PERFORMANCE OF HIGH STRENGTH CONCRETE TRIPLE BLENDED WITH FLY ASH, SILICA FUME AND STEEL FIBERS

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Abstract - *Compressive strength is an integral property of concrete that play a key role in the construction industry. The present works investigates the effect of triple blend of fly ash, silica fume and steel fibers on the compressive, split tensile and flexural strength of concrete. Fly ash (FA) and silica fume (SF) are introduced as a partial replacement for cement for various additions of steel fibers by volume of concrete. A replacement level of 0% FA with 0 %, 5%, 10%, 15% SF in place of cement for 0% addition of steel fibers by volume of concrete is used for the preparation of first set of samples. Second set of samples were prepared with the change in fly ash proportion to 20%, keeping replacement levels of SF unchanged for 0% inclusion of steel fibers and the last set of samples were prepared with 40% FA replacement percentage without any change in the replacements of SF for the same 0% steel fibers. Likewise, the same combinations of FA and SF were repeated for 0.5% and 1% steel fibers and tested for various strength results after 28 days curing. Later, it is seen that an optimum mix of 20% FA with 10% SF for 1% inclusion of steel fibers, produced the maximum compressive strength of 81.20 N/mm2 and maximum flexural strength of 8.40 N/mm2.*

***Key Words*: Fly ash (FA), Silica Fume (SF), Steel fibers, compressive strength, flexural strength**

1.INTRODUCTION

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.

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, CO2, 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 focussed 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 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 realised 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.

2. LITERATURE REVIEW

In order to fulfil the aims and objectives of the present study following literatures have been reviewed.

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.

According to Li and Zhao(2003), blending Fly Ash and Silica Fume presents an excellent behaviour in both short- and long-term compressive strengths and in resistance to H2SO4 attack; and improves the microstructure and hydration rate. The achievement of these advantages becomes more important for HSC proportioning since HSC requires high amounts of cementitious materials.

The results of a study by Shannag (2000) suggest that certain natural pozzolana-Silica Fume combinations can improve the compressive and splitting tensile strengths, workability, and elastic modulus of concretes, more than natural pozzolana or SF alone.

Tahir Kemal Erdem and OnderKırca(2009), used the ternary blend of silica fume and fly ash to obtain high strength concrete mix. They have shown that triple blends almost always made it possible to obtain higher strengths than PC (plain concrete) + SF(silica fume) mixtures at all ages provided that the replacement level by Fly Ash (class F) or Fly Ash (class C or S) was chosen properly. They also showed that the improvements in strengths by ternary blends were more significant at 7 and 28 days than at 3 days.

Isaia GC, Gastaldini ALG et al. (2003), observed the physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete. Particle packing is one reason. In the case of fly ash, the particle is often finer than the cement, this means that the small silica fume particles can perform better in particle packing since the intermediate particle space, slightly smaller than cement, is filled by the fly ash. The chemical binding of chlorides by fly ash due to its content of aluminium works together with the pore refinement due to silica fume to give excellent performance in a chloride environment. Due to low reaction rate, fly ash has often been used in HPC to reduce the heat of hydration and will also give good flow in fresh concrete. However, this gives a problem in fly ash concrete is the early age, what to do until the fly ash has hydrated sufficiently to have strength and to protect against aggressive. In a triple blend, the silica fume takes care of properties in the early age, while fly ash adds its contribution at later ages. Many reinforced concrete structures have suffered from premature chlorides induced corrosion damage and the specification of concrete to prevent this has proven to be difficult. Benefits, in terms of improved resistance to chloride ingress, through the use of additional materials in ternary blends, such as silica fume (SF) and fly ash (FA) are now well established.

Nassim and Suksawang (2003) in their very comprehensive study have a main conclusion: "Combining silica fume and fly ash enhances the durability and mechanical properties of HPC. In fact, it is highly recommended that a minimum of 5 percent silica fume beaded to fly ash concrete to improve its durability. Moreover, the ductility of concrete increases when comparing to ACI recommendation".

M.R. Jones, R.K. Dhir et al (2003), have shown resistance to chloride ingress and carbonation by concrete containing ternary blended binders.

3. MATERIALS USED

3.1 CEMENT:

Cement is one the major component in the manufacturing process of concrete. It has the property to stick to any other raw material added in the preparation process of concrete, especially when comes in contact with water and hence produces a good paste. Ordinary Portland cement 53 grade brand conforming to I.S.I standard is used in the present investigation.

3.2 FINE AGGREGATE

The locally available sand is used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for various properties like specific gravity, bulk density etc., in accordance with IS 2386-1963(28). Grain size distribution of sand shows that it is close to the zone 1 of IS 383-1970(29).

3.3 COARSE AGGREGATE:

Machine crushed angular granite metal from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is also tested for its various properties.

The specific gravity and fineness modulus of coarse aggregate are 2.64,7.14 respectively. The bulk density of coarse aggregate is 1700 kg/m^3.

3.4 ADMIXTURE

The super plasticizer used in this experiment is SP430. It is manufactured by FOSROC. Super plasticizers are new class of generic materials which when added to the concrete causes increase in the workability. They consists mainly of naphthalene or melamine sulphonates, usually condensed in the presence of formaldehyde.

3.5 FLY ASH

Fly ash, an artificial pozzolanna is the unburned residue resulting, from combustion of pulverized coal or lignite. It is collected by mechanical or electrostatic separators called hoppers from flue gasses of power plants where powdered coal is used as fuel. This material, once considered as a by-product finding difficulty to dispose off, has now become a material of considerable value when used in conjunction with concrete as an admixture.

3.6 SILICA FUME

Condensed Silica fume, also known as microsilica, is a dry amorphous powder which, when added with standard cements will increase the durability and strength of the concrete as well as reducing permeability and improving abrasion-erosion resistance. It may also be used in many applications where high strength is required.

The addition of silica fume produces concrete with reduced permeability resulting in increased water tightness enhanced chemical resistance and reduced corrosion of reinforcing steel.

3.7 STEEL FIBERS

The ultimate tensile strength of steel fibre range from 1200 MPa, whereas the length is 50 mm, the aspect ratio (length/diameter) is 50 and the young's modulus is 205 MPa.

Table 1: Concrete Mixes

MIX (CUBES)	MIX (BEAMS)	CEMENT (%)	CSF (%)	FLY ASH (%)
R1,1	A1,1	100	0	0
R1,2	A1,2	80	0	20
R1,3	A1,3	60	0	40
R2,1	A2,1	95	5	0
R2,2	A2,2	75	5	20
R2,3	A2,3	55	5	40
R3,1	A3,1	90	10	0
R3,2	A3,2	70	10	20
R3,3	A3,3	50	10	40
R4,1	A4,1	85	15	0
R4,2	A4,2	65	15	20
R4,3	A4,3	45	15	40
R5,1	A5,1	100	0	0
R5,2	A5,2	80	0	20
R5,3	A5,3	60	0	40
R6,1	A6,1	95	5	0
R6,2	A6,2	75	5	20
R6,3	A6,3	55	5	40
R7,1	A7,1	90	10	0
R7,2	A7,2	70	10	20
R7,3	A7,3	50	10	40
R8,1	A8,1	85	15	0
R8,2	A8,2	65	15	20
R8,3	A8,3	45	15	40
R9,1	A9,1	100	0	0
R9,2	A9,2	80	0	20
R9,3	A9,3	60	0	40
R10,1	A10,1	95	5	0
R10,2	A10,2	75	5	20
R10,3	A10,3	55	5	40
R11,1	A11,1	90	10	0
R11,2	A11,2	70	10	20
R11,3	A11,3	50	10	40
R12,1	A12,1	85	15	0
R12,2	A12,2	65	15	20
R12,3	A12,3	45	15	40
MIX (CUBES)	MIX (BEAMS)	CEMENT (%)	CSF (%)	FLY ASH (%)
R1,1	A1,1	100	0	0
R1,2	A1,2	80	0	20
R1,3	A1,3	60	0	40

4. RESULTS & DISCUSSIONS

4.1 Compressive strength of M80 grade concrete cubes with various percentages of Fly ash, Silica Fume & Fibre

Table 2: 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

Table 3: 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

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

Table 4: 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

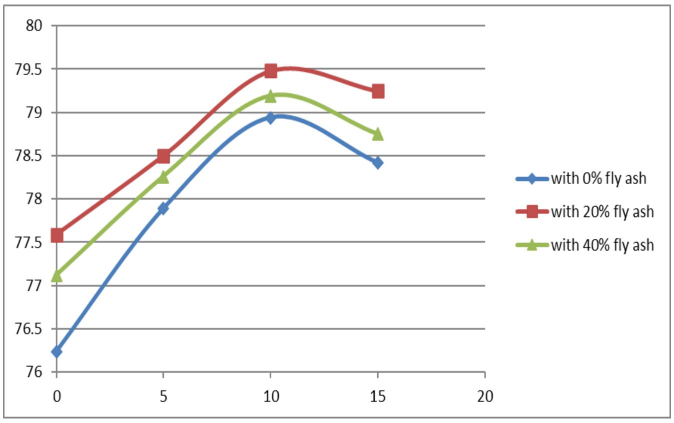

Chart -1: Variation of compressive strength with various percentages of Fly ash and Silica Fume with 0% fibre

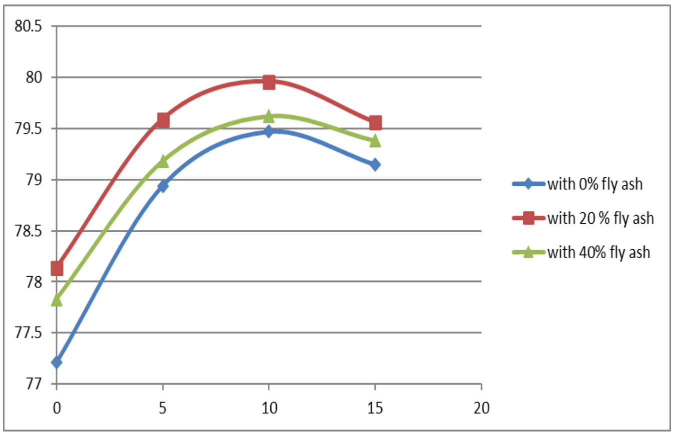

Chart -2: Variation of compressive strength with various percentages of Fly ash and Silica Fume with 0.5% fibre

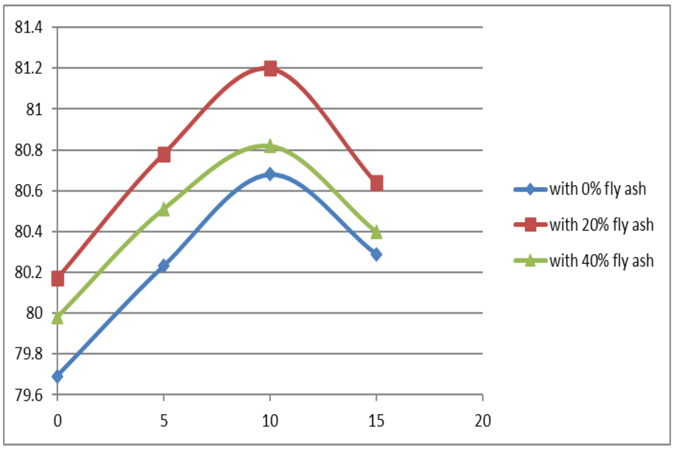

Chart -3: Variation of compressive strength with various percentages of Fly ash and Silica Fume with 1% fibre

4.2 Flexural strength of M80 grade concrete beams with various percentages of Fly ash, Silica Fume & Fibre:

Table 5: 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 FLEXURAL 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

Table 6: 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 FLEXURAL 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

Table 7: 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 FLEXURAL 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

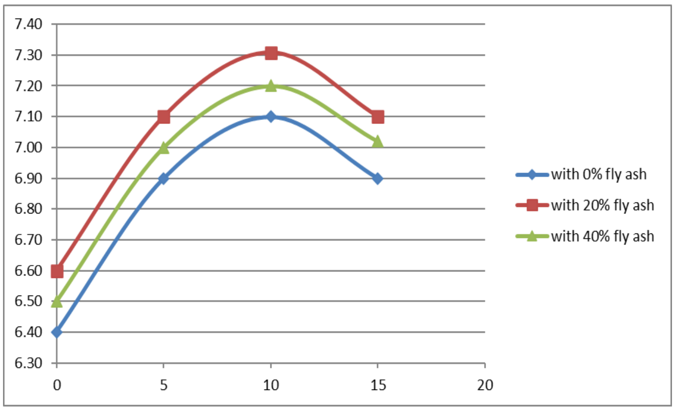

Chart -4: Variation of flexural strength with various percentages of Fly ash and Silica Fume with 0% fibre

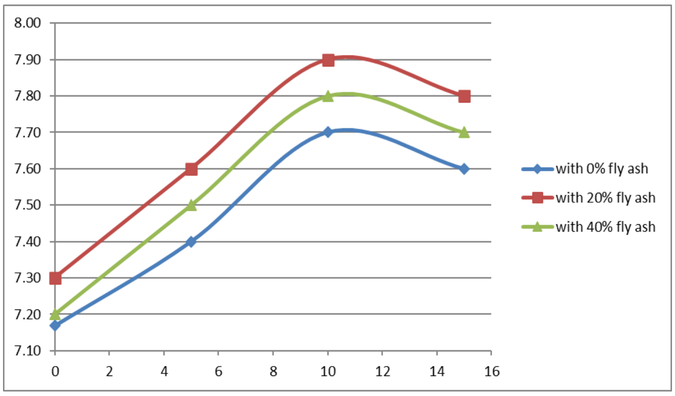

Chart -5: Variation of flexural strength with various percentages of Fly ash and Silica Fume with 0.5% fibre

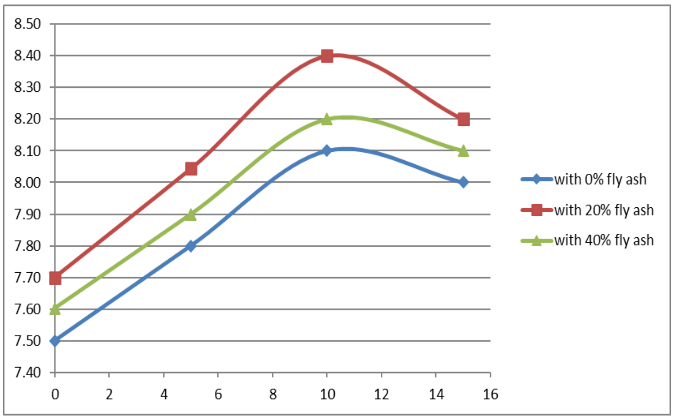

Chart -6: Variation of flexural strength with various percentages of Fly ash and Silica Fume with 1% fibre

Discussions:

Compressive strength results:
The compressive strength results (tables 2, 3, 4) 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.

Flexural strength results:
The flexural strength results (tables 5, 6, 7) 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.

5. CONCLUSIONS

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

1. Higher dosages of superplasticizer 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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