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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 :-Change has been a constant parameter within the concrete industry in view of increasing construction activities and most importantly an increased thrust in high quality yet economic structures. This change has thus, brought along with it, different trends in concrete technology with respect to the way in which it is perceived and more technically, its composition, its handling, mixing etc. . As a result, we have today, different types of concretes such as triple blended concrete, self-compacted concrete, bacterial concrete etc. which have, in their own respective manner, succeeded in enhancing the serviceability of the structure with which they are built, in comparison to ordinary concrete. In this report, we focus and emphasize on Triple Blended Concrete, its meaning, materials involved, process of casting, testing, salient features et al.

I. 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 m^3 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, 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 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.

1.1 What is Triple Blended Concrete?

Triple blended concretes belong to that strata of concretes where the strength and durability characteristics are maximized to the highest extent possible, in comparison to various other types of concretes, by subtle tailoring of its chemical composition, fineness and particle size distribution. Greater varieties are introduced by the incorporation of additives like pozzolana, granulated slag or inert fillers. These lead to different 'specification' of cements in national and international standards.

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.

1.2 Triple Blended High strength concrete

At the commencement of a concrete construction, the anticipated exposure conditions generally decide the type of cement. Requirements of load-carrying capacity are met by the structural design of the members, which decide the required strength grade of concrete and strength class of cement. From logistic and management considerations, it helps if one cement can meet the diverse performance demands. Thus, in order to meet all these requirements, incorporation of high strength concrete into a new yet effective concept of triple blended concretes is considered a needful solution. The objective of doing so is to optimize the thrust in strength and durability parameters achieved by both triple blended cements as well as high strength concrete to obtain what is known as triple blended high strength concrete. But beforeproceeding further, let us understand thoroughly, what is high strength concrete?

Although there is no precise point of separation between high strength concrete and normal strength concrete, the American Concrete Institute defines high strength concrete as a type of concrete generally with a specified compressive strength of 6000psi (41 MPa) or greater. It may also be defined as concrete with a specified characteristic cube strength between 60 and 100 N/mm^2, although higher strengths have been achieved and used. Strength levels of 80 to 100 N/mm2 and even higher are being used. The methods and technology for producing high strength concrete are not substantially different from those required for normal strength concrete although 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, inhomogeneity 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. Super-plasticisers / high range water reducers should be used to achieve maximum water reduction.

The utilisation of fine pozzolanic materials in high strength concrete leads to a reduction of the size of the crystalline compounds, particularly, calcium hydroxide. Consequently, there is a reduction of the thickness of the interfacial zone allowing for efficient load transfer between the cement mortar and the coarse aggregate, contributing to the strength of the concrete.

We generally use high strength concretes in the following circumstances:

- To put concrete into service at a much earlier age, for example opening the pavement at 3 days
- To build high rise buildings by reducing column sizes and increasing available space
- To build superstructures of long span bridges and to enhance the durability of the bridge decks
- To satisfy the specific needs of special applications such as durability, modulus of elasticity and flexural strength. Some of these applications include dams, grandstand roofs, marine foundations, parking garages and heavy duty industrial floors.

It must be noted that the terms "High performance concrete" and "High strength concrete" are often taken to mean the same thing. However, as indicated, "High performance" strictly relates to a concrete that has been designed to have good specific characteristics, such as high resistance to chloride ingress or high abrasion resistance. As a result it may also have a high strength, but this is not the main consideration.

Thus, combination of the two concepts of triple blended concrete and that of high strength concrete by the application of mineral admixtures such as silica fume and fly ash in concrete is an easy and effective way of enhancing the strength and durability parameters of the concrete in a large magnitude.

1.3 Fibre reinforced Concrete

Concrete has become so popular and indispensable, as aforementioned, due to its inherent characteristics and advantages. The use of reinforcement in concrete brought a revolution in the application of concrete. However generally, despite this, compared to other building materials such as metals and polymers, concrete is significantly more brittle and exhibits a poor tensile strength. Based on fracture toughness values, steel, in the form of reinforcement, is at least 100 times more resistant to crack growth than concrete. Concrete in service thus cracks easily, and this cracking creates easy access routes for deleterious agents resulting in early saturation, freeze-thaw damage, scaling, discoloration and steel corrosion.

The concerns with the inferior fracture toughness of concrete are mitiagated 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). When the loads imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly, fibres in concrete provide a means of arresting the crack growth. Reinforcing steel bars in concrete have the same beneficial effect because they act as long continuous fibres. Short discontinuous fibres have the advantage, however, of being uniform.If the modulus of elasticity of the fibre is high with respect to the modulus of elasticity of concrete or the mortar binder, then the fibres help to carry the load, thereby increasing the strength of the material.

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. Significant progress has been made in the last thirty years towards understanding the short and long-term performances of fibre reinforced cementitious materials, and this has resulted in a number of novel and innovative applications.

1.4 Pozzolanic admixtures in concrete

Admixture is defined as a material, other than cement, water and aggregates , that is used as an ingredient of concrete and is added to the batch immediately before or during mixing.

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.

As per the report of the ACI committee 212, admixtures have been classified into 15 groups according to type of materials constituting the admixtures, or characteristic effect of the use.

- Plasticizers
- Super plasticizers
- Retarders and retarding Plasticizers
- Acceleration and Accelerating plasticizers
- Air-entraining admixtures
- Pozzolanic or Mineral Admixtures
- Damp-Proofing and Waterproofing Admixtures

- Gas forming Admixtures
- Air detraining Admixtures
- Alkali-Aggregate Expansion Inhibition Admixtures
- Workability Admixtures
- Grouting Admixtures
- Corrosion Inhibition
- Bonding Admixture
- Color Admixture

Pozzolanas are either naturally occurring or available as waste materials. They mainly contain silica, which becomes reactive in the presence of free lime available in cement when pozzolanic admixtures are mixed with cement. The reactivity varies depending upon the type of pozzolana, its chemical composition and its fineness. In developing countries like India, pozzolanic 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 pozzolanas in construction materials. Out of the above pozzolana admixtures, fly ash can be considered as the one, which is abundantly available. Fly ash concrete possesses certain desirable and enhanced properties compared to ordinary plain concrete. Other pozzolanic admixtures will be discussed in depth in the subsequent sections.

1.5 Significance of triple blended concrete

Although concrete has been serving human beings to provide amenities, the service comes with a significant price. Regarding the immense amount of concrete production annually, it has considerable impacts on the environment. Consumption of vast amount of natural resources, release of almost one tonne of CO_2 into the atmosphere from the production of each tonne of Portland Cement are two major environmental issues. Worldwide, the cement industry alone is estimated to be responsible for about 7% of all CO_2 generated. Moreover, regardless of water supply shortages in most parts of the world, the production of concrete requires large amounts of water. Finally, the demolition and need of disposal of concrete structures, pavements etc., creates another environmental burden. Construction and demolition debris produces a considerable fraction of solid waste in developed countries.

What is listed above indicates that concrete has become the victim of its own achievements but for sure it is still one of the most practical building materials in the world. The challenges that this industry is facing are more of a result of Portland cement production. So, the most effective remedy to solve the problem is to use less Portland cement which means to replace as much Portland cement as possible by supplementary cementitious materials in place of natural resources. Different efforts have been made to reduce the drawbacks of concrete on environment such as aggregates and binders. Furthermore, the partial replacement of Portland Cement with mineral admixtures proves itself to be an economical and cost-effective proposition. This is because, the cost of these admixtures, obtained as industrial bi-products, is much lesser than that of cement. And hence, the cost of any triple blended concrete mix is substantially lesser than that of its corresponding ordinary concrete. It is believed that the adverse effects of cement, CO_2 emission, may be minimized if mineral admixtures are applied; as they reduce cement consumption, energy and cost. In eco cement, large amounts of Portland cement clinker (up to 70%) are replaced by available mineral additives such as natural pozzolanic materials, sand, limestone, granulated blast furnace slag, fly ash, silica fume, glass cullet and ceramic wastes. A case study reveals that a reduction of up to 67% of the energy requirements and 80% in the cementing of pozzolanas added, energy requirements may drop by 33% and cost by 20%.

Additionally, 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 hour 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. Our project 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, we are also mixing concrete with steel fibres to enhance its flexural strength parameter. Description of the materials involved is dealt with in subsequent chapters.

1.6 Objective

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. The description and specifications of the tests and the apparatus have been dealt with in subsequent chapters.

II: LITERATURE REVIEW

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

2.1 NOTABLE PREVIOUS RESEARCH

A number of reports have demonstrated that concretes containing combinations of fly ash and silica fume with Portland cement are superior in certain respects to concretes containing Portland cement only. Studies at the Virginia Transportation Research Council have also demonstrated that silica fume added in relatively small amounts to fly ash concrete significantly improves early resistance of the concrete to penetration by chloride ions when tested in accordance with ASTM C1202.4, 5 The type and source of the cement, characteristics and amounts of fly ash, and silica fume affected the results.

2.1.1 Triple Blended Concrete

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 H_2SO_4 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 OnderK□ rca(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. Particlepacking is one reason. In the case of fly ash, the particle is often finer thanthe cement, this means that the small silica fume particles can perform better in particle packing since the intermediate particlespace, 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.

Lynsdale and Khan studied chloride and oxygen permeability of Triple blends. Their main conclusion is the ternary blends enabled negligible chloride transport even at early ages, both fly ash and silica fume contributing. At low w/c ratio with 10% silica fume, 15-20% fly ash gave the lowest chloride transport of the tests. Studies at the Virginia Transportation Research Council (VTRC) by **D.S. Lane and C. Ozyildirim(1994)**have also demonstrated that silica fume added in relatively small amounts to fly ash concrete significantly improves early resistance of the concrete to penetration by chloride ions and also.

Medhat H. Shehata and Michael D.A. Thomas (2001) have shown use of triple blend (silica fume and fly ash) to suppress expansion due to alkali–silica reaction (ASR) in concrete.They concluded that Practical levels of silica fume and fly ash introduced into high-alkali Portland cement (HAPC) systems were found to be effective in reducing the expansion due to ASR to levels < 0.04% after 3 years.

So as summarily triple blend of silica fume and fly ash can be use for the following purposes.

- To conserve cement
- To produce high strength concrete
- To control alkali-silica reaction
- To reduce chloride associated corrosion and Sulphate attack
- To increase modulus of elasticity

2.1.2 Fibrous-reinforced 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.

When fibre reinforced concrete is used instead of plain concrete, the capacity of the sections to undergo rotation is increased considerably due to the improved ductility of the concrete. At lower percentage and short length of fibre, it is observed that the capacity to undergo rotation is more than two times to that of plain concrete.

The low fatigue strength of plain concrete is mainly due to the presence of micro cracks at stresses much less than the ultimate stresses and their rapid propagation under repetitive loads. Because of the main characteristics of resistance to crack propagation by the closely spaced fibres in the fibre reinforced concrete, the fatigue strength is very much improved.

Significant studies have been carried out on the structural components with fibre reinforced concrete regarding the deflections and cracking which are the two important factors that decide the serviceability of a structural element.

Ghosh, Bhattacharya and **Chakraborty** studied the most important parameters like tensile strength flexural strength of steel fibre reinforced concrete b(SFRC) which dictate the behaviour. It also looks into the probable effect of fibres on the compressive behaviour of SFRC considering the possibility of fibre buckling in the matrix.

Benson, Nicolaides and **Karihaloo** deals with the assessment of the distribution of fibres in a class of high performance short steel fibre-reinforced cementitious composites. The effect of mixing procedure and of the shape of the object cast on the distribution of the fibres is assessed using both a non-destructive and a destructive technique.

Several theories have been formulated to predict the strength of the fibre-reinforced concrete on assumed stress-strain relationship for fibres and matrix, fibre spacing and orientation, critical fibre volume, aspect ratio and interfacial bond between the fibres and the matrix. Among these, the most important factors which influence the ultimate load are the volume percentage of fibres and their aspect ratios. The design of concrete structural members is primarily governed by consideration of deflections and local damage. Since the presence of fibres enhance directly the resistance to cracking and deformation, the use of fibre concrete in conventionally reinforced structural members should not only prove beneficial to the overall behaviour of the members but lead to better usage of the conctituent materials.

The fibre reinforcement may be used in the form of three dimensionally randomly distributed fibres throughout the structural members when the advantages of the fibre to shear resistance and crack control can be further utilised.

2.2 CURRENT USE IN CONCRETE TECHNOLOGY

Triple blends have characterized several major projects done with micro silica and fly ash, such as:

1. Great Belt, Denmark
2. Øresund, Denmark/Sweden
3. Confederation Bridge, Canada
4. Tsing Ma, Hong Kong
5. BandraWorli in Mumbai

As an example, these are performance data from pile-caps in the BandraWorli project Concrete specification in (Kg/m^3)

BandraWorli in Mumbai:

- Cement (53 Grade) -300
- Micro silica - 40
- Fly ash - 196
- Coarse aggregate 20mm - 577
- Coarse aggregate 10mm - 500
- Natural Sand - 423
- Crushed Sand - 327
- Free water (liters) - 134
- Water Binder ratio - 0.25
- Admixture (liters) - 13.4
- Chloride Ion penetration- ASTM C 1202: 600 Coulombs
- Water Permeability (DIN 1048): Nil
- Maximum temperature at the core: 68^o C.
- Max. Temperature difference < 20^o C

2.3 CASE STUDY

A case study was carried at the University of Melbourne by T.N.Ngo ,P.A.Mendis, D.Teo and G.kusuma to assess the performance of a ground floor RC column of a typical office building under a bomb blast. It was found that HSC columns perform better than NSC columns(with the same axial load capacity) when subject to extreme impulsive loading.

A ground floor column (6.4 meters high) of multi-storey building (modified form of a typical building designed in Australia) was analyzed in the case study. The parameters considered were the concrete strength (40MPa for NSC column and 80MPa for HSC column) and spacing of ligatures (400 mm for ordinary detailing-OMRF and 100 mm for special seismic detailing-SMRF). It has been found that with increasing concrete compressive strength, the column size can be effectively reduced. In this case the column size was reduced from 500 x 900 for the NSC column down to 350 x750 for HSC column while axial load capacities of the two columns are still the same. The blast load was calculated based on data from the Oklahoma bombing report (ASCE 1996) with a standoff distance of 11.2m.The simplified triangle shape of the blast load profile was used. The duration of the positive phase of the blast is 1.3 milliseconds.

It can be seen that under this close range bomb blast both columns failed in shear. However, the 80MPa columns with reduced cross section have a higher lateral deflection, which shows a better energy absorption capacity compared to that of 40MPa columns.

Results from the study show that shear failure was the dominant mode of failures for close range explosion.HSC columns were shown to perform better than NSC columns (with the same axial load capacity) when subjected to extreme impulsive loading; they also had higher energy absorption capacity.

On the basis of the literature reviewed with respect to "EFFECT OF TRIPLE BLENDS WITH FIBRE ON THE PROPERTOES OF CONCRETE" the experiments were carried out, which is reflected in the succeeding chapter 3.

III: EXPERIMENTAL INVESTIGATIONS

3.1 GENERAL

An experimental study is conducted to find out the compressive strength and flexural strength of concrete at 28days.In concrete the partial replacement of cement by Fly ash and Silica fume are varied from (0+5)%,(20+5)%,(40+5)%,(0+10)%,(20+10)%,(40+10)%,(0+15)%,(20+15)%,(40+15)%, by weight.

M80 grade of concrete is designed according to DOE method.

The effect of partial replacement of cement by Fly ash and Silica fume (% by weight) on strength and workability of concrete are investigated.

3.2 MATERIALS

3.2.1CEMENT:

Ordinary Portland cement 53 grade brand conforming to I.S.I standard is used in the present investigation.

Test on Cement:

Following are the tests to be conducted to judge the quality of cement.

1. FINENESS
2. SOUNDNESS
3. CONSISTENCY
4. INITIAL AND FINAL SETTING TIME

The cement is tested for the aforementioned properties as per IS code. The results on cement are shown in table 3.1

Table 3.1
PHYSICAL PROPERTIES OF PORTLAND CEMENT 53 GRADE

S .No	PROPERTY	TEST RESULTS
1.	Normal consistency	28.66%
2.	Specific gravity	2.99
3.	Initial setting time Final setting time	30 min 160 min
4.	Soundness (expansion) lechatlier Method	2 min
5.	Fineness of cement	3050
6.	Compressive strength of cement mortar cubes a) 7 days b) 28 days	 33 N/mm² 52 N/mm²

3.2.2 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). The properties of sand are shown in table 3.4. Details of sieve analysis are shown in table 3.5. Grading curve is shown in fig.1.

Table- 3.2
PROPERTIES OF FINE AGGREGATE

S.No	Property	Fine Aggregate
1.	Specific gravity	2.68
2.	Density	1640 kg/m³
3.	Fineness Modulus	2.78

Table- 3.3
SIEVE ANALYSIS FOR FINE AGGREGATE SAMPLE- 2000gms

S.No	I.S.Sieve Size	Weight Retained	Percentage Weight Retained	Cumulative Percentage Weight Retained	Percentage of passing
1.	80mm	-	-	-	-
2.	40mm	-	-	-	-

3.	20mm	-	-	-	-
4.	10mm	-	-	-	-
5.	4.75mm	30.30	1.50	1.50	98.50
6.	2.36mm	40.00	2.00	3.50	96.50
7.	1.18mm	324.20	16.21	19.71	80.29
8.	600µ	822.00	41.10	60.81	39.19
9.	300 µ	664.00	33.20	94.01	5.99
10.	150 µ	106.00	5.30	99.31	0.69
	Total	2000		278.04	

Fineness modulus =2.78

3.2.3COARSE 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/m³. The details are tabulated in table 3.6. Sieve analysis is carried out ant grading results are shown in table 3.7.

Table- 3.4
PROPERTIES OF COARSE AGGREGATE

S.No	Property	Coarse Aggregate
1.	Specific Gravity	2.64
2.	Density	1700kg/m³
3.	Fineness Modulus	7.14

Table- 3.5
SIEVE ANALYSIS FOR COARSE AGGREGATE SAMPLE- 5000 gms

S.No	I.S.Sieve Size	Weight Retained	Percentage Weight Retained	Cumulative Percentage Weight Retained	Percentage of passing
1.	80mm	-	-	-	-
2.	40mm	-	-	-	-
3.	20mm	960	19.20	19.20	80.8
4.	10mm	3740	74.80	94.00	6.0
5.	4.75mm	300	6.00	100.00	-
6.	2.36mm	-	-	100.00	-
7.	1.18mm	-	-	100.00	-
8.	600µ	-	-	100.00	-
9.	300 µ	-	-	100.00	-
10.	150 µ	-	-	100.00	-
	Total	50000.0			

Fineness modulus =7.14

3.2.4 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.

3.2.4.1 Classification of Fly Ash

ASTM-C 618-93categories natural pozzolannas into the following categories.

Class N fly ash: Raw or calcined natural pozzolannas such as some diatomaceous earths, opalinechert and shale, stuffs volcanic ashes and pumice comes in this category. Calcinedkaoline clay and laterite shale also fall in this category of pozzollanas.

Class F fly ash: Fly ash normally produced from burning anthrdoete or bituminous coal falls in this category. This class of fly ash exhibits pozzolanic property but rarely if any, self-hardening property.

Class C fly ash: Fly ash normally produced from lignite or sub-bituminous coal is the only material included in this category. This class of fly ash has both pozzolanic and varying degree of self cementitious properties.

Table 3.6 Chemical and Physical requirement of Fly ash

Requirements	Mineral Admixture Class A	F	C
ChemicalRequirements			
SiO_2+Al_2O_3+Fe_2O_3 min %	70.0	70.0	70
SO_3 .max %	4.0	5.0	5.0
Moisture content. Max %	3.0	3.0	3.0
Loss on Ignition. Max%	10.0	6.0	6.0
Physical requirements			
Amount retained when wet sieved on 45µm sieve. Max %	34	34	34
Pozzolanic activity index with Portland Cement at 28 days min % of control	75	75	75
Pozzolanic activity index with lime at 7days min (Mpa)	5.5	5.5	--
Water requirement max % of control	115	105	105
Autoclave expansion or contraction max %	0.8	0.8	0.8
Specific gravity max variation from average%	5	5	5
Percent retained on 45µm sieve max variation Percentage points from average	5	5	5

Fig1: Class C (left) and Class F (right) Fly Ash

In this project the fly ash used belongs to **class F** and was brought from VIZAG THERMAL POWER STATION, VIJAYAWADA.

3.2.4.2Composition of Fly Ash

The temperature in a pulverised fuel boiler would be around 1400°C and the fuel gas velocity is such that to remove the ash particlesrapidly out of the boile. Due to this reaction with Ca $(OH)_2$ we obtain the pozzolanic activity of fly ash.

Traditionally, the composition of fly ash is expressed in terms of oxide composition, through the constituents are not strictly present in the form of oxides. The typical composition of Indian fly ash is shown in table.

Table 3.7 Typical composition of Fly ash and Cement

Constituents	**Indian Fly ash**	**Cement**
SiO_2	49-67	17-25
Al_2O_3	16-33	3-8
Fe_2O_3	4-10	0.2-6
CaO	1-4	60-65
MgO	0.2-2.0	0.5-4
SO_3	0.1-2.0	1-2
Na_2O	0.1-0.2	0.5
K_2O	0.1-1.0	0.5
LOI	0.1-1.6	1-3

3.2.4.3Properties of Fly Ash

Physical Properties

Particle Morphology

As per morphological studies, fly ash particles usually consists of clear glassy spheres and spongy aggregate ranging in diameter from 1 to 150µm, the majority being less than 45µm as seen under-energy dispersive X-ray analysis.

Fineness

Fineness is one of the primary characteristics of fly ash that relates to its pozzolanic activity. A large fraction of ash particle is smaller than 3 µm in size. In bituminous ashes, the particle sizes range from less than 1 to over 100 µm. The average size lies between 7 to 12 µm.

Specific gravity

The specific gravity of fly ash is related to shape as well as chemical composition of particles. Specific gravity of fly ash usually varies from 1.3 to 4.8. Coal particles with some mineral impurities have specific gravity between 1.3 to 1.6. Opaque spherical magnetite and hematite particles, light brown to black in colour, when present in sufficient quantity in fly ash increases the specific gravity to about 3.6 to 4.8.

Chemical Properties

Table 3.3 Chemical Requirements

S.No	Characteristic	Requirement
(i)	Silicon dioxide plus aluminium oxide plus iron oxide percent by mass Min	70.00
(ii)	Silicon dioxide percent by mass Min	35.00
(iii)	Magnesium oxide percent by mass Max	5.00
(iv)	Total sulphur as sulphur trioxide percent by mass Max	2.75
(v)	Available alkalis as sodium oxide percent by mass Max	3.00

Mineralogical Characteristics

It forms from ***Anhydrite ($CaSo_4$)***reaction of CaO, SO_2 and O_2 in the furnace or fuel. The amount of anhydrite increases with the increasing SO_3ansCaO contents in the ash. Anhydrite is a characteristics phase in high calcium class C Fly ashes. For most ashes, only about half of the SO_3 is present as anhydrite.

Periclase (MgO)

Periclase refers to the crystalline form of magnesium oxide (MgO). It is always present in high calcium ash and commonly found in intermediate calcium ash. For most of the Flyash, only about half of the MgO is present as periclase.

Magnetite and Hematite

There is atleast a small amount from 0.1 to 1% of iron present as hematite in almost all types of Fly ashes. High calcium class C Fly ashes have however less amount of hematite as well as total Fe_2O_3.

Tri calcium Aluminate (3 CaO, Al_2O_3)

High calcium class C Fly ash invariably contain tri-calcium aluminate with its relative content increasing with an increase of CaO content of the ash. Sometimes intermediate calcium ashes with CaO content of 8 to 15% have also been found to contain this compound.

3.2.4.4Reaction Mechanism of Fly Ash

Reaction mechanism for Fly ash can be basically explained as pozzolanic reaction mechanism Fly ash is considered to be a Pozzolanna. Pozzolannas are materials which, though not cementitious in themselves, contain certain constituents, which at ordinary temperatures in the presence of water, will combine with lime to form stable insoluble compounds with cementitious properties behaves as a more or less inert material and serves as a precipitation nucleus for lime {$Ca(OH)_2$} and calcium-silicate hydrate-gel originating from the cement hydration. The subsequent pozzolanic reaction appears to be a slow process.

Fly ash from bituminous coal consists of a major part of glass phase with crystallization inclusions, the glass being an alumina-silica-glass. The pozzolanic reaction starts when the glass of the Fly ash particles dissolves. The formation of C-S-H gel takes place when the glass of the Fly ash particles has gone into solution. The decomposition of the glass network appears to be strongly dependent on the alkalinity of pore water. The glass structure of the Fly ash is only decomposed substantially beyond a pH of about 13.2 or 13.3.

In the beginning of cement hydration, the composition of the pore water is dominated by a saturated lime solution with gypsum. The pH of the pore solution is lower than 13. After about one week the pH increases. The lime and sulphate concentration decreases to very low level and concentrations of hydroxyl, potassium and sodium ions increase rapidly.

This may be due to the following reasons.

- The Fly ash may act as nucleus for lime precipitation so that cement reaction is accelerated.
- Fly ash itself may contribute to the alkalinity.

The later could be due to the release of sodium and potassium ions from the surface Fly ash particles.

However, after some months of hardening, the pore water cement shows a gradual decrease in pH, which means that the reaction rate of Fly ash decreases with time. The deceleration of Fly ash reaction is augmented by the decreasing permeability of the concrete caused by the decreasing mobility of the ions during the densification of the pores.

Various factors influencing the Fly ash reaction are,

Cement Type: Rapid hardening cements develop high alkalinity faster than ordinary cements. Consequently, Fly ash reaction starts earlier. Similarly different cements effect accordingly.

Temperature: Development of hydroxyl concentration appears to be much slower at 2°C. At 40°C the pH reaches a high value within one day of hydration so that the reaction of Fly ash can start from the first day. Temperature also affects the reactivity of Fly ash itself. That means at a higher temperature the reaction will be initiated at lower alkalinity.

Water Cement Ratio: There is a strong relation between Fly ash activity and water/cement ratio. Higher the W/C ratio, lower the alkalinity and slower the reaction.

Types of Fly ash: Pozzolanic activity or reaction of Fly ash depends upon parameters such as fineness, amorphous matter, chemical and mineralogical composition and un-burnt carbon contents.

3.2.4.5 Effect of Fly Ash on Concrete

Fly ash contributes to the physical and chemical aspects of concrete as follows:

(a)Physical aspect

Main influence of fly ash is on water demand and workability. For a constant workability, reduction in water demand due to fly ash is usually between 5 to 15 percent by comparison with a Portland cement only.

A concrete mix containing fly ash is cohesive and has a reduced blending capacity. Reduction in water demand of concrete caused by presence of fly ash is usually ascribed to their spherical shape, which is called "ball-bearing effect" **Neville AM (2005)** However, other mechanisms are also involved and may well be dominant. In particular, in consequence of electric charge, the finer fly ash particles become adsorbed on the surface of cement particles. If enough fine fly ash particles are present to cover the surface of the cement particles, which thus become deflocculated, the water demand for a given workability is reduced.

(b)Chemical contributions

Like silica fume, in fly ash product of reaction closely resemble C-S-H product by hydration of Portland cement. However reaction does not start until sometime after mixing. Because glass material of fly ash is broken down only when the PH value of pore water is more than 13 and this increase in alkalinity of pore water require that a certain amount of hydration of Portland cement in the mix has taken place. Moreover reaction products of Portland cement participate on the surface of fly ash particle, which acts as nuclei.

Class C fly ash which has high lime content reacts, to some extent, direct with water; in particular, some C2S may be present in fly ash and this compound reacts to form C-S-H. Also, crystalline C3A and aluminates are reactive. In addition to this with class F fly ash, there is a reaction of silica with calcium hydroxide produced by hydration of Portland cement. Thus, class C fly ash reacts earlier than class F fly ash. As the reaction of class F fly ash required a high alkalinity of pore water and this alkalinity is reduced when silica fume is used in the mix. So in the ternary mix of fly ash and silica fume, class C fly ash is used

3.2.4.6Proportioning of Fly Ash concrete

Using of Fly ash in concrete has to meet one or more of the following objectives.

- Reduction in cement content,
- Reduced heat of hydration,
- Improved workability and
- Gaining levels of strength in concrete beyond 90 days of testing.

Fly ash is introduced into concrete by one of the following methods.

- Cement containing Fly ash may be used in place of OPC.
- Fly ash is introduced as an additional component at the time of mixing.

The first method is simple and problems of mixing additional materials are not there, there by uniform control is assured. The proportions of Fly ash and Cement are predetermined, and mix proportion is limited.

The second method allows for more use of Fly ash as a component of concrete. Fly ash plays many roles such as, in freshly mixed concrete, it acts as a fine aggregate and also reduces water cement ratio in hardened state, because of its pozzolanic nature, it becomes a part of the cementitious matrix and influences the strength and durability.

The assumptions made in selecting an approach to mix proportioning Fly ash concrete are

(i) It reduces the strength of concrete at early ages.

(ii) For same workability, concrete containing Fly ash requires less water than concrete containing ordinary Portland cement.

The basic approaches that are generally used for mix proportioning are

- Partial Replacement of cement,
- Addition of Fly ash as fine aggregates and
- Partial replacement of cement, fine aggregate and water

In the first approach, there is direct replacement of a percentage of cement by Flyash. Replacement of cement by Fly ash (either by volume or by mass basis), results in lower compressive and flexural strength up to 90 days of moist curing and develops greater strengths beyond 180 days of curing.

At early ages, Fly ash exhibits very little cementing effects and acts as a fine aggregate, but at later ages cementing activity becomes apparent and its contribution in the development of strength is observed.

In the second approach, Fly ash is added to the mix without a reduction in the quantity of cement used. The cementitious content of the concrete is enhanced for long periods of moist curing.

In the third approach, proportioning of Fly ash concrete requires a part of cement to be replaced by an excess mass of Fly ash with necessary adjustments in fine aggregate and water content.

3.2.4.7 Application of Fly Ash

Fly ash is highly recommended for mass concrete applications, i.e. large mat foundations, dams etc. The Hungry Horse dam, Conyan ferry dam and the Wilson dam, Hart well dam and sultan dam in USA, the Lednock dam in UK and sudagin dam in Japan are few examples abroad.

LUI center in Vancouver successfully used 50% Fly ash for all structural elements. In India, some portions of Rihand dam in UP and some part of barrages in Bihar are some examples.

Fly ash can be used for the following

1. Filling of mines,
2. Replacement of low lying waste land and refuse dumps,
3. Replacement of cement mortar,
4. Air pollution control,
5. Production of ready mix Fly ash concrete,
6. Laying of roads and construction of embankments,
7. Stabilizing soil for road construction using lime-Fly ash mixture
8. Construction of rigid pavements using cement-Fly ash concrete,
9. Production of lime-Fly ash cellular concrete,
10. Production of precast Fly ash concrete building units,
11. Production of sintered Fly ash light weight aggregate and concrete and
12. Making of lean-cement Fly ash concrete.

3.2.4.8Properties of Fresh concrete with Fly Ash

Time of setting: The initial setting time of 7.5 h are compared to those of control concrete made with the water content and Water/Cementitious materials, whereas the final setting time of set were retarded by 3h compared with that of control.
Bleeding: Bleeding tests performed on High strength Fly ash concrete have shown that this concrete does not bleed.
Density of fresh concrete: This is comparable to the density of Portland cement concrete without Fly ash.
Dosage requirement of super plasticizer: Because of the very low water/cementitious materials, the use of super plasticizers is mandatory.

3.2.4.9Properties of Hardened Concrete with Fly Ash

Temperature rise: Because of the very low cement content the temperature rise in the first few days after placement is normal.
Strength properties: Fly ash concrete exhibits adequate strength development characteristics both at early and late ages.
Young's modulus of elasticity: The modulus of elasticity of Fly ash concrete is somewhat higher than the modulus of elasticity of probably due to the glassy, unhydrated Fly ash particles acting as a fine filler material in the concrete.
Creep characteristics: The creep stains of high strength Fly ash concrete at 1 year age is comparable to or lower than that of Portland cement concrete of comparable strength.

3.2.5 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.
Silica fume has a bulk density of approximately 610kg/m³.

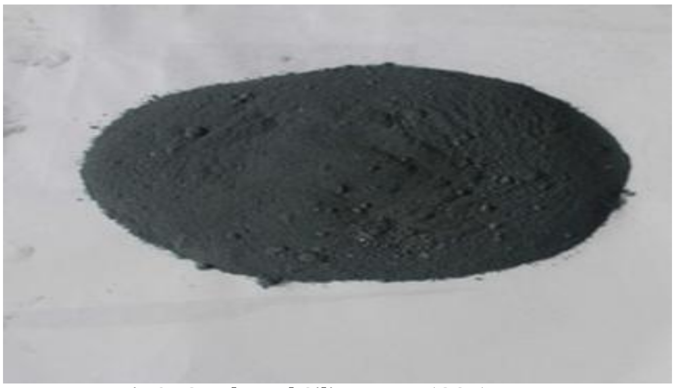

Fig 2: Condensed Silica Fume (CSF)

3.2.5.1 Silica fume and its sources:

Silica is very pozzolanic material composed of amorphous silica produced by electric arc furnaces as a by-product of the production of elemental silica or Ferro-silicon alloys. High purity Quartz is heated to 2000°c with coal, coke or wood chips as fuel and an electric arc introduced to separate out the material. As the quartz is reduced it releases silicon oxide vapours. This mixes with oxygen in the upper parts of the furnace where it oxidizes and condenses into micro spheres of amorphous silicon dioxide. The fumes are drawn out of the furnace through a pre collector and a cyclone, which remove the larger coarse particles of unburnt wood or carbon, and then blown into a series of special filter bags.

3.2.5.2 Characteristics:

Silica fume is, when collected, an ultra-fine powder having the following properties
1. At least 85% SiO_2 content
2. Mean particle size between 0.1 and 0.2 micron
3. Minimum specific surface of 15,000m²/kg

4. Spherical particle shape

The powder is normally grey in colour but this can vary according to the source

Fig 3: schematic diagram of silica fume production

3.2.5.3 Physical properties:

The primary physical properties of micro silica /silica fume are particle size, bulk density, specific gravity and specific surface .Following is a discussion of each of these properties. Note that the major physical properties are included in the standard specifications for micro silica/silica fume.

Particle size: Micro silica/silica fume particles are extremely small, with more than 95% of the particles being less than 1 μm (one micrometre). Particle size is extremely important for both the physical and chemical contributions of micro silica/silica fume in concrete.

Bulk density: This is just another term for unit weight. The bulk density of the as-produced fume depends upon the metal being made in the furnace and upon how the furnace is operated. Because the bulk density of the as-produced micro silica/silica fume is usually very low, it is not very economical to transport it for long distances.

Specific gravity: Specific gravity is a relative number that tells how micro silica/silica fume compares to water, which has a specific gravity of 1.00. Micro silica/silica fume has a specific gravity of about 2.2, which is somewhat lighter than Portland cement, which has a specific gravity of 3.15. Thus, adding micro silica/silica fume to a concrete mixture will not "densify" the concrete in terms of increasing the density of the concrete.

PHYSICAL PROPERTIES OF SILICA FUME	
Particle size (typical):	< 1 μm
Bulk density: (as-produced): (densified):	130 to 430 kg/m³ 480 to 720 kg/m³
Specific gravity:	2.2
Specific surface:	15,000 to 30,000 m²/kg

Specific surface: Specific surface is the total surface area of a given mass of a material. Because the particles of micro silica/silica fume are very small, the surface area is very large. We know that water demand increases for sand as the particles become smaller; the same happens for micro silica/silica fume.Use of Silica Fume in Concrete, estimates that for a 15% CSF replacement of cement there are approximately 2,000,000 particles of silica fume for each grain of Portland cement.

3.2.5.4 Chemical Properties

The primary chemical properties of micro silica/silica fume are shown in Table. Following is a discussion of each of these properties. Note that the major chemical properties are included in the standard specifications for micro silica/silica fume.

Amorphous: This term simply means that micro silica/silica fume is not a crystalline material. A crystalline material will not dissolve in concrete, which must occur before the material can react. Don't forget that there is a crystalline material in concrete that is chemically similar to micro silica/silica fume. That material is sand. While sand is essentially silicon dioxide (SiO2), it does not react because of its crystalline nature.

Silicon dioxide (SiO2): This is the reactive material in micro silica/silica fume. Trace elements. There may be additional materials in the micro silica/silica fume based upon the metal being produced in the smelter from which the fume was recovered. Usually, these materials have no impact on the performance of micro silica/silica fume in concrete. Standard specifications may put limits on some of the materials in this category.

CHEMICAL PROPERTIES OF SILICA FUME
■ Amorphous
■ Silicon dioxide > 85%
■ Trace elements depending upon type of fume

3.2.5.5Reactions of Silica Fume in Concrete

The benefits seen from adding silica fume are the result of changes to the microstructure of the concrete. These changes result from two different but equally important processes. The first of these is the physical aspect of silica fume and the second is its chemical contribution. Here is a brief description of both of these aspects

(a)Physical contributions
Adding silica fume brings millions and millions of very small particles to a concrete mixture. Just like fine aggregate fills in the spaces between coarse aggregate particles, silica fume fills in the spaces between cement grains. This phenomenon is frequently referred to as particle packing or micro-filling.fig (2.6) shows the basic concept of particle packing - filling the spaces between cement grains with silica fume particles.

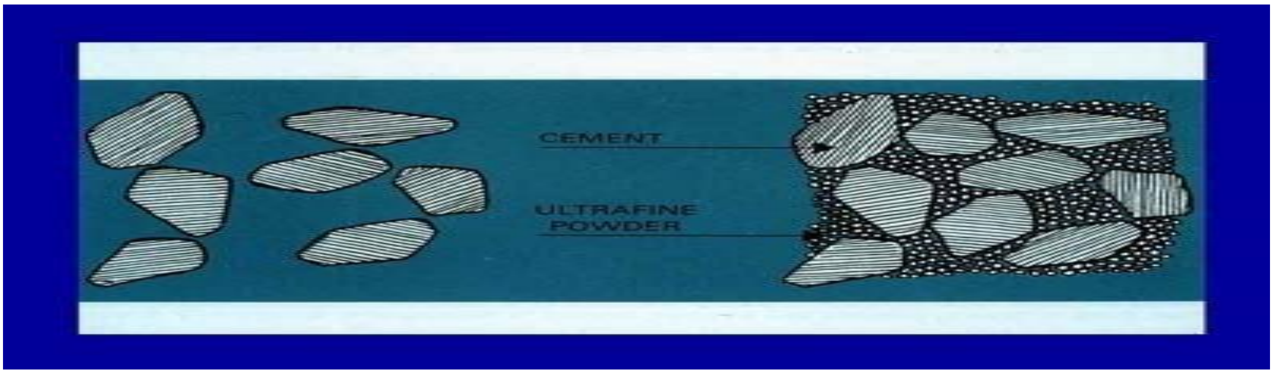

Fig.4: Concept of particle packing - filling the spaces between cement grains with silica fume particles (source: silica fume user manual "US department of transportation)

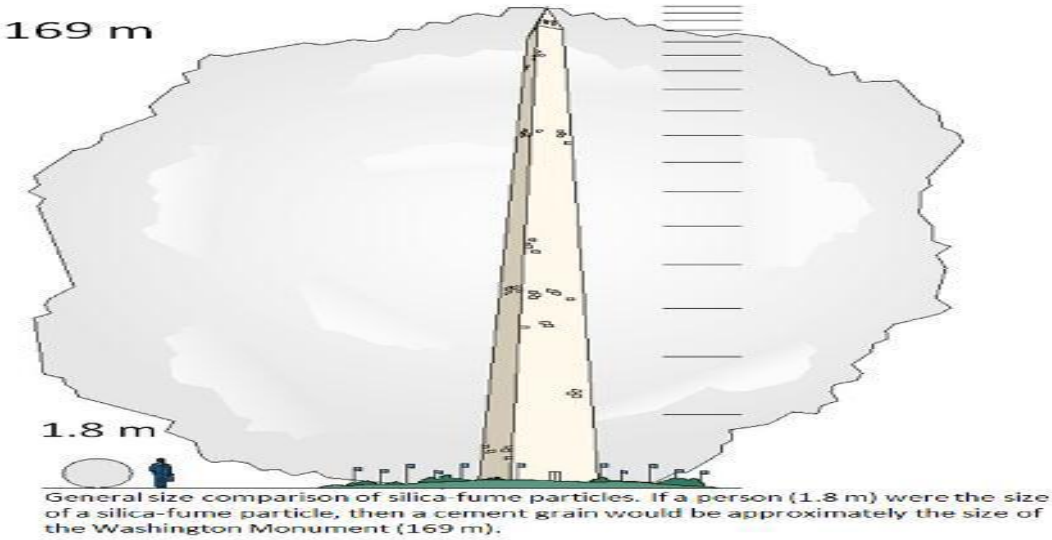

Fig.5:Comparison of silica fume particle with cement grains (source: silica fume user manual "US department of transportation)

Even if silica fume did not react chemically, the micro-filler effect would bring about significant improvements in the nature of the concrete. Figure (2.7) present a comparison of the size of silica-fume particles to other concrete ingredients to help understand how small these particles actually are.

(b)Chemical contributions
The reaction of cement with water causes a series of complex chemical reactions. The main compounds in cement are two calcium silicates (i.e., di-calcium silicate and tri-calcium silicate), and the physical behavior of these compounds is similar to that of cement during hydration. Highly crystalline portlandite [Ca(OH)2] and amorphous calcium-silicate-hydrate (C-S-H) are formed in the hydration of Portland cement (PC). The hydrated cement paste consists of approximately 70% C-S-H, 20% CH, 7% sulfo-aluminate, and 3% secondary phases [10]. Calcium hydroxide, which is formed as a result of chemical reaction, is soluble in water and has low strength. These properties affect the quality of concrete negatively. Adding mineral admixtures (silica fume and fly ash) to cement decreases the amount of Ca(OH)2. According to **M. Lessard et al(1992)**, cement paste containing silica fume (SF) produces amorphous C-S-H gel with high density and low Ca/Si ratio. The benefits of this reaction can be seen in the crucial interfacial zone increasing the bond strength between concrete paste and aggregates, yielding greatly increased compressive strengths and a concrete that is more resistant to attack from aggressive chemicals than the weaker calcium hydroxide found in ordinary Portland cement concretes.

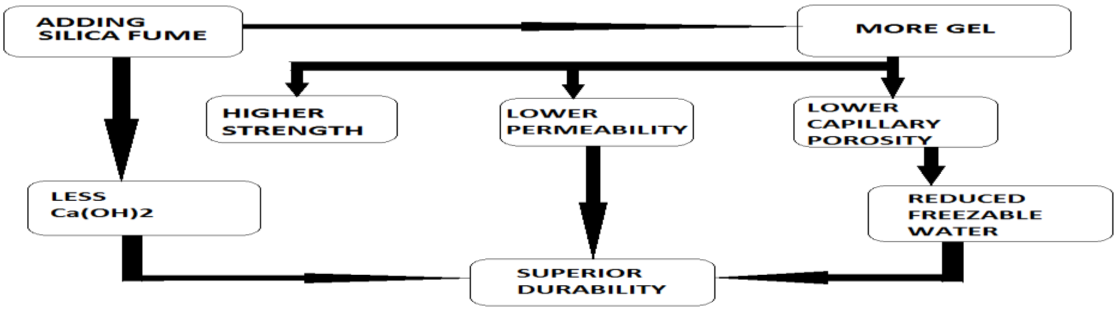

Fig.6: effects of adding silica fume to concrete

3.2.5.6 Silica fume in concrete:

Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material. Silica fume is added to Portland cement concrete to improve its properties in particular compressive strength, bond strength and abrasion resistance. These improvements stem from both mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions. When it is used in concrete it acts as filler material and as a cementitious material. The small silica fume particles fill space between cement particles and between the cement paste matrix and aggregate particles. The silica fume also combines with calcium hydroxide to form additional calcium hydrate through the pozzolanic reaction. Both of these actions result in a denser, stronger and less permeable material.

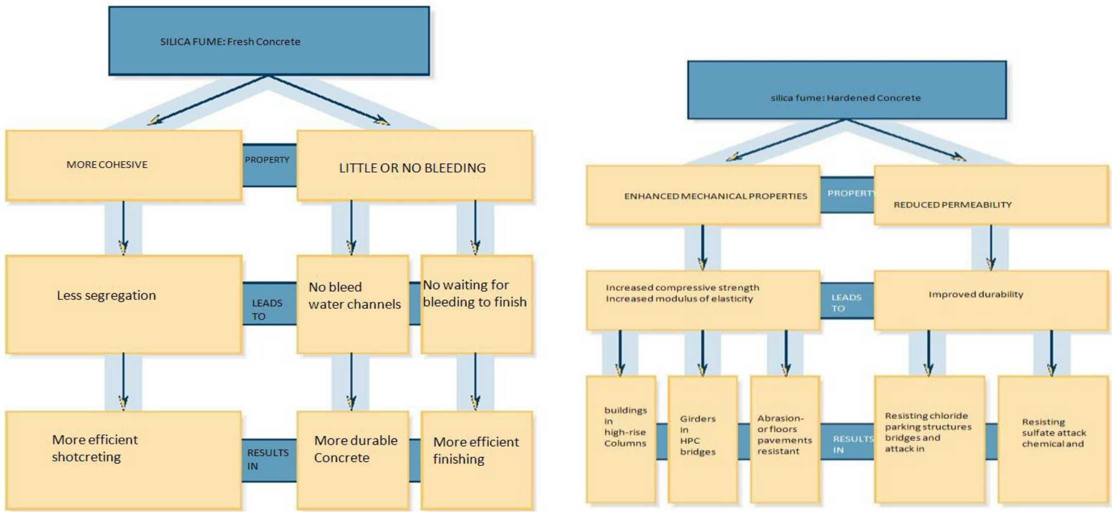

Fig 7: Schematic diagram of the advantages of silica fume

3.2.5.7 Hardened Concrete-Durability Related Properties

The use of a silica fume concrete, with its potential for greater strengths, both compressive and tensile, its more refined pore structure and lower permeability, gives the opportunity of providing a more durable with a longer working life span than a conventional concrete in the same environment.

Permeability:

The two main methodologies permeability are statically or such as allowing a concrete to dry out and noting the weight loss, or actively, by subjecting the material to a liquid or gas under pressure and measuring the depth of penetration. In studies using drying methods (Sellevold et al..,1982 a, b; Sorensen,1982) the efficiency factor for silica fume concrete was between 6 and 8. This indicates that the physical size and high reactivity of the silica fume have more influence on permeability than on compressive strength. Permeability should not be confused with porosity, as the pore structure is modified but not decreased (sellevold et al.., 1982 a, b). The permeability of concretes particularly to chemicals such as chlorides and sulphates, is a great concern around the world with regard to durability . Research has been ongoing results are frequently added to the list of references.

Sulphate Resistance:

In a major initiated in Oslo in the first years of testing silica fume concretes various specimens were buried in the acidic, sulphate-rich ground in Oslo. The 20-year results are available for this trail (Mage, 1984; Fiskaa, 1971) and indicate that silica fume concretes performed as well as those made with sulphate-resisting cement. This is confirmed in the 40-year report further laboratory tests (Fiskaa, 1973, Mather, 1980). When testing in conjunction ggbs or pfa(carlsen and vennesland 1982), silica fume mixes were found to show greater resistance to sulphate attack than those made with special sulphate-resisting cements. This has resulted in silica fume concrete. Such performance of the concrete can be attributed to:

- The refined pore structure and thus the reduced passage of harmful ions (popovic,1984)
- The increased amount of aluminum incorporated into the micro silica, thus reducing the amount of alumina available for ettringite formation
- The lower calcium hydroxide content.

Carbonation:

Results for tests on carbonation rates are somewhat varied and contradictory depending on the viewpoint taken when analyzing the findings. A study (Vennesland and Gjorv,1983) into the effect of micro silica on carbonation and the transport of oxygen showed that adding up to 20% micro silica caused a slight reduction in these two actions in water-saturated concrete. In essence the conclusion shown by those reports available (Johansen, 1981;Vennesland and Gjorv,1983;vennesland,1981)are that for equal strengths and any concrete below 40 MPa show reduction in carbonation rate and it is only these concrete that are deemed susceptible to attack and damage if there is reinforcement present. As silica fume concrete is normally used where the compressive strengths are above 40MPa it is a moot point as to whether carbonation is a serious risk. Correct curing procedures are essential to ensure optimum performance of the silica fume concrete.

Efflorescence:

These actions occur mainly when one or more surfaces of the concretes surfaces of the concrete subjected to either continuous water contact or intermittent wetting and drying. The excess calcium hydroxide is leached through the concrete to the surface where it carbonates, giving a white powdery deposit. Efflorescence not only reduces the aesthetic quality of structures but can also result in increased porosity and permeability and ultimately a weaker and less durable concrete. It has been found in studies (Samuelsson, 1982) that the addition of silica fume will reduce efflorescence due to the refined pore structure and increased consumption of the calcium hydroxide. The results indicated that the more efficient the curing and longer curing time before exposure, the more resistant the concrete became.

Frost resistance:

It will be appreciated that as the major producers and users in the early years were Scandinavian countries this particular property of silica fume concrete has been well scrutinized. Investigations have included using silica fume as an addition on its own and with super plasticizers, varying dosages of air entrainers, different aggregates and various curing regimes. For air-entrained concrete of the required strength it is necessary to achieve the correct amount of air, the right dispersion of the bubbles and a mix stable enough under compaction. Many different concretes have been compared (Okkenhaug and Gjorv, 1982;Okkenhaug, 1983) to determine the effect of silica fume addition. It was found to be difficult to entrain air in a silica fume mix that did not use a plasticizer but that by increasing the dosage of air entrainer and adding a plasticizer it was easy to achieve the desire levels. There is some speculation as to the reason for the increased dosage of air entrianer with the most likely one being that the air and the silica fume compete for the same space in the mix. Once in the mix it was noted that the bubble spacing and stability were greatly improved. The variations of air content for given dosages, as sometimes happen when using pfa, were not noticed in the silica fume concretes. The use of silica fume with air entrainment is considered to be the best option with microsilica maintaining good stability and uniform bubble spacing of the air which gives maximum frost protection, based around a mix design guideline for a concrete 30-50 MPa, utilizing 8% microsilica and 5% air entrainment as an optimum. In all cases the concrete should be cured for the longest allowable time before exposure to the working environment.

Alkali-Silica reaction

To view the effect of silica fume on this form of attack it is necessary to remember the three main factors that are required for potential reaction.

- A high alkali content in the mix
- Reaction aggregates
- Available water

Silica fume reacts with the librated calcium hydroxide to form calcium silicate hydrates and this reduction leads to a lowering of the pH and a lower risk of reaction due to high alkalis. In the formation of the calcium silicate hydrates the K+ and Na+ ions are bound in the matrix and cannot react with any potentially siliceous aggregates. The minute size and pozzolonic reactivity of the silica fume greatly refines the pore.

3.2.6 FIBRES:

The use of fibres in brittle matrix materials has a long history going back at least 3500 years when sun-baked bricks reinforced with straw were used to build the 57 m high hill of AqarQuf near Baghdad (Newman et al, 2003). In addition, horsehair was used to reinforce masonry mortar and plaster (ACI Committee 544.1R, 1996). After that, asbestos fibres have been used to reinforce cement products, such as roofing sheets, for about 100 years. However, primarily due to health hazards associated with asbestos fibres, alternate fibre types were introduced throughout the 1960s and 1970s.

The low tensile strength and brittle character of concrete have been bypassed by the use of reinforcing rods in the tensile zone of the concrete since the middle of the nineteenth century (ACI Committee 544, 1986). Moreover, patents have been granted since the turn of the century for various methods of incorporating discontinuous steel reinforcing elements such as, nails, wire segments or metal chips into concrete.

During the early 1960s in the United States, the first major investigation was made to evaluate the potential of steel fibres as a replacement for steel reinforcing rods in concrete (Romualdi et al, 1963). Since then, a substantial amount of research development, experimentation, and industrial application of steel fibre reinforced concrete has occurred. In the early 1960s, experiments using plastic fibres in concrete with and without steel reinforcement were conducted

(Goldfein, 1963). Since 1997 Japanese construction companies have been using structural synthetic fibres to replace steel fibre reinforcement and the technology has since spread into Australia, Europe and North America (Elasto Plastic Concrete, epc).

Over the past 40 years, a number of applications have been recommended for the use of fibre reinforced concrete including road and floor slabs, refractory materials and concrete products (ACI Committee 544, 1986).

3.2.6.1 Types of Fibres

There are numerous fibre types, in various sizes and shapes, available for commercial and experimental use. The basic fibre categories are steel, glass, synthetic and natural fibre materials. However, in slabs on grade, steel, polypropylene and structural synthetic fibre reinforced concrete is the three main types of fibre, which are used as a replacement for conventional steel fabric reinforcement.

Steel Fibres

Many efforts have been made in recent years to optimise the shape of steel fibres to achieve improved fibre-matrix bond characteristics, and to enhance fibre dispersibility in the concrete mix. ASTM A 820 provides a classification for four general types of steel

Fibres based on the product used in their manufacture (ACI Committee 544.1R, 1996):

- Cold-drawn wire
- Cut sheet
- Melt extracted
- Other fibres

Fig 8: Steel Fibres

A few of the more common types of steel fibres being shown in figure 1.1 (Knapton, 2003). Rounded, straight steel fibres are produced by cutting or chopping wire, typically having diameter between 0.25mm and 1.0mm. Flat, straight steel fibres having typical

Cross sections ranging from 0.15mm to 0.41mm thickness by 0.25mm to 1.14mm width are produced by shearing sheet or flattening wire. Crimped and deformed steel fibres are produced either with full length crimping or bent or enlarged at the ends only. Some fibres are deformed by bending or flattening to increase bonding and facilitate handling and mixing (Concrete Society, 1994). Some fibres have been collated into bundles to facilitate handling and mixing. During mixing, the bundles separate into individual fibres.

Fibres are also produced from cold drawn wire that has been shaved down in order to make steel wool. Moreover, steel fibres are produced by the melt-extraction process (ACI Committee 544.1R, 1996).

The ultimate tensile strength of steel fibre range from 345-1700 MPa, whereas the length range from 19 to 60mm, the aspect ratio (length/diameter) range from 30 to 100 and the young's modulus is 205 MPa

Synthetic Fibres

Synthetic fibres are man-made fibres resulting from research and development in the petrochemical and textile industries. Synthetic fibre reinforced concrete utilises fibres derived from organic polymers which are available in a variety of formulations

Polypropylene Fibres (micro-synthetic fibres)

Polypropylene fibres are gaining in significance due to the low price of the raw polymer material and their high alkaline resistance (Keer, 1984; Maidl, 1995). They are available in two forms i.e. monofilament or fibrillated manufactured in a continuous process by extrusion of a polypropylene homopolymer resin (Keer, 1984; Knapton, 2003). Micro synthetic fibres, based on 100% Polypropylene are used extensively in ground-supported slabs for the purpose of reducing, plastic shrinkage cracking and plastic settlement cracking. These fibres are typically 12mm long by 18µm diameter (Perry, 2003)

Structural Synthetic Fibres (macro-synthetic fibres)

Macro synthetic fibres have been developed during the last seven years. They have the potential to provide concrete with significant ductility. As a result, in concrete floors and slabs, these fibres are able to control cracking caused by thermal movements and long-term drying shrinkage (Concrete Society, 2003). Although these macro-synthetic fibres

Usually contain some polypropylene, they differ from polypropylene micro-fibres in that they are significantly larger- typically 40-50mm long and 1.0 to 1.5mm wide-, made from selected polymers and used at significantly higher dosage than

polypropylene microfibers (Perry, 2003). These properties allow synthetic structural fibres to provide a significant level of post-crack control in the same way as that achieved by steel fabric and steel fibres (Clements, 2002)
The following sections discuss the addition, mixing, placing, finishing and curing of steel, polypropylene and structural synthetic fibres. Also, they present the effect of adding theses fibre types on the properties of fresh and hardened concrete

3.2.6.2 Mechanical Properties of Fresh Steel Fibre-Reinforced Concrete
Achieving adequate workability is one of the most important problems generated when using steel fibre reinforced concrete. The inclusion of the fibres into the concrete mix influences its workability, with increasing in the fibre volume and aspect ratio leading to decreased workability (Hannat, 1978; Swamy, 1974). The ACI Committee report in 1996, reported that in the typical ranges of volume fractions used for steel-fibre reinforced concrete (0.25 to 1.5 volume percent), the addition of steel fibres may reduce the measured slump of the composite as compared to plain concrete in the range of 25 to 102mm. Also, since compaction by mechanical vibration is recommended in most SFRC applications, assessing workability of a SFRC mixture with the V-B test, which simulates the effects of vibration, is recommended rather than the conventional slump measurement. Incorporation of super plasticiser is essential to maintain good workability (120-150 mm). In addition to the above consideration the balling of fibres must be avoided.

3.2.6.3 Mechanical Properties of Hardened Steel Fibre-Reinforced Concrete
The most significant consequence of fibre addition to concrete is the delay and control of tensile cracking in the composite material (Ramakrishnan, 1988). Through intercept micro-cracks, many of the mechanical properties of the composite are improved. The level of improvement achieved, compared to plain concrete, depends on the dosage rate and type of fibre (ACIFC, 1999). Some of the properties affected will be discussed in this section.
Steel fibres improve the ductility of concrete under all modes of loading. But their effectiveness in improving strength varies among compression, tension, shear, torsion and flexure.
Compressive strength is slightly affected by the presence of fibres, with observed increases ranging from 0 to 15%, on the other hand, direct tension improved significantly, with increases of the order of 30 to 40%, similarly, shear and torsion generally increased although there are little data dealing strictly with the shear and torsion (ACI Committee 544.1R, 1996, Amir, 2002). Much greater effect on flexural strength than on either
Compressive or tensile strengths, with increase of more than 100% has been reported (Johnston, 1974; Khaloo et al, 2005). The post-crack flexural performance is a most important part of the commercial uses of steel fibre concrete enabling reductions of thickness to be made in sections subject to flexure or point load. Impact strength and toughness, defined as energy absorbed to failure are greatly increased (Hauwaert et al, 1999), the increased in toughness results from the increased of the area under the load
Deflection curve in tension and flexure (Newman et al, 2003). Increased resistance to dynamic load and fatigue is often claimed (Concrete Society, 1994), it seems to be related to the distribution of the fibres in concrete (Cachim et al, 2002). Also, it has 15% higher resistance to wear than plain concrete.
Modulus of elasticity and Poisson ratio are generally taken as equal to those of similar non-fibrous concrete when the volume percentage of fibre is less than 2% (ACI Committee 544.1R, 1996). Generally, steel fibre concrete is more durable than plain concrete, having a positive influence on the shrinkage behaviour of concrete by reducing the number and controlling the width of cracks (Concrete Society, 1994; ACI Committee 544.1R, 1996). If the
Concrete is well compacted the corrosion of fibres will be limited to the surface of the concrete (ACI Committee 544.1R, 1996), these fibres will corrode rapidly in exposed conditions. Fibres also can reduce the deterioration caused by freeze-thaw cycling (ACI Committee 544.1R, 1996), and they also reduce the permeability of cracks even at low volume (Rapoport et al, 2001).

3.2.7 WATER:

Potable water has been used in the experiment for mixing and curing.

3.2.8 SUPER PLASTICIZER:
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.
Super plastised concrete is a conventional concrete containing a chemical admixture of super plasticizing agent. It enhances workability state to make reduction in water cement ratio of super plasticized concrete, while maintaining workability of concrete. The use of super plasticizers in ready mixed concrete and construction reduces the possibility of deterioration of concrete for its appearance and density. On the other hand, it makes the placing of concrete more economical by increasing productivity at the construction site.

3.2.9 PROPERTIES OF HARDENED CONCRETE:
The basic characteristic of concrete, after it has set, is that it is hard

- Strength- strength of concrete depends upon grade of concrete, water cement ratio, method of compaction, and time period elapsed. Characteristic strength of concrete goes on increasing even after 28 days of casting, though at a slower rate. The quantum of increase depends upon the grade and type of cement, curing and environmental conditions.

- Shrinkage of concrete- Concrete shrinks with age. The total shrinkage of concrete depends upon constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by by the cement content and the water added during preparation of the mix.
- Creep of concrete- the permanent dimensional changes that take place due to loading is termed as creep. The creep of concrete depends upon constituents of concrete, size of matter used, stress in concrete, environmental conditions, age of concrete at loading and duration of loading.
- Thermal expansion- coefficient of thermal expansion depends upon nature of cement and aggregate, size of sections, cement content and relative humidity.
- Imperviousness- it can be defined as the resistance of the concrete to the flow of water through its pores. If there is access water, evaporation of water will leave a large number of continuous pipes, making concrete permeable. This will reduce the durability of the concrete. Concrete can be made impermeable by using low water cement ration, proper compacting, continuous curing at low temperature and sue of dense and well graded aggregate.
- Durability- it is the property of concrete by which the concrete offers resistance against disintegration and decay. Concrete must be resistance to variable temperature conditions, weather conditions such as action of atmospheric gases and moisture changes.

3.2.10 FACTORS EFFECTING STRENGTH OF CONCRETE:

Following are the factors that affect the strength of concrete:

1. Water-Cement ratio
2. Type of cementing material
3. Amount of cementing material
4. Type of aggregate
5. Air content
6. Admixtures

1. Water-Cement ratio:

It is water cement ratio that basically governs the property of strength. Lesser the water cement ratio, greater will be strength.

2. Type of cement:

Type of cement affects the hydration process and therefore strength of concrete.
Amount of cementing material: it is the paste that holds or binds all the ingredients. Thus greater amount of cementing material greater will be strength.3. Type of Aggregate:
Rough and angular aggregates are preferable as they provide greater bonding.4. Admixtures: Chemical admixtures like plasticizers reduce the water cement ratio and increase the strength of concrete at same water cement ratio.
Mineral admixtures affect the strength at later stage and increase the strength by increasing the amount of cementing material.

3.3MIX 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.
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

DESIGN OF M80 GRADE HIGH STRENGTH CONCRETE BY D.O.E.METHOD:

Materials:

Cement : OPC 53 grade
Coarse aggregate : crushed stone
Fine aggregate : natural river sand

Properties of materials:

Cement : specific gravity =2.99
Coarse aggregate : Fineness modulus=7.14
Bulk specific gravity=2.64
Absorption characteristic=0%
Fine aggregate : Fineness modulus=2.78
Absorption characteristics=1%

Parameters:

Assume standard deviation = 5 N/mm²
Assume slump of concrete = 75mm

STEP-1:

Target mean strength = (specific characteristic strength) + (Standard deviation * risk factor)
= 80 + (5*1.65)
=88.25mPa

STEP-2:

W/C for 88.25 MPa =0.31

STEP-3:

Water content for slump of 75mm and 20mm uncrushed aggregates = 195 kg/m³

STEP-4:

With W/C ratio of 0.31 and water content of 195 kg/m³
The cement content = 195/0.31
= 629.03 kg

STEP-5:

For water content of 195kg/m³, 20mm uncrushed aggregate of specific gravity of 2.64, the density of fresh concrete i.e., wet density = 2400
Weight of total aggregates = 2400-(195+629.03)
= 1575.97 kg/m³

STEP-6:

For 20mm size aggregates, w/c ratio of 0.31, slump of 75mm and for 50% of fines Passing through 600 micron sieve, the % of fine aggregate =38%

STEP-7:

Weight of fine aggregate = 1575.97*(38/100) = 598.86 kg/m³

STEP-8:

Weight of coarse aggregate =1575.97-598.86= 977.28 kg/m³

ESTIMATED QUANTITIES IN 1M³ OF CONCRETE:

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

CONCRETE MIXES

MIX (CUBES)	MIX (BEAMS)	CEMENT (%)	CSF (%)	FLY ASH (%)	FIBRE (%)
R1,1	A1,1	100	0	0	0
R1,2	A1,2	80	0	20	0
R1,3	A1,3	60	0	40	0
R2,1	A2,1	95	5	0	0
R2,2	A2,2	75	5	20	0
R2,3	A2,3	55	5	40	0
R3,1	A3,1	90	10	0	0
R3,2	A3,2	70	10	20	0
R3,3	A3,3	50	10	40	0
R4,1	A4,1	85	15	0	0
R4,2	A4,2	65	15	20	0
R4,3	A4,3	45	15	40	0
R5,1	A5,1	100	0	0	0.5
R5,2	A5,2	80	0	20	0.5
R5,3	A5,3	60	0	40	0.5
R6,1	A6,1	95	5	0	0.5
R6,2	A6,2	75	5	20	0.5
R6,3	A6,3	55	5	40	0.5
R7,1	A7,1	90	10	0	0.5
R7,2	A7,2	70	10	20	0.5
R7,3	A7,3	50	10	40	0.5
R8,1	A8,1	85	15	0	0.5
R8,2	A8,2	65	15	20	0.5
R8,3	A8,3	45	15	40	0.5
R9,1	A9,1	100	0	0	1
R9,2	A9,2	80	0	20	1
R9,3	A9,3	60	0	40	1
R10,1	A10,1	95	5	0	1
R10,2	A10,2	75	5	20	1
R10,3	A10,3	55	5	40	1
R11,1	A11,1	90	10	0	1
R11,2	A11,2	70	10	20	1
R11,3	A11,3	50	10	40	1
R12,1	A12,1	85	15	0	1
R12,2	A12,2	65	15	20	1
R12,3	A12,3	45	15	40	1

SPECIMENS REQUIRED:

- Combinations : 36
- No of samples per combination : 6 (3 cubes & 3 beams)
- Total no of samples : 36*6=216

3.4 CASTING OF TEST SPECIMENS

The present experimental programme includes casting and testing of specimens for compression. Specimens are prepared M80 grade of concrete with and without Fly ash. Total of 18 cube specimens with various percentages of Fly ash are casted. The details of casting and testing of specimens are described below.
(Note: all of the following specifications are in adherence to IS: 516-1959)

3.4.1 Sampling of materials

Representative samples of the materials of the concrete for use were obtained by careful sampling. Test samples of cement were made up of a small portion taken from each of a number of bags on site. Test samples of aggregates were taken from larger lots by quartering and sieving.

3.4.2 Preparation of Materials

All materials were at room temperature which was about 27 + 3oC before commencing the tests. The cement samples were thoroughly mixed dry by hand to ensure the greatest possible blending and uniformity in the material. Care was taken to avoid the intrusion of foreign matter. The cement was then stored in a dry place.
Samples of aggregates for each batch of concrete were of the desired grading and were in air dried condition. In general the aggregate was separated into coarse and fine fractions and recombined for each concrete batch in such a manner as to produce the desired grading. IS Sieve 480 was normally used for separating the fine and coarse fractions.

3.4.3 Proportioning
The proportions of the materials, including water in concrete mixes used for determining the suitability of the materials available were similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used are to be specified in terms of volume, they were calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

3.4.4 Weighing
The quantities of cement, each size of aggregate and water for each batch were determined by weight to an accuracy of 0.1% of the total weight of the batch.

3.4.5 Mixing of concrete
Some combinations were mixed by hand while the rest by a laboratory batch mixer. The advantage of the latter is that there is a certain precision that is ensured in the mixing because the loss of water and other materials is minimised. However, to ascertain the difference in the consistencies and other parameters, hand mixing for a few combinations has also been adopted. Each batch of concrete was of such a size as to leave about 10% excess after moulding the desired number of test specimens.

3.4.5.1 Machine mixing
When the mixing drum is charged by a power loader, all the mixer was introduced into the drum before the solid materials; the skip was loaded with about one-half of the coarse aggregate on top. Where the mixing drum was hand loaded, it was charged with the dry materials in a similar manner and the water was added immediately before the rotation of the drum was started. The period of mixing was about 2 minutes till the uniform concrete was uniform in appearance. When using pan mixers, the concrete was heaped together before sampling.

3.4.5.2 Hand mixing
- The concrete was mixed on a water-tight, non-absorbent platform with a shovel, trowel or similar suitable implement, using the following procedure:
- The cement, fly ash and silica fume along with fine aggregate was mixed dry until the mixture was thoroughly blended and was uniform in colour
- The coarse was then added and mixed with the mixture until the coarse aggregate was uniformly distributed throughout the batch. This was then followed by addition of fibres and mixing in a similar manner.
- The water and super-plasticiser mixture was then added and the entire batch was mixed until the concrete appeared to be uniform and homogenous and had the desired consistency.

3.4.6 Workability
Each batch of concrete was tested for consistency immediately after mixing by the compaction factor method as described in IS : 1199 – 1959. No water or any other material was lost. The concrete used for the consistency tests was remixed with the remainder of batch before making the test specimens. The period of re-mixing was kept as short as possible and yet at the same time, was sufficient to produce a homogenous mass. The fresh concrete is tested for workability using compaction factor apparatus.

3.4.6.1 <u>Compaction Factor test</u>
Compaction factor measures the workability in an indirect manner by determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap door is opened so that the concrete falls in the lower hopper. Then the trap door of the lower hopper is opened and the concrete is allowed to fall in to the cylinder. I n the case of a dry mix, it is likely that the concrete may not fall on opening trap door.

In such a case a slight pocking by the rod may be required to set the concrete in motion. The excess concrete remaining top level of the cylinder is then cut off with the help of plain blades supplied with the apparatus. The surface of the cylinder is wiped clean and weighed to the nearest 10gms. This weight is known as "weight of partially compacted concrete".

The cylinder is emptied and then refilled with the concrete from the sample in layers of each about 5cms depth. The layers are heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted concrete is then carefully struck off and the cylinder is weighed to the nearest 10gms. The weight is known of fully compacted concrete.

Compaction Factor:

Weightof partially compacted concrete/Weight of fully compacted concrete:

The compaction factor is calculated for various percentages of Fly ash concretes and various ordinary concretes keeping the water cement ratio constant.

3.4.7 Size of the test specimens

3.4.7.1 For compression test
As the largest size of aggregate exceeded 2 cm, the size of test specimen used was 100 x 100 x 100 mm cubes, as proposed by the IS Code.

3.4.7.2 For flexure test
As the largest nominal size of aggregate does not exceed 19 mm, the size of test specimen made is 100 x 100 x 500 mm.

3.4.8Casting of specimen

For casting the specimens, standard C.I metal moulds have been used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before concrete is poured into the mould. Thoroughly mixed concrete is filled in to mould.

3.4.9 Compaction by vibration

Each layer of concrete in the mould was vibrated using a vibrating table till the specified condition was achieved and till each corner and void within the mould was not completely and properly filled.

3.4.10Curing

The test specimens after casting and leaving them in a dry place for 24 hours, were stored at a place free from vibration, in moist air having at least 90% relative humidity and at a temperature of $27^o \pm 2^oC$ for 24 hours $\pm$ ½ hour from the time of addition of water to the dry ingredients. After this period, the specimens were marked and removed from the moulds and then immediately submerged in clean, fresh water and kept there until taken out just prior to test. The water in which the specimens were submerged were renewed every seven days and maintained at a temperature of $27^o \pm 2^oC$. The specimens were not allowed to become dry at any time until they have been tested.

3.5 TESTING OF SPECIMENS

3.5.1 Compressive strength test

Testing Machine

The compressive testing machine, which has been used in our project, is of a reliable type and of sufficient capacity for the tests. Its permissible error is not greater than $\pm$ 2 percent of the maximum load. The testing machine is equipped with two steel bearing platens with hardened faces. One of the platens (the one that will bear on the upper surface of the specimen) is fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen is a plain rigid bearing block. The bearing faces of both the platens larger than the nominal size of the specimen to which the load is applied. The bearing surfaces of the platens do not depart from a plane by more than 0.01mm at any point and they are maintained with a permissible variation limit of 0.02mm. The movable portion of the spherically seated compression platen is held on the spherical seat but the design is such that the bearing face is rotated freely and can be tilted through small angles in any direction.

Fig 9: Compressive testing machine that was used to test the strength of the cubes

Age at test

The tests are made at the recognised ages of the test specimens, the most usual being 7 and 28 days. The ages shall be calculated from the time of the addition of water to the dry ingredients.
In our project we have taken the curing time to be that of 28 days.

Test Procedure

Specimens stored in water were tested immediately upon removal from water and while they were still in wet condition. Surface water and grit were wiped off the specimens and any projecting fins were removed. Specimens when received dry were kept in water for 24 hours before being taken for testing.

Placing the specimen in the testing machine

The bearing surfaces of the testing machine were wiped clean and any loose sand or other material were removed from the surfaces of the specimen which was to be in contact with the compression platens. Since our specimens were in the form of cubes, they were placed in the machine in such a manner that the load was applied to the opposite sides of the cubes as cast, that is, not to the top and bottom. The axes of the specimens were carefully aligned with the centre of thrust of the spherically seated platen. No packing was used between the faces of the test specimen and the steel platen of the test machine as per the specifications of the IS code. As the spherically seated block was brought to bear on the specimen, the movable portion was rotated gently by hand so that the uniform seating may be obtained. The load was applied without shock and increased continuously at a rate of approximately 140kg/sq.cm/min until the resistance of the specimen to the increasing load broke down and no greater load could be sustained. The maximum load applied to the specimen was then recorded and the appearance of the concrete and any unusual features in the type of failure was noted.

Calculation

The measured compressive strength of the specimen was calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and are expressed to the nearest kg per sq.cm. Average of the obtained values have been taken as the representative of the batch that is when the individual variation was not more than ± 15 percent of the average.

The cube specimens cured as explained above are tested as per standard procedure after removal from the curing tank and allowed to dry under shade. The cube specimens tested under digital compression testing machine of 2000 KN capacity. The results are tabulated in table No.4.1. The compressive strength test the test cube specimen was placed with the cast faces of the cubes at right angles to that as cast in the compression testing machine. According to the standard specifications the load on the cube was applied at standard constant rate up to the failure of the specimen and the ultimate load was noted. Cube compressive strength was tested and the results were tabulated.

The process of casting involves weighing of materials, mixing, casting, compacting and curing. All these stages are in strict compliance to IS : 516 – 1959 which comprises the specifications for all the above stages of casting as well as testing.

The IS code includes a clause that specifies the procedure for making and curing compression test specimens of concrete in the laboratory where accurate control of the quantities of materials and test conditions are possible and where the maximum nominal size of aggregate does not exceed 38 mm. the method is specially applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine the suitable mix proportions.

3.5.2 Flexure test

Apparatus

The testing machine is of a reliable type of sufficient capacity for the tests and capable of applying the load at the rate specified. The permissible errors are not greater than + 0.5 percent of the appointed load where a high degree of accuracy is required and not greater than + 1.5 percent of the applied load for commercial type of use. The bed of the testing machine is provided with two steelrollers, 38 mm in diameter, on which the specimen is supported and these rollers are so mounted that the distance from centre to centre is 60 cm for 15 cm specimens or 40 cm for 10 cm specimens. The load is applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load is divided equally between the two loading rollers and all rollers are mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

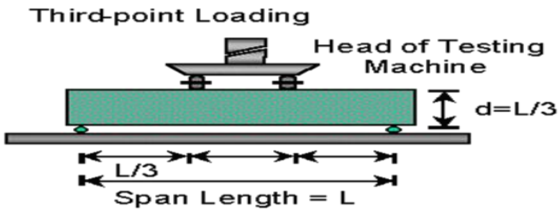

Fig 10: third point loading arrangement

Test procedure

Test specimens stored in water at a temperature of 24o C to 30o C for 48 hours before testing will be tested immediately on removal of water whilst they are still in a wet condition. The dimensions will be noted before testing. No preparation of the surfaces will be required.

Placing the specimen in the testing machine

The bearing surfaces of the supporting and loading rollers are wiped clean and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen will then be placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20 or 13.3 cm apart. The axis of the specimen will be carefully aligned with the axis of the loading device. No packing will be used between the bearing surfaces of the specimen and the rollers. The load will be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 kg/sq. cm/min, that is, at a rate of loading of 400 kg/min for the 15 cm specimens and at a rate of 180 kg/min for the 10 cm specimens. The load will be increased till the specimens fail and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure will be noted.

Fig 11: universal testing machine with three point loading arrangement used for the flexure test

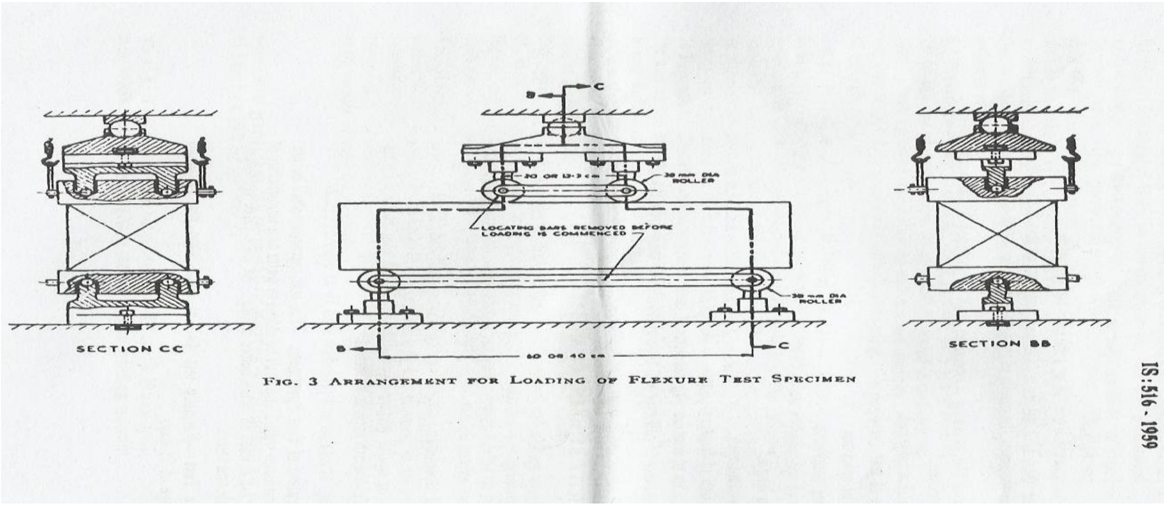

Fig 11: placing of specimen in the testing machine

Fig12: Arrangement for loading of flexure test specimens as per IS : 516 - 1959

Calculations

The flexural strength of the specimen shall be expressed as the modulus of rupture fb, which if ‘a ‘equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq. cm as follows:

Case 1:*when ‘a’ is greater than 20 cm for 15 cm specimen or greater than 13.3 cm for a 10 cm specimen:*

$$f_b = \frac{p \times l}{b \times d^2}$$

Case 2*:When ‘a’ is less than 20 cm but greater than 17 cm for 15 cm specimen or less than 13.3 cm but greater than 11 cm for a 10 cm specimen:*

$$f_b = \frac{3p \times a}{b \times d^2}$$

Where,

b = measured width in cm of the specimen
d= measured depth in cm of the specimen at the point of failure
l = length in cm, of the span on which the specimen was supported
p= maximum load in kg applied to the specimen.

Case 3:*If ‘a ‘ is less than 17 cm for a 15 cm specimen, or less than 11 cm for a 10 cm specimen*:
The results of the test shall be discarded.

Fig 13: Sampling and preparation of materials

Fig 14: Mixing of materials by hand mixing

Fig 15: Dried concrete mixture before addition of water and super-plasticiser

Fig 16: Fixing of moulds

Fig 17: De-moulded samples

Fig 18: Placing dried samples in the curing tank

Fig 19: Failure pattern in concrete beams after flexure test was carried out on them

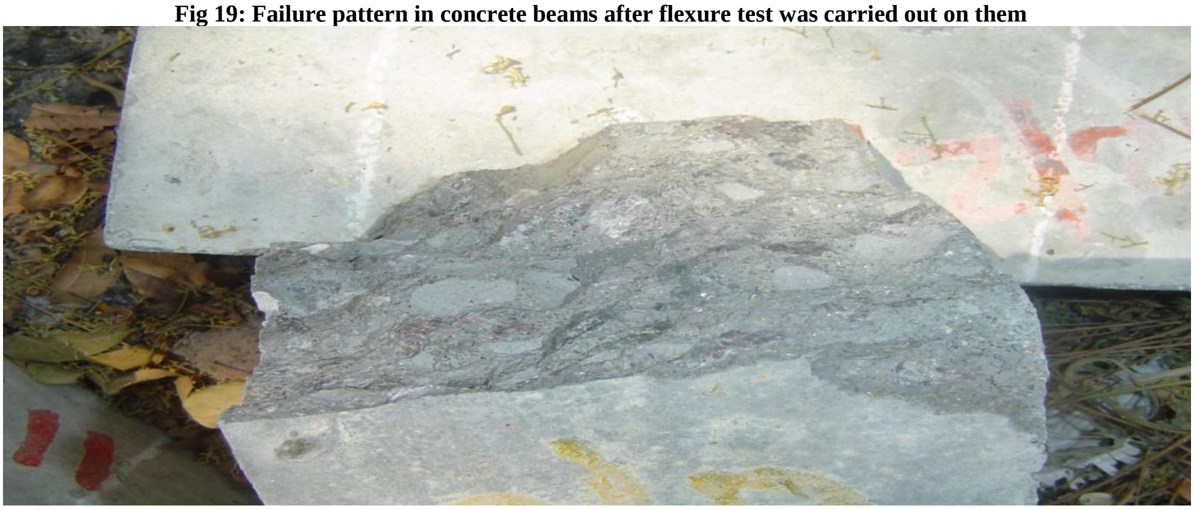

Fig 20: Failure pattern in concrete cubes after undergoing compression test

Fig 21: Failure pattern in concrete beams after undergoing flexure test

IV: RESULTS AND DISCUSSION

4.1 PRESENTATIONOF RESULTS:

The present experimental investigation on the strength properties of triple blended steel fibres reinforced mixes has been carried out. The results obtained are shown by means of graphs and tables.

The overall values of average compressive and average flexural strength obtained after 28 days of curing, have been tabulated in Table 4.1

Tables 4.2.1, 4.2.2, 4.2.3 present the values of 28days compressive strength for various percentages of Silica Fume and Fly ash used as a replacement to cement in M80 grade concrete mix used in present investigation

Different steel fibres percentages like 0%, 0.5% & 1% were used in each case respectively. The same are plotted and shown under graphs. Similarly flexural strength results are presented in tables 4.2.1, 4.2.2 and 4.2.3 and are plotted under graphs.

Table 4.1

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	20	80	77.59	6.60
A1,3		0	40	60	77.12	6.50
A2,1	0	5	0	95	77.89	6.90
A2,2		5	20	75	78.5	7.10
A2,3		5	40	55	78.26	7.00
A3,1	0	10	0	90	78.94	7.10
A3,2		10	20	70	79.48	7.31
A3,3		10	40	50	79.19	7.20
A4,1	0	15	0	85	78.42	6.90
A4,2		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	81.2	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	80.4	8.10

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

4.2.1 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

4.2.2 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

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

4.2.3 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

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

4.3.1 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

4.3.2Variation 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

4.3.3 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

GRAPHS

4.4 Graphs depicting results for compressive strength

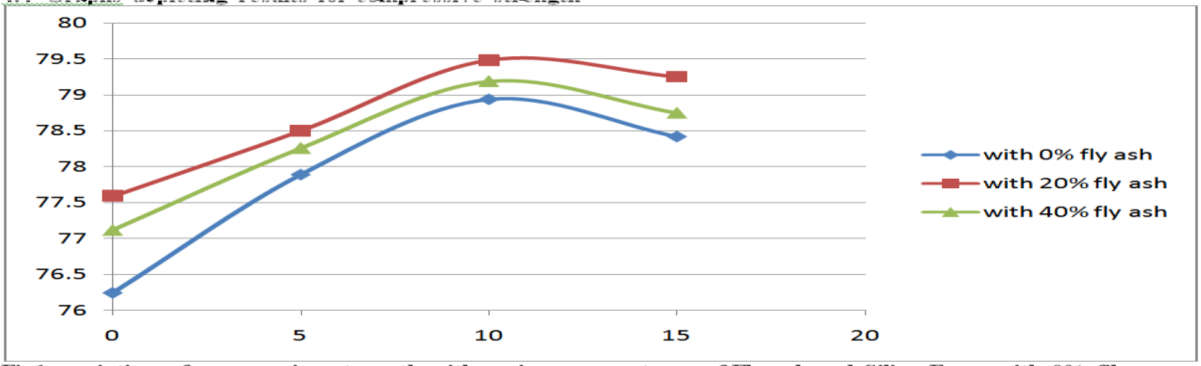

Fig1: variation of compressive strength with various percentages of Fly ash and Silica Fume with 0% fibre

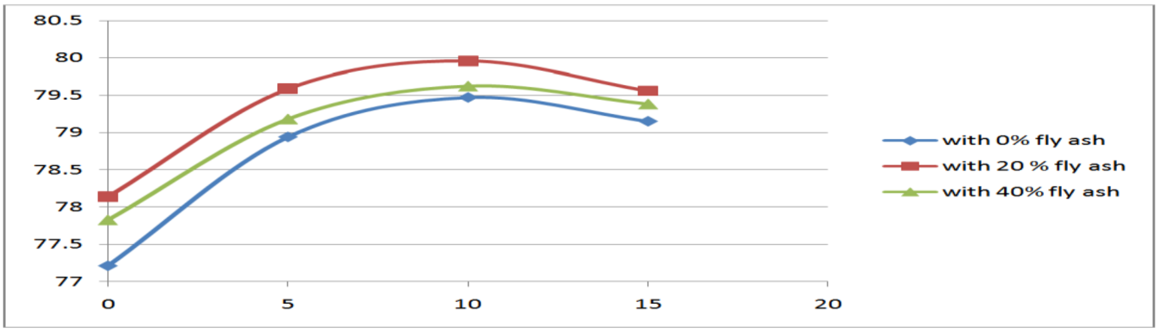

Fig2: variation of compressive strength with various percentages of Fly ash and Silica Fume with 0.5% fibre

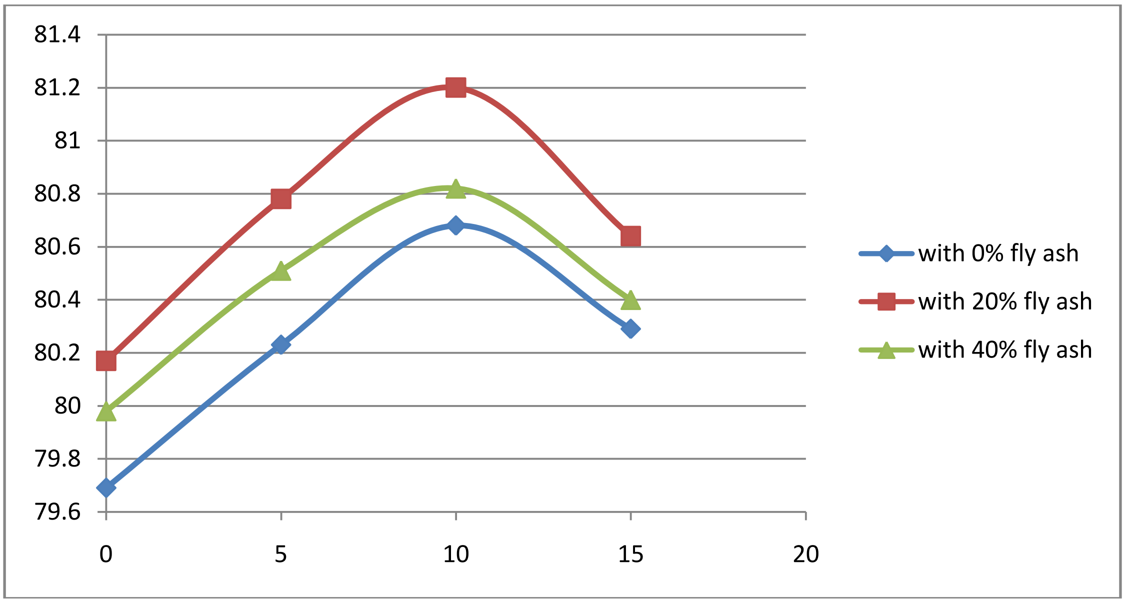

Fig3: variation of compressive strength with various percentages of Fly ash and Silica Fume with 1% fibre

4.4 Graphs depicting results for flexural strength

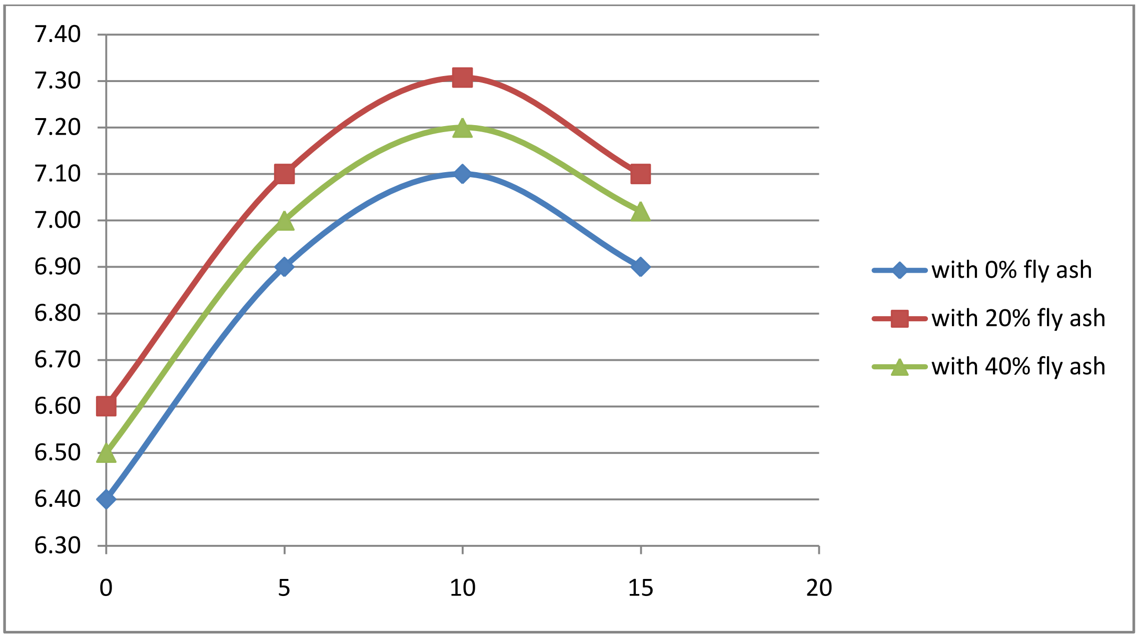

Fig4: variation of flexural strength with various percentages of Fly ash and SilicaFume with 0% fibre

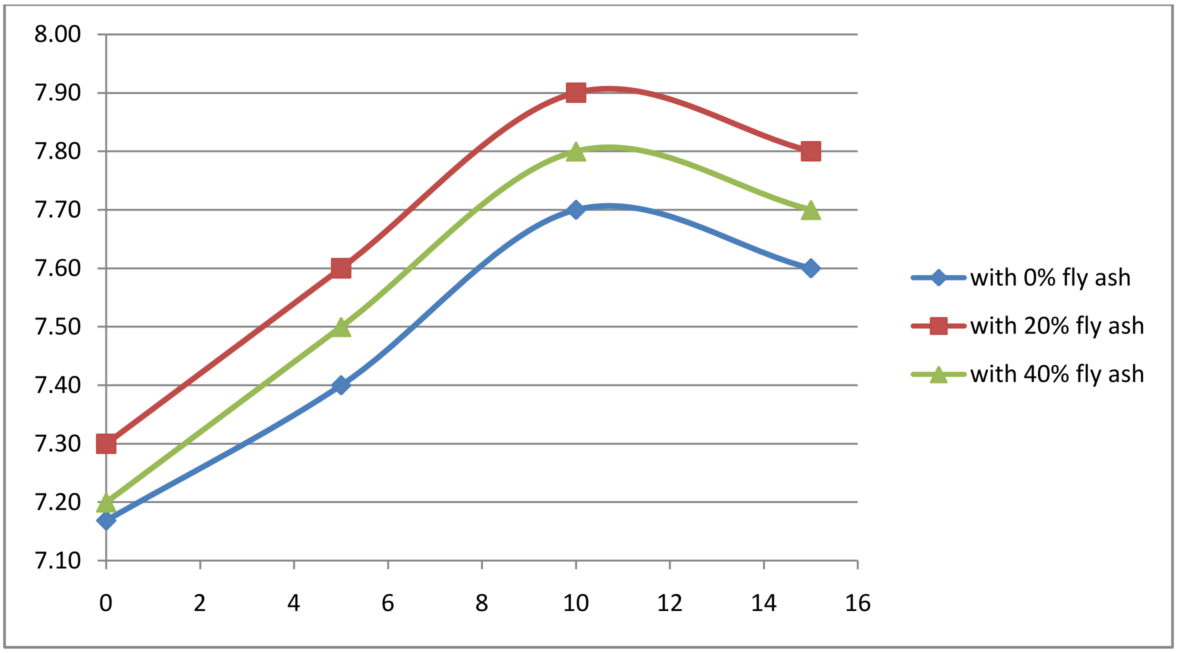

Fig5: variation of flexural strength with various percentages of Fly ash and SilicaFume with 0.5% fibre

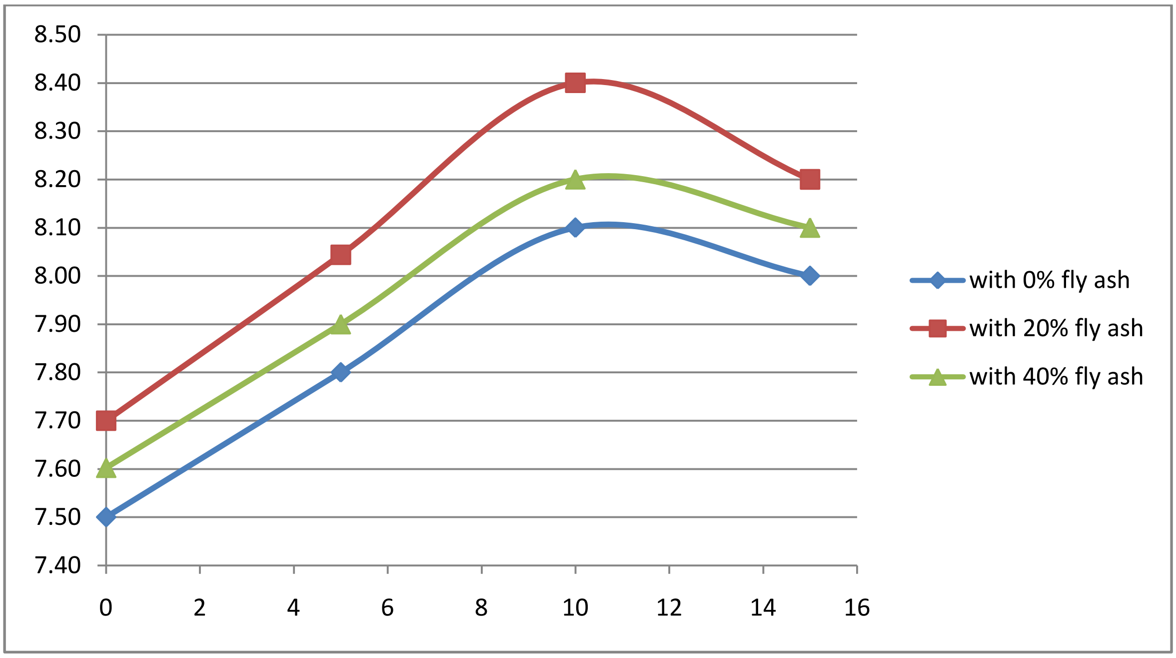

Fig6: variation of flexural strength with various percentages of Fly ash and SilicaFume with 1% fibre

4.6 DISCUSSION OF RESULTS:

The present experimental investigation on the strength properties of triple blended steel fibres reinforced mixes has been carried out. The results obtained are shown by means of graphs and tables.

Tables 4.2.1, 4.2.2, 4.2.3 present the values of 28days compressive strength for various percentages of Silica Fume and Fly ash used as a replacement to cement in M80 grade concrete mix used in present investigation

Different steel fibres percentages like 0%, 0.5% & 1% were used in each case respectively. The same are plotted and shown under graphs. Similarly flexural strength results are presented in tables 4.2.1, 4.2.2 and 4.2.3 and are plotted under graphs.

4.6.1 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 629.03kg/m^3. 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.

When mineral admixtures like fly ash and silica fume were added with various percentages and further when steel fibres were added the workability was becoming very low. Hence superplasticizer had to be added up to a maximum % of 2% to maintain workability.

Hence higher dosages of superplasticizer are required for high strength concrete mixes particularly when mineral admixtures and fibres were employed to maintain workability.

4.6.2 Compressive strength results:

The compressive strength results (tables 4.2.1, 4.2.2, 4.2.3) 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

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

4.6.2 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

4.7 NEED FOR TRIPLE BLENDING

1. In the present experimental investigation, triple blending of ordinary Portland cement was carried out so as to arrive at a mix with optimum properties
2. With the increase in fly ash percentage beyond 20% 28 days strength decreased and with the increase of silica fume % up to an optimum of 10% strength gets increased.
3. On the overall, strength loss with the higher percentages of fly ash is compensated by silica fume
4. Thus an optimum high strength concrete mix possessing optimum strength properties can be obtained resorting to triple blending.

Employing steel fibres in the triple blended SFRC:

1. The presence of steel fibres contributes towards marginal increase in compressive strength and higher increase in flexural strength and tensile strength.
2. Concrete is a material used for making various structural components, where tensile and flexural strengths are important
3. This is achieved by using certain % of metallic fibres like steel fibres. Besides, fibres contribute several other benefits

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

ACKNOWLEDGEMENTS

We are deeply indebted to **Dr.B.L.P.SAWMI**and **Prof. M Bhaskar,**the guides of this project. As a guide he gave us maximum help and coordination in finishing the project work. His past years of experience and teaching steered us to come out with success through the most difficult problems faced by us in understanding several concepts of dynamics of structures during the project work. We would like to place on record our deep sense of gratitude to our guidesfor their cooperation and unfailing courtesy to us at every stage from the inception of this project.

We thank **Dr.SRIDHAR**(professor and Head of the department of civil engineering, VCE) for his co-ordination at various stages of the project work.

V. 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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