement. With steel fibres present in the mix, it is also observed that there is marginal increase in the compressive strength.

a) Influence of silica fume on the mix:

1. Referring to the tables and graphs it can be seen that silica fume contributes towards increase in the compressive strength. 10% silica fume is found to be optimum in all the cases with and without fibres.
2. Highest compressive strength was obtained at 10% CSF with 20% fly ash and 1% fibre. This value is 81.2mPa. The compressive strength of the reference mix without any mineral admixtures and without fibre was obtained as 76.24mPa. There is an increase of nearly 7% in compressive strength over the reference mix
3. For this combination of 10% silica fume with 20% fly ash the compressive strength has shown an increase from 2 to 7 % with various percentages of fibre

b) Influence of Fly ash on the mix:

1. It can be seen from the tables that as the Fly ash percentage increases, the compressive strength is gradually decreasing. This happened in the case of all other combinations.
2. As discussed earlier the optimum percentage of mineral admixture is obtained as 20% fly ash with 10% CSF
3. 20% fly ash generates marginal increase in strength. To compensate for the loss of strength when higher percentages of fly ash is used silica fume is added
4. Fly ash is pozzolanic in nature and slowly reacting and it requires longer curing periods even beyond 28 days to generate high strength particularly when percentage is more

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c) Influence of steel fibres on mix:
1. In present investigation steel fibres was employed at percentages of 0%,0.5%,1%
2. It can be seen from tables and graphs as the percentage of steel fibre is increased there is marginal increase in the compressive strength for all the combinations
3. Steel fibres are mainly employed to contribute towards tensile and flexural strengths. There are also advantages like denser concrete, elimination of micro cracks etc in concrete
4. In addition , steel fibres contribute towards impact strength and shock absorption and other advantages

B. Flexural strength results:

The flexural strength results (tables 4.3.1, 4.3.2, 4.3.3) are given for 3 fibre percentages and various percentages of silica fume and fly ash considered. In general it is found that flexural strength is getting reduced with fly ash replacement and getting increased with silica fume replacement. With steel fibres present in the mix, it is also observed that there is increase in the flexural strength.

a) Influence of silica fume on the mix:

1. Referring to the tables and graphs it can be seen that silica fume contributes towards increase in the flexural strength. 10% silica fume is found to be optimum in all the cases with and without fibres.

2. Highest flexural strength was obtained at 10% CSF with 20% fly ash and 1% fibre. This value is 8.4mPa. The flexural strength of the reference mix without any mineral admixtures and without fibre was obtained as 6.4mPa. There is an increase of nearly 31.5% in flexural strength over the reference mix

3. For this combination of 10% silica fume with 20% fly ash the compressive strength has shown an increase from 15 to 31.5 % with various percentages of fibre

b) Influence of Fly ash on the mix:

1. It can be seen from the tables that as the Fly ash percentage increases, the flexural strength is gradually decreasing. This happened in the case of all other combinations.

2. As discussed earlier the optimum percentage of mineral admixture is obtained as 20% fly ash with 10% CSF

3. 20% fly ash generates increase in strength. To compensate for the loss of strength when higher percentages of fly ash is used silica fume is added

4. Fly ash is pozzolanic in nature and slowly reacting and it requires longer curing periods even beyond 28 days to generate high strength particularly when percentage is more

c) Influence of steel fibres on mix:

1. In present investigation steel fibres was employed at percentages of 0%,0.5%,1%

2. It can be seen from tables and graphs as the percentage of steel fibre is increased there is increase in the flexural strength for all the combinations

3. Steel fibres are mainly employed to contribute towards tensile and flexural strengths. There are also advantages like denser concrete, elimination of micro cracks etc in concrete

4. In addition , steel fibres contribute towards impact strength and shock absorption and other advantages

Table 4: Variation of flexural strength at 28 days with addition of 0% fibre by volume of concrete and with various % of Silica Fume and Fly ash

S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	6.40		
2	5	0	6.90	7.81	7.81
3	10	0	7.10	10.93	2.89
4	15	0	6.90	7.81	-2.81
5	0	20	6.60	3.12	-4.34
6	5	20	7.10	10.93	7.57
7	10	20	7.31	14.21	2.95
8	15	20	7.10	10.93	-2.87
9	0	40	6.50	1.56	-8.45
10	5	40	7.00	9.37	7.69
11	10	40	7.20	12.50	2.85
12	15	40	7.02	9.68	-2.5

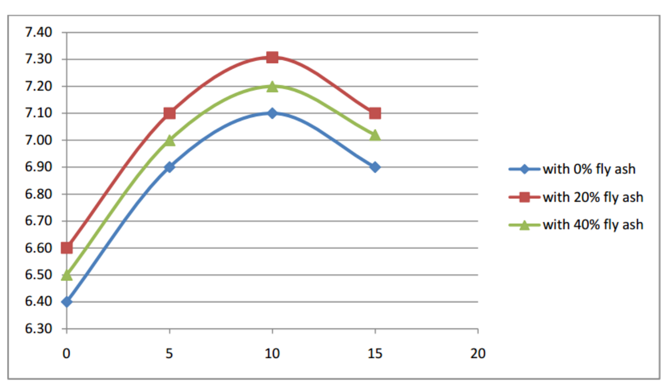

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Fig 4: Variation of flexural strength at 28 days with addition of 0% fibre by volume of concrete and with various % of Silica Fume and Fly ash

Table 5: Variation of flexural strength at 28 days with addition of 0.5% fibre by volume of concrete and with various % of Silica Fume and Fly ash

S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	7.17		
2	5	0	7.40	3.20	3.20
3	10	0	7.70	7.39	4.05
4	15	0	7.60	5.99	-1.29
5	0	20	7.30	1.81	-3.94
6	5	20	7.60	5.99	4.10
7	10	20	7.90	10.18	3.94
8	15	20	7.80	8.78	-1.26
9	0	40	7.20	0.41	-7.69
10	5	40	7.50	4.60	4.16
11	10	40	7.80	8.78	4.00
12	15	40	7.70	7.39	-1.28

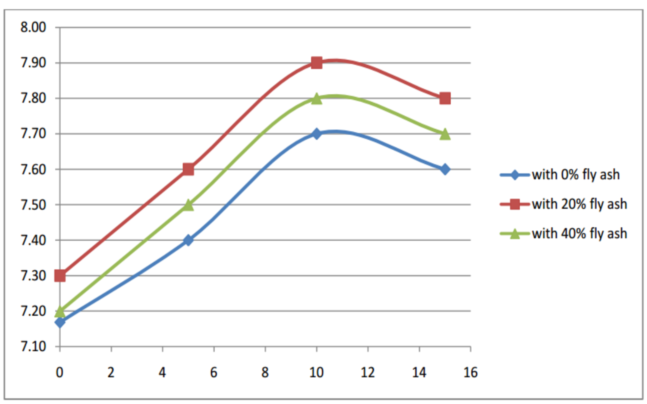

Fig 5: Variation of flexural strength at 28 days with addition of 0.5% fibre by volume of concrete and with various % of Silica Fume and Fly ash

Table 6: Variation of flexural strength at 28 days with addition of 1% fibre by volume of concrete and with various % of Silica Fume and Fly ash

S.NO	% SILICA FUME	% FLY ASH	28 DAYS COMPREESIVE STRENGTH IN MPA		
			STRENGTH	% INCREASE OVER 0%	% INCREASE OVER PRECEDING
1	0	0	7.50		
2	5	0	7.80	4.0	4.0
3	10	0	8.10	8.0	3.84
4	15	0	8.00	6.66	-1.23
5	0	20	7.70	2.66	-3.75
6	5	20	8.04	7.2	4.41
7	10	20	8.40	12.0	4.47
8	15	20	8.20	9.33	-2.38
9	0	40	7.60	1.33	-7.31
10	5	40	7.90	5.33	3.94
11	10	40	8.20	9.33	3.79
12	15	40	8.10	8.0	-1.21

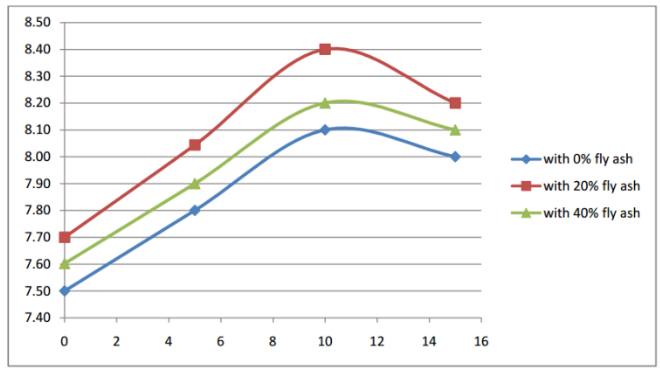

Fig 6: Variation of flexural strength at 28 days with addition of 1% fibre by volume of concrete and with various % of Silica Fume and Fly ash

V. CONCLUSION

Based on the present experimental investigations the following conclusions are drawn:

1. Higher dosages of super plasticizer are required for high strength concrete mixes particularly when mineral admixtures and fibres were employed to maintain workability.
2. For this combination of 10% silica fume with 20% fly ash the compressive strength has shown an increase from 2 to 7 % with various percentages of fibre
3. 20% fly ash generates marginal increase in strength. To compensate for the loss of strength when higher percentages of fly ash is used silica fume is added
4. Fly ash is pozzolanic in nature and slowly reacting and it requires longer curing periods even beyond

28 days to generate high strength particularly when percentage is more

5. As the percentage of steel fibre is increased there is marginal increase in the compressive strength for all the combinations
6. For this combination of 10% silica fume with 20% fly ash the compressive strength has shown an increase from 15 to 31.5 % with various percentages of fibre
7. As the percentage of steel fibre is increased there is higher increase in the flexural strength for all the combinations
8. An optimum high strength concrete mix possessing optimum strength properties can be obtained resorting to triple blending.
9. In the case of triple blended cement concrete mixes, adding certain percentages of steel fibres would help in generating optimum structural concrete mixes possessing all the strength and durability properties

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