STUDY OF COMPRESSIVE AND FLEXURAL STRENGTH OF FIBROUS TRIPLE BLENDED HIGH STRENGTH CONCRETE WITH FLY ASH AND CONDENSED SILICA FUME

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Abstract

Concrete is the most widely used Civil Engineering material employed for the construction of various types of structures in the world. Continuous research has been carried out in the area of concrete technology to improve the quality of concrete and to make it suitable for different purposes. As a result, many forms of concrete like High strength concrete (HSC), High performance concrete (HPC), Fibre reinforced concrete (FRC), self-compacting concrete (SCC) have been developed. Mineral admixtures like flyash, condensed silica fume(CSF), ground granulated blast furnace slag (GGBS) etc are being tried as part replacement cement to impart additional properties and benefits. Metallic fibres like steel when mixed at certain percentages in concrete, generate higher strength particularly in tension and flexure besides preventing micro cracks .

In the present experimental investigations, triple- blending of ordinary portland cement (OPC) and two mineral admixtures, flyash and CSF are blended together to develop triple blended concrete mix. M80 design mix of concrete is taken as reference. The percentages of flyash and CSF are varied. Various percentages of steel fibres like 0, 0.5 and 1.0 are employed in various mixes. Thus, various combinations of triple blended fibrous concrete mixes of high strength are developed. Tests were conducted on samples of triple blended fibrous high strength concrete mixes for compression and flexure.

The results have indicated that triple blending has helped concrete in respect of using lesser cement, without sacrificing the strength. Fibres have helped to improve the tensile and flexural strengths of concrete in addition to preventing micro cracks and improving the ductility property. The triple blended fibrous high strength concrete has optimum properties in all the respects.

Keywords: Triple blending, flyash, silica fume, fibre reinforcement , high strength concrete.

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1. INTRODUCTION:

1.1. High Performance Concrete:

Increase in structural needs in the form of high rise buildings, ong 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.

1.2. Triple Blending:

Triple blended cement is characterised by part replacement of cement with mineral admixtures/additives such as fly ash, silica fume, granulated slag etc. 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.

1.3. Triple Blended High Strength Concrete:

The production of high strength concrete does require more research and more attention to quality control than conventional concrete. From the general principles behind design of high strength concrete mixtures, it is apparent that high strengths are made possible by reducing porosity, homogeneity and micro cracks in the hydrated cement paste and the transition zone. The target water/cement ratio should be in the range 0.30-0.35 or even lower. Superplasticisers/high range water reducers should be used to achieve maximum water reduction.

1.4. Fibre Reinforced Concrete:

The concerns with the inferior fracture toughness of concrete are mitigated to a large extent by reinforcing it with fibres of various materials. The resulting material with a random distribution of short, discontinuous fibres is termed fibre reinforced concrete (FRC). Increases in the length, diameter ratio (called the aspect ratio) of the fibres usually augment the flexural strength and the toughness of the concrete. The values of this ratio are generally not kept too high as fibres which are too long tend to “ball” in the mix and create workability problems. As a rule, fibres are generally randomly distributed in the concrete so that after processing the concrete, the fibres become aligned in the direction of the applied stress and will thus result in greater tensile and flexural strength. Fibre reinforced concrete is slowly becoming a well accepted mainstream construction material.

1.5. Mineral Admixtures:

These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it suitable for any situation. In developing countries like India, Pozzolonic materials are mainly available as industrial waste by-products, fly ash, silica fume; stone dust, blast furnace slag, rice husk ash etc., are some of the industrial wastes. Extensive research work has been carried on the use of pozzolonas in construction materials.

1.6. Objectives of the present Investigation:

The most important point to be noted in terms of significance of triple blended cements is that, cements to which supplementary cementitious materials in the form of mineral admixtures are added, have enhanced strength and durability parameters. This is the primary premise on the basis of which the concept of triple blending is considered to be the need of the our in civil engineering. This paper focuses on mineral admixtures used as a supplementary cementitious material in order to reduce Portland cement and how they enhance the properties of the corresponding concrete. The work revolves around the usage of triple blended high strength concrete in which the supplementary mineral admixtures used are that of fly ash and silica fume. In addition to these, concrete is mixed with steel fibres to enhance its flexural strength.

1.7. Brief Review of the Previous Work:

Balendran et al (1) studied the strength and durability performance of high performance concrete at elevated temperatures. The authors concluded that the inclusion of pozzolonas in concrete enhances the properties in both fresh and hardened states.
Brooks J Jeal (12) studied the effect of admixtures on the setting times of high strength concrete mixes. Silica fume combinations improve the workability, compressive strength, splitting tensile strength, elastic modulus of concrete.
Jon M Rouse et al (7) studies creep and shrinkage properties of high performance fibre reinforced concrete and concluded that the material exhibits pseudo strain hardening response.

2. EXPERIMENTAL INVESTIGATION:

2.1. Materials:

The following materials are employed in the present investigation.

2.1.1. Cement 53 grade:

Ordinary Portland cement of 53 grade from the local market was used and tested for physical and chemical properties as per IS: 4013-1988 and found to be confirming to various specifications of are 12269-1987.

2.1.2. Fine Aggregate:

In the present investigation, fine aggregate is natural river sand which was obtained from local market. The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS-2386.

2.1.3. Coarse Aggregate:

The crushed coarse aggregate of 10mm maximum size was obtained from the local crushing point. The physical properties of coarse aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS-2386.

2.1.4. Fly ash:

In the present investigation work, the TYPE-II fly ash was used as cement replacement material. It is obtained from Vijayawada thermal power station in Andhra Pradesh. The specific surface of fly ash is found to be 4750 cm^2/gm by Blaine’s permeability apparatus.

2.1.5. Condensed Silica Fume (CSF):

Condensed silica fume was obtained from M/s. V.B. Ferro Alloys Ltd., Rudraram near Hyderabad.

2.1.6. Superplasticizer:

Superplasticizer (B233 of M/s. BASF INDIA LTD) was employed for the preparations of SCC.

2.1.7. Viscosity Modifying Agent (VMA):

The inclusion of VMA ensured the homogeneity and the reduction of the tendency of the highly fluid mix to segregate. Glenium-2 VMA of M/s. BASF India Ltd., is used for this work.

2.1.8. Steel Fibres:

It has been shown that design recommendations for traditional vibrated steel fibre reinforced concrete (SFRC) can also be used for steel fibre reinforced self compacting concrete (SFRSCC).

2.1.9. Polypropylene Fibres:

Addition of polypropylene fibres to concrete arrests cracking caused by volume change (expansion and contraction).

2.1.10. Water:

Potable water which is fit for drinking is used for making concrete.

2.2. Concrete Mix Design (M80):

High strength concrete mix of M80 grade was designed according to the D.O.E. method ( ). The mix proportions are given in table.1. The quantities of materials required for one cubic meter of concrete are shown in table.2.

Table 1. M80 Concrete Mix Proportions

Cement	Fine Aggregate	Coarse Aggregate	Water/Cement
1.0	0.95	1.55	0.31

Table 2. Quantities of Materials required for 1 c.m of Concrete

Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water/ Cement Ratio (Lit.)
629.03	598.86	977.28	195.00

2.3. Mix Combinations:

In the designed M80 mix, replacement of OPC was made fly ash (0 to 40%) and CSF (0 to 15%). Steel fibre percentages were varied from 0 to 1.0% by volume. In all 36 combinations of mixes with various percentages of fly ash, CSF and steel fibre were tried including the reference mix (table.3).

2.4. Workability Test:

The workability as measured by the compacting factor apparatus was found to be almost nearer to medium value. But as the proportions of mineral admixtures as well as the percentage of steel fibre were increased the workability was becoming low. To improve the workability for the use of placing and casting, certain varying dosages of superplasticizer were added. The dosage was kept to be less than 1%.

2.5. Mixing, Casting, Curing and Testing:

All the ingredients including the admixtures were weighed and mixed using a pan mixer. standard cube and beam moulds of required number were cast for each combinations. After 24 hrs. demoulding was carried out and the specimens were transferred to the curing tank for testing at the age of 28 days. All the operations were carried out as per the standard specifications.
Compression test was carried out on the cube specimens and flexure test on the beam specimens. Standard equipment was used and standard procedures were followed for testing. The average values of the respective strengths are tabulated in table.3.

3. DISCUSSION OF THE RESULTS:

After carrying out the present experimental investigation on the strength properties of triple blended steel fibres reinforced mixes, the results are shown by means of graphs and tables.

3.1. Workability of M80 Concrete Mix:

In the present experimental investigation high strength concrete mix M80 is considered. The mix is designed by the D.O.E. method and for the basic reference mix, the cement content 629.03 kg/m3. The water to cement ratio is 0.31. When mixed a stiff and a relatively dry mix was obtained. The compacting factor was found to be 0.7 which indicates a lower workability. Hence, a superplasticizer SP430 COMPLAST was added 1% by weight of cement. This gave a workability of 0.82. Though workability is on the lower side the experiment was continued even by adding more dosages of superplasticizer to maintain medium or slightly less than medium workability.

3.2. Compressive Strength Results:

The compressive strength results (tables 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.

3.2.1. Influence of Silica Fume on the Mix:

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.

3.2.2. Influence of Fly Ash on the Mix:

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

3.2.3. Influence of Steel Fibres on Mix:

In present investigation steel fibres was employed at percentages of 0%, 0.5%, 1%. 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. 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. In addition, steel fibres contribute towards impact strength and shock absorption and other advantages.

3.3. Flexural Strength Results:

The flexural strength results are given for 3 fibre percentages and various percentages of silica fume and flyash 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.

3.3.1. Influence of Silica Fume on the Mix:

Highest flexural strength was obtained at 10% CSF with 20% Fly ash and 1% fibre. This value is 8.4 MPa. 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. For this combination of 10% silica fume with 20% fly ash the flexural strength has shown an increase from 15 to 31.5% with various percentages of fibre.

3.3.2. Influence of Fly Ash on the Mix:

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

3.3.3. Influence of Steel Fibres on Mix:

In present investigation steel fibres was employed at percentages of 0%, 0.5%, 1%. 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. 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. In addition, steel fibres contribute towards impact strength and shock absorption and other advantages.

3.4. Need for Triple Blending:

In the present experimental investigation, triple blending of ordinary Portland cement was carried out so as to arrive at a mix with optimum properties. On the overall, strength loss with the higher percentages of fly ash is compensated by silica fume.

3.5. Employing Steel Fibres in the Triple Blended SFRC:

The presence of steel fibres contributes towards marginal increase in compressive strength and higher increase in flexural strength and tensile strength. 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.

4. CONCLUSIONS:

Higher dosages of superplasticizer are required for high strength concrete mixes particularly when mineral admixtures and fibres were employed to maintain workability.
For the 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.
As the percentage of steel fibre is increased there is marginal increase in the compressive strength for all the combinations.
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 percentage of fibre.
As the percentage of steel fibre is increased there is higher increase in the flexural strength for all the combinations.
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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Table.3. Average Compressive Strength and Average Flexural Strength in N/mm^2 for all the combinations

Beam	Fibre %	CSF %	Fly Ash %	Cement %	Average Compressive Strength (mPa)	Average Flexural Strength (mPa)
A1,1	0	0	0	100	76.24	6.40
A1, 2	0	0	20	80	77.59	6.60
A1, 3	0	0	40	60	77.12	6.50
A2, 1	0	5	0	95	77.89	6.90
A2, 2	0	5	20	75	78.50	7.10
A2, 3	0	5	40	55	78.26	7.00
A3, 1	0	10	0	90	78.94	7.10
A3, 2	0	10	20	70	79.48	7.31
A3, 3	0	10	40	50	79.19	7.20
A4, 1	0	15	0	85	78.42	6.90
A4, 2	0	15	20	65	79.25	7.10

A4, 3		15	40	45	78.75	7.02
A5, 1	0.5	0	0	100	77.21	7.17
A5, 2		0	20	80	78.14	7.30
A5, 3		0	40	60	77.83	7.20
A6, 1	0.5	5	0	95	78.94	7.40
A6, 2		5	20	75	79.59	7.60
A6, 3		5	40	55	79.18	7.50
A7, 1	0.5	10	0	90	79.47	7.70
A7, 2		10	20	70	79.96	7.90
A7, 3		10	40	50	79.62	7.80
A8, 1	0.5	15	0	85	79.15	7.60
A8, 2		15	20	65	79.56	7.80
A8, 3		15	40	45	79.38	7.70
A9, 1	1	0	0	100	79.69	7.50
A9, 2		0	20	80	80.17	7.70
A9, 3		0	40	60	79.98	7.60
A10, 1	1	5	0	95	80.23	7.80
A10, 2		5	20	75	80.78	8.04
A10, 3		5	40	55	80.51	7.90
A11, 1	1	10	0	90	80.68	8.10
A11, 2		10	20	70	81.20	8.40
A11, 3		10	40	50	80.82	8.20
A12, 1	1	15	0	85	80.29	8.00
A12, 2		15	20	65	80.64	8.20
A12, 3		15	40	45	80.40	8.10

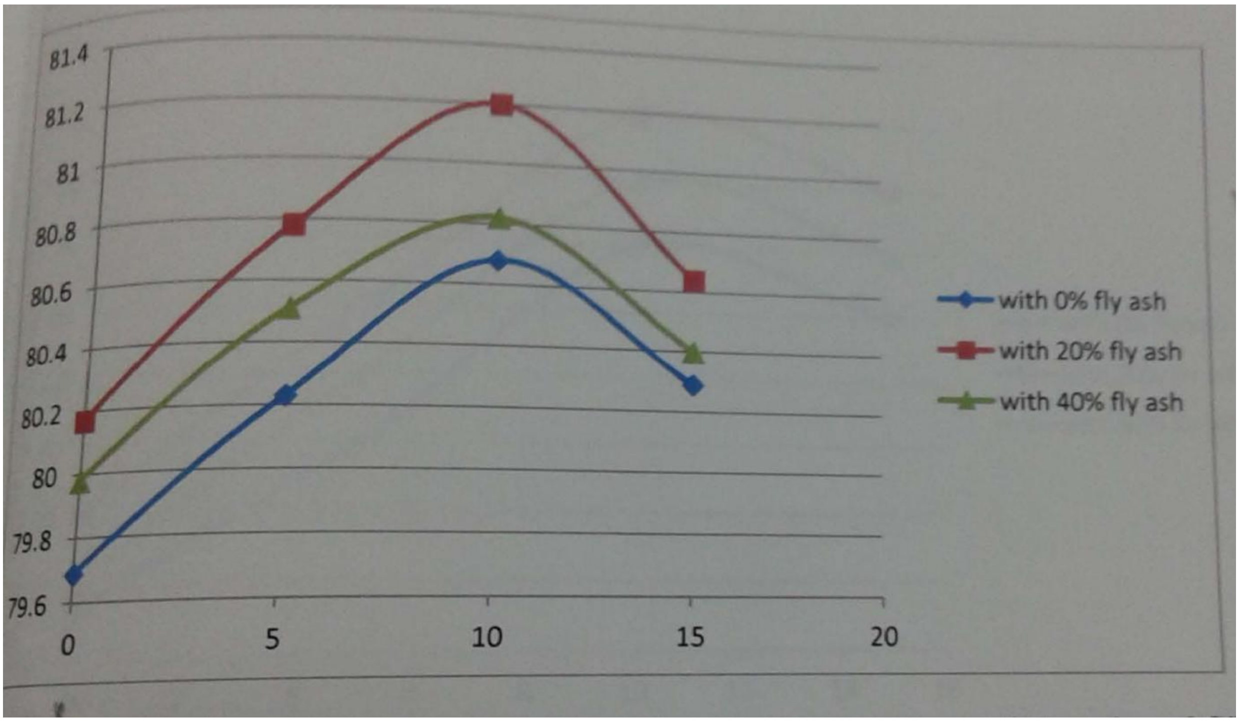

Fig.1. Variation of Compressive Strength with Various Percentages of Fly ash and Silica Fume with 1% Fibre

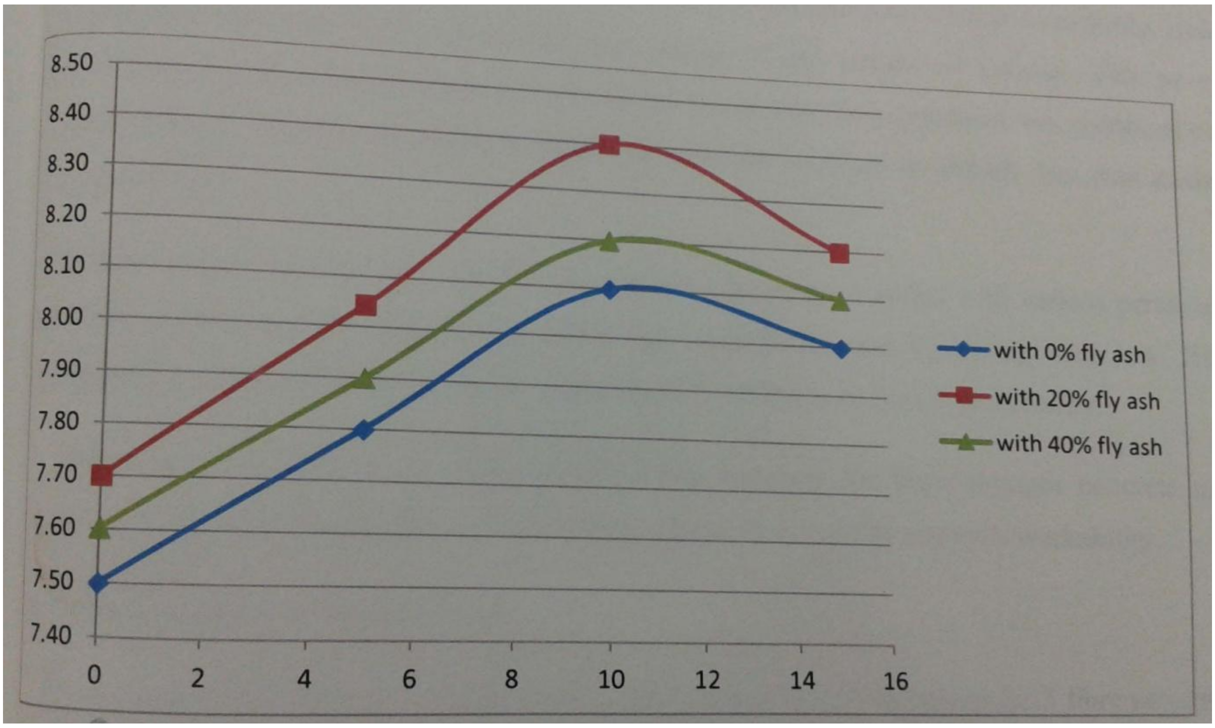

Fig.2. Variation of Flexural Strength with Various Percentages of Fly ash and Silica Fume with 1% Fibre