EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE USING HYBRID FIBRE AND SAP

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INTRODUCTION

1.1 GENERAL

High performance concrete (HPC) is a concrete that meets special combinations of performance and uniformity requirements which cannot always be achieved routinely using conventional constituents and normal mixing and placing and curing practices. To produce high performance concrete it is generally essential to use chemical and mineral admixtures in addition to the same ingredients, which are generally used for normal concrete. In recent times, many researches are going on for improving the properties of concrete with respect to strength, durability, and performance as a structural material. There are many materials like Fly Ash, Furnace Slag, and Silica Fume etc. One among these special concretes is the Silica Fume concrete which is new emerging as one of new generation construction material in producing high strength and performance concrete for special structures. The interest in Silica Fume started in enforcement of air pollution control in many countries. This implies that the industry had to stop releasing Silica Fume along with other fine gases into the atmosphere. To find solution to this problem studies were initiated and after some investigations, it was found that the Silica Fume could be used as a very useful material in concrete. Silica Fume is being used in concrete for quirt some time in countries like Norway and U.S. very high strength concrete is being

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produced using this very fine highly reactive industrial by product. In India, imported Silica Fume is finding its use now a day.

1.1.1 HIGH PERFORMANCE CONCRETE (HPC)

The large scale production of cement has imposed many environmental problems on one hand and unrestricted depletion of natural resources on the other hand. This threat to our ecology has led to many investigations in the usage of industrial by-products as supplementary cementations material in making concrete. Another problem in this fast growing world is to encompass the durability and the strength of the structures. High Performance Concrete (HPC) has been developed over the last two decades, and was primarily introduced through private sector architectural design and construction such as high rises and parking garages. Public agencies tend to be more conservative than the private sector when it comes to changing specifications, but the public sector now is committed to incorporating this technology in the field. By using of by-products such as Silica Fume with super plasticizer we can achieve high performance concrete, which possess high workability, high strength, and high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. HPC is often called "durable" concrete because its strength and impermeability to chloride penetration makes it last much longer than conventional concrete. High-strength and high-performance concrete are widely used throughout the world and to produce them it is necessary to reduce the water/binder ratio and increase the binder content. Super plasticizers are used in these concretes to achieve the required workability; moreover, different kinds of cement replacement materials are usually added to them because a low porosity and permeability are desirable. Silica Fume is the one of the most popular pozzolanas, whose addition to concrete mixtures results in lower porosity, permeability and bleeding because their oxides (SiO_2) react with and consume calcium hydroxides, which is produced by the hydration of ordinary Portland cement. The main results of pozzolanic reactions are: lower heat liberation and strength development; lime-consuming activity; smaller pore size distribution. In HPC, materials and admixtures are carefully selected and proportioned to form high early strengths, high ultimate strengths and high durability beyond conventional concrete.

1.1.2 NEED FOR HIGH PERFORMANCE CONCRETE

Cementitious materials have been in existence for a long time and it is a well-known fact that their use in construction activity dates back to the time of Babylonians, Romans and Egyptians. These materials had undergone several changes over the ages and during the past four decades. Changes both in the process and production have established that cement and concrete composites are the most economical construction materials as on today. Inspite of these advancements, the rapid deterioration of concrete structures especially, in coastal regions and in industrial locations having aggressive environments, necessitated enhancing the durability aspects of concrete mixers. As a first step, it has been established that the lower w/c ratio results in HSC that can resist the environment degradation better. But the requirements of workability inhibited the initial attempts in this direction, until super plasticizers or high range water reducers were developed. These materials facilitated the production of reasonably high strength concrete having low w/c ratio; through mostly with higher cement contents. However, it was soon learnt that this approach to improve the performance levels necessitated an increase in cement content, making the concretes much more relative to the environments. These aspects resulted in prescribing norms to the minimum and the maximum cement contents permissible in the different environments. Also, it was realized that the high strength alone will not be an effective method for achieving high performance and that the durability of these materials in various environments need a better understanding to achieve an appropriate solution. These necessitated the utilization of industrial wastes having pozzolanic properties in concrete and showed the possibilities of obtaining improvements in durability, besides attaining HSC composites..

1.1.3 SALIENT FEATURES OF HPC

- Low shrinkage with high strength.
- Durability against chloride attack.
- Due to high compressive strength, the cross-sectional area of structural element gets reduced.
- Reduced maintenance cost.
- Increased durability in marine environment.
- Higher Strength at earlier ages and low heat of hydration.

- It has good resistance against abrasion, cavitations and erosion
- Very little micro cracks.
- Long life in severe environments.

1.2 OBJECTIVE

- To incorporate internal curing of HPC by means of Super Absorbent Polymers.
- To study the effect of different compositions of SAP on mechanical properties of HPC.
- To determine the suitability of percentage replacement of silica fume with respect to durability characteristics.
- To investigate the effects of HPC mixes made with different combination of silica fume and 0.3% glass fibre.
- The durability studies such as acid résistance, impact strength, saturated water absorption and permeability test were carried out for the concrete mixtures with mineral admixtures.

EXPERIMENTAL INVESTIGATION

4.1 SIGNIFICANCE OF THE PROJECT

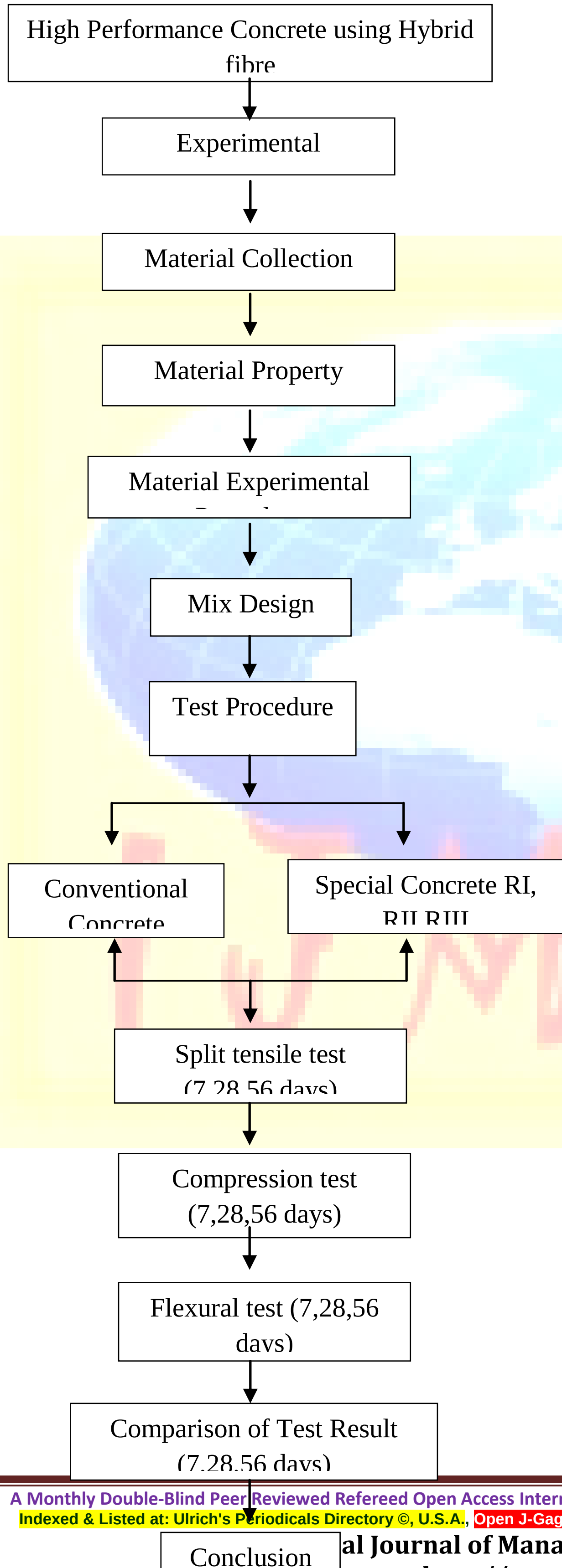
Now-a-days HPC has become an object of intensive research due to its growing use in the construction practice. However, low w/c ratio (below 0.4) of HPC, which is necessary for the enhancement of strength and durability, leads to self desiccation of concrete, as a result of cement hydration process. This causes considerable volume changes, which in turn lead to cracking as well as strength reduction.

Internal Curing of concrete using small well distributed water reservoirs seems to be able to solve this problem. In this study, the effect of Super Absorbent Polymer as an agent for internal curing on mechanical strengths of concrete with low w/c is investigated.

The effects of adding polymer on mechanical strength of concrete are studied experimentally and the results are discussed.

4.2 DEFINITION OF INTERNAL CURING (IC)

METHODOLOGY



The ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing Water." Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, super absorbent polymers, or saturated wood fibres) Created. 'Internal curing' is often also referred as 'Self–curing.'

4.3 NECESSITY OF INTERNAL CURING (IC)

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- Often specially in HPC, it is not easily possible to provide curing water from the top surface at the rate required to satisfy the ongoing chemical shrinkage, due to the extremely low permeabilities often achieved.

4.4 POTENTIAL MATERIALS FOR INTERNAL CURING

The following materials can provide internal water reservoirs:

- Lightweight Aggregate (natural and synthetic, expanded shale),
- LWS Sand (Water absorption =17 %)
- LWA 19mm Coarse (Water absorption = 20%)
- Super-absorbent Polymers (SAP) (60-300 mm size)
- SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)
- Wood powder

4.5 ADVANTAGES OF INTERNAL CURING

- Internal curing (IC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do. In low w/c ratio mixes (under 0.43 and increasingly those below 0.40) absorptive lightweight aggregate, replacing some of the sand, provides water that is desorbed into the mortar fraction (paste) to be used as additional curing water. The cement, not hydrated by low amount of mixing water, will have more water available to it.

- IC provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.

- IC maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally & externally induced strains can cause cracking.

- IC can make up for some of the deficiencies of external curing, both human related (critical period when curing is required is the first 12 to 72 hours) and hydration related (because hydration products clog the passageways needed for the fluid curing water to travel to the cement particles thirsting for water).

Following factors establish the dynamics of water movement to the unhydrated cement particles:

- Thirst for water by the hydrating cement particles is very intense,
- Capillary action of the pores in the concrete is very strong, and
- Water in the properly distributed particles of LWA (fine) is very fluid.

4.6 CONCRETE DEFICIENCIES THAT IC CAN ADDRESS

The benefits from IC can be expected when

- Cracking of concrete provides passageways resulting in deterioration of reinforcing steel,
- low early-age strength is a problem,
- permeability or durability must be improved,

- Rheology of concrete mixture, modulus of elasticity of the finished product or durability of high fly-ash concretes are considerations.
- Need for reduced construction time, quicker turnaround time in precast plants, lower maintenance cost, greater performance and predictability.

4.7 IMPROVEMENTS TO CONCRETE DUE TO IC

- Reduces autogenous cracking,
- largely eliminates autogenous shrinkage,
- Reduces permeability,
- Protects reinforcing steel,
- Increases mortar strength,
- Increases early age strength sufficient to withstand strain,
- Provides greater durability,
- Higher early age (say 3 day) flexural strength
- Higher early age (say 3 day) compressive strength,
- Lower turnaround time,
- Improved rheology
- Greater utilization of cement,
- Lower maintenance,
- use of higher levels of fly ash,
- higher modulus of elasticity, or
- greater curing predictability,
- higher performance,
- does not adversely affect pumpability
- Reduces effect of insufficient external curing.

4.8 GLASS FIBER REINFORCED POLYMER (GFRP)

Concrete is extremely strong in compression but weak in tension. If the tensile nature of the concrete increases the flexural behavior. Tensile strength can be increased by many techniques. One of the latest techniques is Fiber Reinforced Polymer (FRP). FRP is available in many forms such as mats, pultruded sections, fibers etc. In most of cases it combines with resin to give to give a composite technique. But in this project the fibers are mixed in concrete to have a composite action with concrete.

4.8.1 SALIENT FEATURES OF GFRP

- High Alkali resistance
- High dispersion
- Immunity to corrosion
- High number of fibers
- Excellent mechanical strength and stiffness
- High flexibility, and
- High consistency

4.8.2 DURABILITY

High strength concrete alone cannot perform well in aggressive environments. Hence, the production of HPC involves appropriate selection and proportioning of the constituents to produce a composite mainly characterized by its low porosity and fine pore structure. Thus in turn, improve the resistance of concrete to the penetration of harmful substances such as chloride and sulphate ions, carbon dioxide, water and oxygen and hence the enhanced durability performance. The improved pore structure of HPC is mainly achieved by the use of chemical and mineral admixtures. The mineral admixtures provide additional reduction to the porosity of the mortar matrix and improve the influence with the aggregate. To trace the history of concrete, more attention has been given to the aspect of its strength. Concrete performance has been specified and evaluated in terms of its compressive strength. When the compressive strength is higher the expected performance will be better. However, experience has shown that considerations of durability become more important for structures, especially those exposed to severe environmental conditions. This has led to the development of high performance concrete (HPC) which considers simultaneously both aspect of strength and durability. The production of HPC involves appropriate selection and proportioning of the constituents to produce a composite concrete mainly characterized by its low porosity and fine pore structure. The improved and refined pore structure of HPC is mainly achieved by the use of chemical and mineral admixtures. The mineral admixtures provide additional reduction to the porosity of the mortar matrix and improve the porosity with the aggregates. The most essential factor governing concrete durability is the penetration of water, gas and ions which depends on the micro structure and porosity, and above all on the permeability of cement paste. Hence in this project, experimental investigation were carried out on the HPC test specimens to ascertain the durability-related property such as saturated water absorption, acid resistance, permeability and impact strength of the designed trial mixes. Minimum three specimens were tested for each trial mix for each test. The entire tests were performed as per specifications.

4.9. SUPER ABSORBENT POLYMERS

4.9.1 GENERAL

Super absorbent polymers (also called slush powder) are polymers that can absorb and retain extremely large amounts of a liquid relative to their own mass. Water absorbing polymers, which are classified as hydro gels when cross-linked; absorb aqueous solutions through hydrogen bonding with water molecules. A SAP's ability to absorb water is a factor of the ionic concentration of the aqueous solution. In deionized and distilled water, a SAP may absorb 500 times its weight (from 30–60 times its own volume), but when put into a 0.9% saline solution, the absorbency drops to maybe 50 times its weight.

The total absorbency and swelling capacity are controlled by the type and degree of cross-linkers used to make the gel. Low density cross-linked SAP generally has a higher absorbent capacity and swells to a larger degree. These types of SAPs also have a softer and stickier gel formation. High cross-link density polymers exhibit lower absorbent capacity and swell, but the gel strength is firmer and can maintain particle shape even under modest pressure.

4.9.2 SUPER-ABSORBENT POLYMER (SAP) FOR IC

The common SAPs are added at rate of 0–0.6 wt % of cement. The SAPs are covalently cross-linked. They are Acrylamide/acrylic acid copolymers. One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm; another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. The size of the swollen SAP particles in the cement pastes and mortars is about three times larger due to pore fluid absorption. The swelling time depends especially on the particle size distribution of the SAP. It is seen that more than 50% swelling occurs within the first 5 min after water addition.

MATERIALS USED

5.1 INTRODUCTION

This chapter deals with the study of various materials used.

5.2 MATERIALS USED

- Cement: Portland Pozzolona cement, 43 Grade conforming to IS:12269 – 1987.
- Fine aggregate: Locally available river sand conforming to Grading zone II of IS: 383 – 1970.
- Coarse aggregate: Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 – 1970.
- Silica fume: Obtained from ELKEM India (P) Ltd., Navi Mumbai conforming to ASTM C 1240 as mineral admixture in dry form.
- A commercially available Poly Carboxylic Ether based super plasticizer was used as chemical admixture to enhance the workability of the concrete.
- Water: potable water.
- Glass fiber – FORSAAC Coimbatore
- Super Absorbent polymer – ALCHEMY Bangalore.

5.3 MATERIAL PROPERTIES

5.3.1 CEMENT:

Portland Pozzolona cement (43 Grade) was used for casting all the Specimens. To produce high performance concrete, the utilization of high strength cements is necessary.

Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

Specific Gravity of Cement (IS: 4031)

In concrete Technology, specific gravity of cement is made use of in design calculations of concrete mixes, and it is also used to calculate its specific surface. The specific gravity is defined as the ratio between the weight of given volume of cement to the weight of an equal volume of water. The most popular method of determining specific gravity of cement is by the use of kerosene which doesn't react with cement.

Initial and Final Setting Time of Cement

As soon as water is added to cement, hydration of cement starts which results in changing the water cement mix from fluid to solid (setting). Initial Setting Time is that time period between the times at which water is added to cement paste, placed in the Vicat'smould 5mm to 7mm from the bottom of the mould. It is usually desirable that concrete should be placed and compacted before Initial Set has started and not disturbed after.

In the second stage of hydration, hardening takes place and the Final Setting Time is that time period between the time water is added to cement and the time at which needle with annular collar attachment fails to makes an impression on the surface of cement paste.

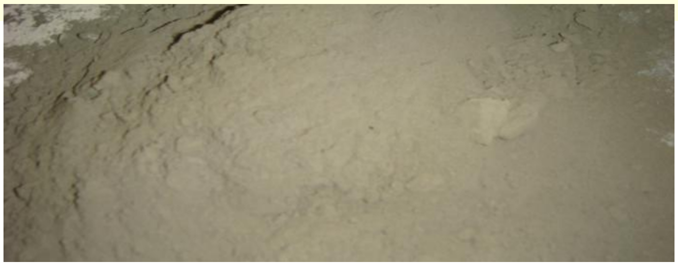


Fig 5.1 CEMENT

Table 5.1 PROPERTIES OF CEMENT

S. No.	Property Of Cement	Values
1	Fineness Of Cement	7.5%
2	Grade Of Cement	43
3	Specific Gravity	3.15
4	Initial Setting time	28 min
5	Final Setting Time	600 min
6	Normal consistency	35%

5.3.2 FINE AGGREGATE:

Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

Fig 5.2 FINE AGGREGATE

Table 5.2 PROPERTIES OF FINE AGGREGATE

S. No.	Properties	Values
1	Specific Gravity	2.65
2	Fineness Modulus	2.25
3	Water absorption	1.5%

5.3.3 COARSE AGGREGATE:

Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

Fig.5.3 COARSE AGGREGATE

Table 5.3 PROPERTIES OF COARSE AGGREGATE

S. No.	Properties	Values
1	Specific Gravity	2.655
2	Size Of Aggregates	Passing Through 12.5 mm Sieve
3	Fineness Modulus	5.96
4	Water absorption	2.0%
5	Impact Test	15.2%
6	Crushing Test	22.5%

5.3.4 SUPER PLASTICIZER

The inter particle friction between fibers and aggregates controls the orientation and distributions of the fibers and consequently the properties of concrete. Therefore Napthalene-

Formaldehyde Sulphonated based super plasticizer is added as a friction reducing admixture to improve the cohesiveness of mix.

Fig.5.4 SUPER PLASTICIZER CONPLAST SP 337, SULPHONATED NAPHTHALENE POLYMERS

In this investigation, Super plasticizer Conplast SP 337, based on Sulphonated naphthalene polymers, complies with IS 9103-1999\and ASTM C-494 was used.

Color	:	Brown
Specific Gravity	:	1.22 to 1.225
Chloride Content	:	Nil
Solid Contents	:	40%

ADVANTAGES

- Reduction in water-cement ratio of the order of 20-25%.
- Flowing, pumpable concrete.
- Excellent workability and retention even in extreme temperatures.
- Compatible with mineral admixtures.
- Waterproofing effect by drastic reduction in permeability of concrete.
- High quality concrete of improved durability reduces heat of hydration even with very high strength cements.

5.3.5 SILICA FUME

Silica fume is one of the artificial pozzolans, commonly used as mineral admixture in HPC. Silica fume is very fine non- crystalline silica, produced in electric arc furnaces, as a by product of the production of elemental silicon or alloys containing silicon also known as condensed silica fume or micro silica.

Fig 5.5 SILICA FUME

There are two reactions in the silica fume, Pozzolanic reactions are, Silica fume reacts with the calcium hydroxide, which is liberated during process of Hydration, about 22-24 percent and produces calcium-silicate-hydrate (C-S-H). The following are the chemical reactions that are taking place.

- Portland cement reaction : C_3+H = C-S-H+CH
- Portland reaction of silica fume : S+CH+H = C-S-H

Particle packing are,

The second function silica fume performs in cementitious compounds is a physical one. Because silica fume is 100 to 150 times smaller than cement particle it can fill the voids created by free water in the matrix. This function, called particle packing, refines the microstructure of concrete, creating a much denser pore structure. Impermeability is dramatically increased, because silica fume reduces the number and size of capillaries that would normally enable contaminants to infiltrate the concrete. Thus silica fume modified concrete is not only stronger, it lasts longer, because it's more resistant to aggressive environments. As a filler and pozzolan, silica fume's dual actions in cementitious compounds are evident throughout the entire hydration process.

5.3.5.1 GENERAL CHARACTERISTICS

The SF is the another type of pozzolana and its merit being the 'Silica Fume Concrete' produced using this to attain compressive strength of 96 MPa which is 2 to 3 times the strength of Portland Cement Concrete (PCC). This result in reduction in weight and size of structure, lower its permeability and makes it as a very durable material.

SF used as an admixtures, improves the properties of fresh and hardened concrete. Due to high surface area of SF, SFC requires more water for obtaining the given slump. The fresh SFC mix is cohesive and there is no risk of segregation during handling of concrete and desired finish can be achieved. Silica Fume increases the electrical resistivity of concrete because it reduces the rate of carbonation of concrete. For instance PCC has electrical resistivity of 4200 ohms-cm and SFC produced with 20% SF in cements has 110,000 ohms cm.

5.3.5.2 PHYSICAL PROPERTIES OF SILICA FUME

The particle size, color, oversize, specific gravity, etc. are explained briefly:-

- **Particle Size**: - SF particles are smooth, spherical size is 1/100 the diameter of Portland cement particle and average particle diameter lies between 0.1 to 0.2 micron range.

- **Fineness**: - The specific surface area of SF as measured by nitrogen absorption method usually lies between 13sq.m/g to 28 sq.m/g. Generally the SF has the fineness value of about 22 sq.m/g.

- **Colour**: - The colour of SF depends on carbon content; lower the carbon content of SF, the lighter is shade of grey. Usually, ferrosilicon furnaces manufacturing low silicon content alloys shoe darker silica fume.

- **Specific Gravity**: - The specific gravity of SF produced from high quality silicon and high grade ferrosilicon alloys typically ranges between 2.2 and 2.3,

Table 5.4 CHEMICAL PROPERTIES OF SILICA FUME

Chemical parameter	Silica fume (%)
SiO_2	97.1
Al_2O_3	0.4
Fe_2O_3	0.3
CaO	0.3
MgO	0.0
SO_3	0.2
Total alkalies (Na_2O)	0.0
LOI	1.7

5.3.6 WATER

Casting and curing of specimens were done with the potable water that is available in the college permises.

Fig 5.5 WATER

5.3.7 Super-Absorbent Polymer (SAP)

The common SAPs are added at rate of 0–0.6 weightt % of cement. The SAPs are covalently cross-linked. They are Acryl amide/acrylic acid copolymers. One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm; another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. The size of the swollen SAP particles in the cement pastes and mortars is about three times larger due to pore fluid absorption. The swelling time depends especially on the particle size distribution of the SAP. It is seen that more than 50% swelling occurs within the first 5 min after water addition.

Fig.5.6 Super Absorbent Polymer

Figure.5.7 SAP before and after addition of water

5.3.8 GLASS FIBRES

Glass fibres with an aspect ratio of 857:1 are used.

Fig. 5.8 GLASS FIBRES

PHYSICAL PROPERTY

Filament diameter	-	14 μ
Specific gravity	-	2.6
Length	-	12 mm
Specific surface area	-	105 m^2/kg
Aspect ratio	-	857:1

ADVANTAGES OF GLASS FIBERS

- 85 percent Reduction in plastic shrinkage cracking
- Reduction in bleeding- 25 percent
- Increase in compressive strength by 13 percent
- Increase in flexural strength by 15 percent
- Reduction in permeability by 50 percent
- Reduction in free/thaw expansion by 66 percent

EXPERIMENTAL PROCEDURE

6.1 CONSTITUENT MATERIALS USED

Materials that are used for making concrete for this study will be tested before casting the specimens. The preliminary tests will be conducted for the following materials.

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Silica fume
- Super Absorbent Polymer
- Glass Fibre

6.1.1 Cement

Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cements (e.g., Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g., lime and gypsum plaster) must be kept dry in order to retain their strength. The most important use of cement is the production of mortar and concrete. The bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

6.1.2 Aggregates

"Fine aggregate" is defined as material that will pass a No. 4 sieve and will, for the most part, be retained on a No. 200 sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Coarse aggregate is a material that will pass the 3-inch screen and will be retained on the No. 4 sieve. As with fine aggregate, for increased workability and economy as reflected by the use of less cement, the coarse aggregate should have a rounded shape. Even though the definition seems to limit the size of coarse aggregate, other considerations must be accounted for.

Coarse aggregates:

Broken granite stone/gravel and its size is 4.75mm gauge plus i.e., retained on 4.75mm IS sieve.

Table 6.1 PROPERTIES OF COARSE AGGREGATE

S. No.	Properties	Values
1	Specific Gravity	2.65
2	Size Of Aggregates	Passing Through 4.75 mm Sieve
2	Fineness Modulus	5.96

All in aggregates:

Sieve analysis enables us to ascertain the proportions of different sizes of aggregate. The results which are generally given as percentage of total aggregate passing through each of sieve are considered as a method of standardization of grading of aggregates for most economical mix and workability with minimum quantity of cement.

6.1.3 Super plasticizers

Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement- super plasticizer incompatibilities.

6.1.4 Silica Powder

Silica fume in powder form is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance.

These improvements stem from both the 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 and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

Effect of silica fume on different properties of fresh and harden concrete:-

a) **Workability**: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

b) **Segregation and Bleeding**: Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

6.2 FRESH CONCRETE PROPERTIES

6.2.1 Slump Test

Fresh concrete when unsupported will flow to the sides and sinking in height will take place. This vertical settlement is known as slump.

The workability (ease of mixing, transporting, placing and compaction) of concrete depends on wetness of concrete (consistency) i.e., water content as well as proportions of fine aggregate to coarse aggregate and aggregate to cement ratio.

The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

Table 6.2 SLUMP RESULT

Ratio	Slump value
Conventional Concrete	
Control mix	26mm
Special Concrete M40	
Ratio I	25.65mm
Ratio II	26.52mm
Ratio III	26.20mm

6.3 HARDENED CONCRETE PROPERTIES

6.3.1 Compression Test on Concrete Cubes

The determination of the compressive strength of concrete is very important because the compressive strength is the criterion of its quality. Other strength is generally prescribed in terms of compressive strength. The strength is expressed in N/mm^2. This method is applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions. The concrete to be tested should not have the nominal maximum size of aggregate more than 38mm test specimens are either 15cm cubes or 15cm diameter, 30cm used. At least three specimens should be made available for testing. Where every cylinder is used for compressive strength results the cube strength can be calculated as under.

Minimum cylinder compressive strength =

0.8 x compressive strength cube (10 cm x 10 cm)

The concrete specimens are generally tested at ages 7 day, 28 days and 56 days.

6.3.2 Tensile Strength of Concrete (Split Tensile Test)

Concrete is strong in compression but weak in tension. Tension stresses are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradient etc.

In concrete road slab this tensile stresses are developed due to wheel loaded and volume changes in concrete are available to determine this. Split test is one of the indirect methods available to find out the tensile strength.

6.3.3 Flexural strength of Concrete

It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 6x6 inch concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as “Modulus of Rupture” (MR) in psi. Flexural MR is about 12 to 20 percent of compressive strength.

MIX DESIGN

7.1 DEFINITION

Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible.

7.2 OBJECTIVE OF MIX DESIGN

The objective of concrete mix design as follows.

The first objective is to achieve the stipulated minimum strength.

The second objective is to make the concrete in the most economical Manner. Cost wise all concrete's depends primarily on two factors, namely cost of material and cost of labour. Labour cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete.

7.3 FACTORS TO BE CONSIDERED IN MIX DESIGN

- Grade of concrete
- Type of cement
- Type & size of aggregate
- Cement content
- Type of mixing & curing
- Water /cement ratio
- Degree of workability
- Density of concrete
- Air content

7.4 MIX DESIGN

Design Stipulations:

Grade Designation	= M-40
Type of cement	= P.P.C-43 grade
Fine Aggregate	= Zone-II
Sp. Gravity Cement	= 3.15

Sp. Gravity Fine Aggregate = 2.61

Sp. Gravity Coarse Aggregate = 2.65

Mix Calculation:

1. Target Mean Strength = 40 + (5 X 1.65) = 48.25 MPa

2. *Selection of water cement ratio*

Assume water cement ratio = 0.35

3. *Calculation of cement content: -*

Assume cement content 475 kg / m^3

4. *Calculation of water: -*

475 X 0.35 = 150 kg which is less than 186 kg (As per Table No. 4, IS: 10262)

Hence o.k.

5. Calculation for C.A. & F.A. (As per IS: 10262, Cl. No. 3.5.1)

$$V = [\ W + (C/S_c) + (1/p)\ .\ (f_a/S_{fa})\ ]\ x\ (1/1000)$$

$$V = [\ W + (C/S_c) + \{1/(1-p)\}\ .\ (ca/S_{ca})\ ]\ x\ (1/1000)$$

Where

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air,

W = mass of water (kg) per m^3 of concrete,

C = mass of cement (kg) per m^3 of concrete,

S_c = specific gravity of cement,

(p) = Ratio of fine aggregate to total aggregate by absolute volume,

(fa) , (ca) = total mass of fine aggregate and coarse aggregate (kg) per m^3 of Concrete respectively, and

S_{fa} ,S_{ca} = specific gravities of saturated surface dry fine aggregate and Coarse aggregate respectively.

As per Table No. 3, IS-10262, for 20mm maximum size entrapped air is 2%.

Assume F.A. by % of volume of total aggregate = 36.5 %

0.98 = [160 + (400 / 3.15) + (1 / 0.365) (Fa / 2.61)] (1 /1000)

=>Fa = 588.2 kg

Say Fa = 588 kg.

0.98 = [160 + (400 / 3.15) + (1 / 0.635) (Ca / 2.655)] (1 /1000)

=>Ca = 1159.37 kg.

Say Ca = 1159 kg.

Hence Mix details per m^3

Table 7.1 Mix Proportion

Cement (kg)	FA (kg)	CA (kg)	Silica Fume (kg)	Super Plasticizer (kg)	Water (liter)
475	588	1159	25	5	150

Cement = 475 kg

Water = 150 kg

Fine aggregate = 588 kg

Coarse aggregate = 1159 kg

Water: cement: F.A.: C.A. = 0.35: 1: 1.25: 2.42

TESTING PROCEDURE

8.1 General Procedure

Within the experimental research program concerning the development of mechanical properties of a high performance reference concrete of grade M40 (REF) was considered with the following composition, accordingly. The w/c-ratio is 0.32. The w/b ratio is 0.30. The super plasticizer is poly carboxylic ether. Coarse aggregates were chosen, having a particle size mainly varying between 2 mm and 20 mm. The silica fume, containing more than 90% of amorphous SiO2, has a specific surface area of 20 m^2/g. A previous study, with a similar HPC composition (w/b ratio of 0.33), indicates tensile failure of the HPC after 6 days due to internal restraint of the autogenous shrinkage. In order to mitigate this and to prevent early-age cracking, additional internal curing water will be provided by means of SAP. The SAP used, is a suspension polymerized, covalently cross linked acryl amide/acrylic acid copolymer. The particle density is 785 kg/m^3 (diameter between 80 μm and 150 μm) and has a water absorption capacity of 45 g/g after 5 min (the approximate mixing time). Based on this absorption level, the amount of SAP to be added to the concrete is estimated, aiming for an amount of internal curing water equal to 45 kg/m3 (SAP45), 67.50 kg/m3 (SAP67.5) and 90 kg/m3 (SAP90). This leads to a corresponding SAP amount of respectively 1 kg/m^3, 1.5 kg/m^3 and 2.00 kg/m^3. The amount of curing water itself has to be added to the concrete during mixing. As compensation, the sand content is reduced in order to obtain 1 m^3 of concrete. Concrete mixes are made using a planetary mixer according to the following mixing procedure: first the dry components (binder, fine and coarse aggregates, SAP) are mixed for 1 min, and afterwards the water glass fibre and super plasticizer are added and mixing continues for another 4 min. An intensive experimental program is performed to study the effect of internal curing on different types of concrete properties: (i) fresh properties (slump and density); (ii) mechanical properties (compressive strength, flexural strength, splitting tensile strength and elastic modulus).

8.1.1SPLIT TENSILE TEST

- The size of cylinders 300 mm length and 150 mm dia are placed in the machine such that load is applied on the opposite side of the cubes are casted. Align carefully and load is applied, till the specimen breaks. The formula used for calculation.

Split tensie strength = 2P/ □ dl

Fig 8.1 SPLIT TENSILE TESTING MACHINE

8.1.2 COMPRESSIVE STRENGTH TEST

At the time of testing, each specimen must keep in compressive testing machine. The maximum load at the breakage of concrete block will be noted. From the noted values, the compressive strength may calculated by using below formula.

Compressive Strength = Load / Area

Fig 8.2 COMPRESSIONS TESTING MACHINE

8.1.3 FLEXURAL STRENGTH TEST

During the testing, the beam specimens of size 5000mmx100mmx100mm were used. Specimens were dried in open air after 28 days of curing and subjected to flexural strength test under flexural testing assembly. Apply the load at a rate that constantly increases the maximum stress until rupture occurs. The fracture indicates in the tension surface within the middle third of span length. The flexural strength was obtained using the formula (R)

R = Pl/bd^2

Where, R = Modulus of rupture (N/mm^2)

P = Maximum applied load (N/mm^2)

l = Length of specimen (mm)

b = Width of specimen (mm)

d = depth of specimen (mm)

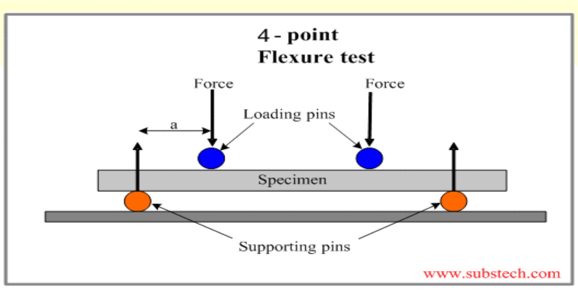
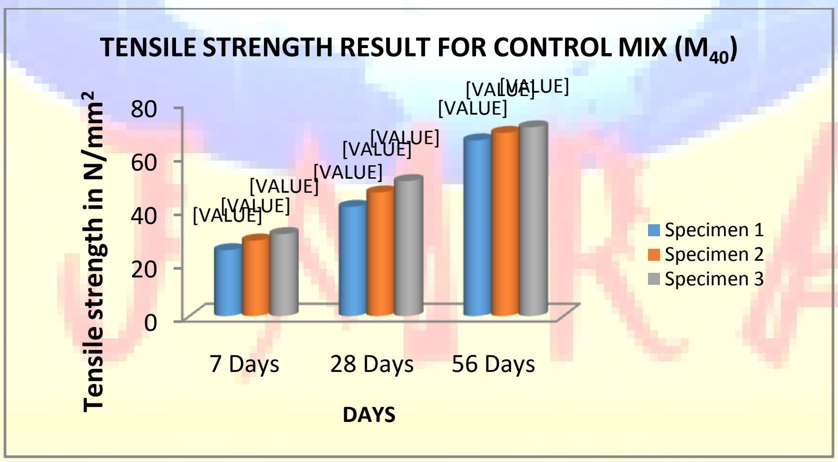


Fig 8.3 FLEXURAL STRENGTH TEST

8.2 TEST RESULT FOR CONROLLED CONCRETE

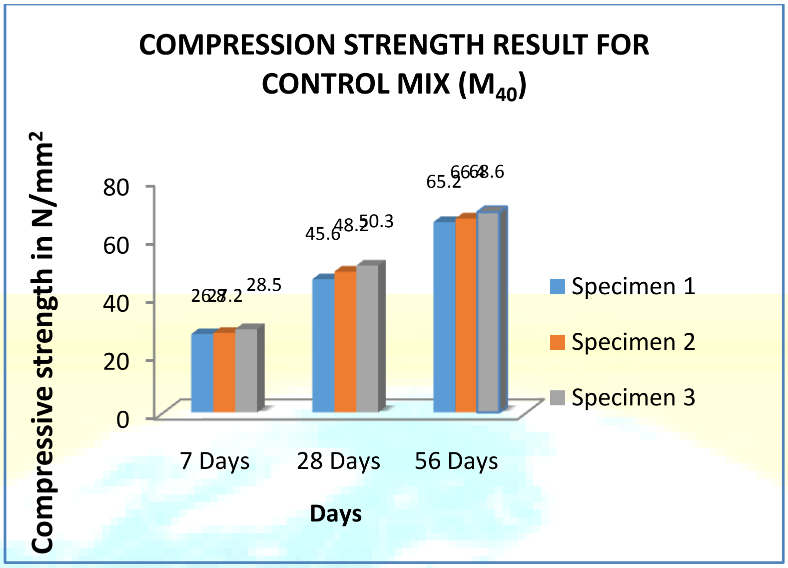
8.2.1 SPLIT TENSILE TEST FOR CYLINDER

Control Mix	Best Tensile Strength in N/mm^2		
	7 Days	28 Days	56 Days
M40	24.6	40.8	65.6
	28.2	46.2	68.4
	30.6	50.4	70.5



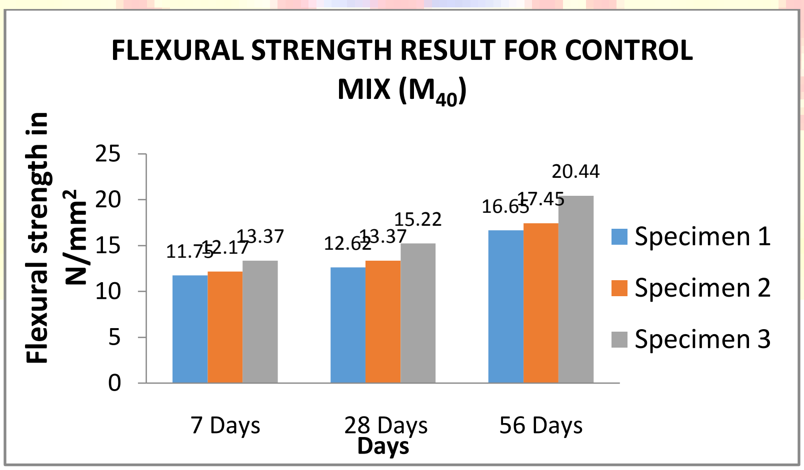
8.2.2 COMPRESSIVE STRENGTH OF CUBE

Control Mix	Best Compressive Strength in N/mm^2		
	7 Days	28 Days	56 Days
M40	26.8	45.6	65.2
	27.2	48.2	66.4
	28.5	50.3	68.6



8.2.3 FLEXURAL STRENGTH OF BEAM

Control Mix	Best Flexural Strength in N/mm^2		
	7 Days	28 Days	56 Days
M40	11.75	12.62	16.65
	12.17	13.37	17.45
	12.37	15.22	20.44



8.3 RATIOS FOR SPECIAL CONCRETE (EXTRA INGREDIENTS)

RATIO –I

Glass fibre – 1%

Silica fume – 5% by replacement of cement

Superplasticizer – 10 ml per Kg of cement

Super Absorbent Polymer – 0.25%

RATIO - II

Glass fibre – 2%

Silica fume – 7.5% asper above condition

Superplaticizer – Aspercodition

Super Absorbent Polymer – 0.35%

RATIO – III:

Glass fibre – 3%

Silica fume – 10%

Superplaticizer – Asper condition

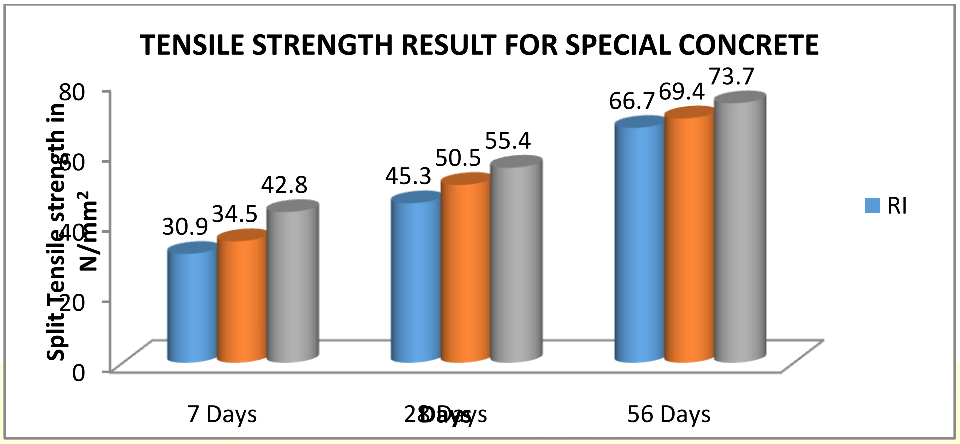
Super Absorbent Polymer – 0.5%

Above all ingredients are added by weight of cement.

8.4 TEST RESULT FOR SPECIAL CONCRETE

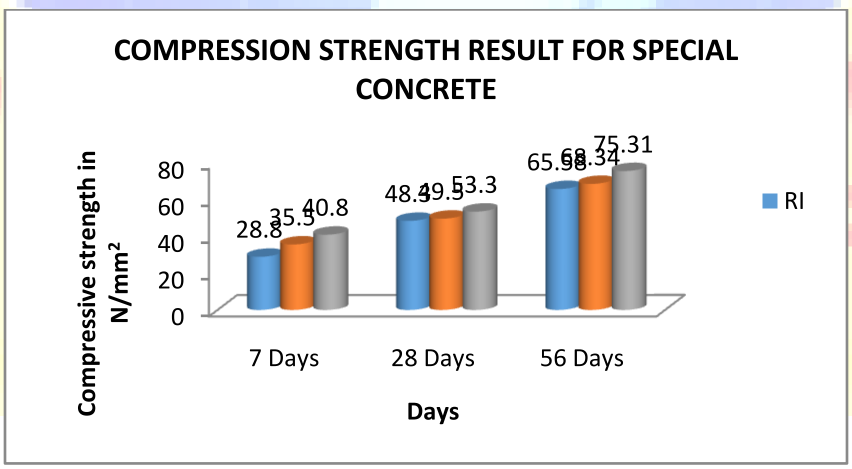
8.4.1 SPLIT TENSILE STRENGTH OF CUBE

Grade of concrete	Ratio	Best Compressive Strength in N/mm^2		
		7 Days	28 Days	56 Days
M40	I	26.8	45.3	66.7
	II	34.5	50.5	69.4
	III	42.8	55.4	73.7



8.4.2 COMPRESSIVE STRENGTH OF CUBE

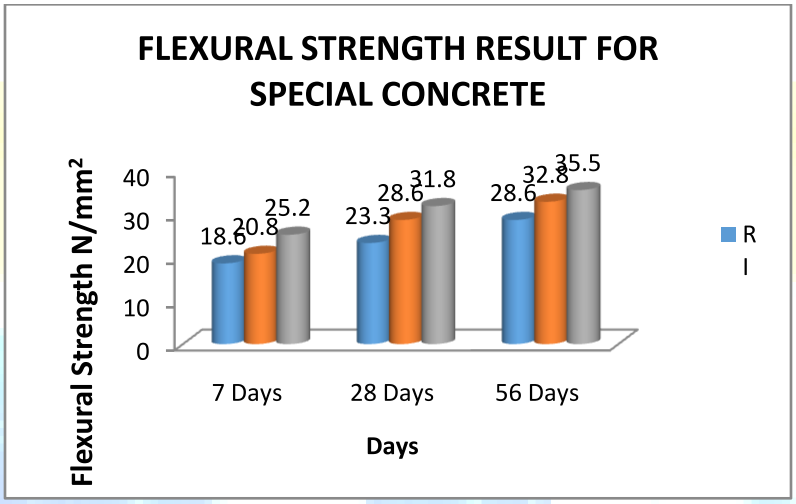
Grade of concrete	Ratio	Best Compressive Strength in N/mm^2		
		7 Days	28 Days	56 Days
M40	I	28.8	48.3	65.58
	II	35.5	49.5	68.34
	III	40.8	53.3	75.31



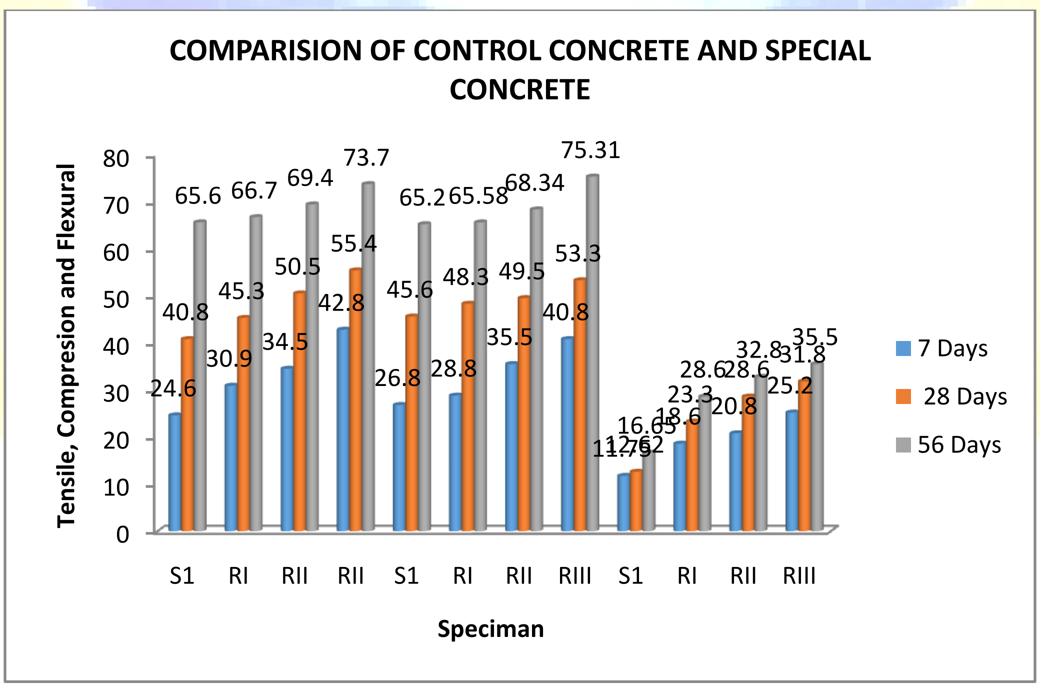
8.4.3 FLEXURAL STRENGTH OF BEAM

Grade of concrete	Ratio	Best Compressive Strength in N/mm^2		
		7 Days	28 Days	56 Days

M40	I	18.6	23.3	28.6
	II	20.8	28.6	32.8
	III	25.2	31.8	35.5



8.10 COMPARISION OF CONTROL CONCRETE AND SPECIAL CONCRETE.



CONCLUSION

9.1 CONCLUSION

The conclusions drawn from these experimental investigations are as follows.

- The Saturated water absorption of HPC mixes containing silica fume and 3% glass fibre were lower compared with that of the conventional mix.

- Cement replacement level of 10 percent silica fume and 3% glass fibre in concrete mixes was found to be the optimum level to obtain lower value of the saturated water absorption at the age of 56 days.

- The results of the saturated water absorption tests have demonstrated superior durability characteristics of HPC mixes containing silica fume and glass fibre. This is due to the fact that micro structure in cement paste matrix is improved due to pozzolanic action and micro pore filler effects of silica fume resulting fine and discontinuous pore structure.

- The coefficient of permeability was found to be negligible in all the samples of concrete mixes containing silica fume whereas the coefficient of permeability was more in concrete mixes without silica fume and glass fibre.

- The presence of silica fume and glass fibre in concrete mixes acts as pore fillers and causes reduction in the pores, resulting fine and discontinuous pore structures and thereby increases the impermeability of concrete.

- The Impact resistance was more when the percentage of cement replacement by silica fumes and glass fiber in concrete mixes was also more up to the optimum replacement level. This indicates that the addition of silica fume and glass fibre in concrete mixes increases the impact resistance.

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