ULTRA HIGH PERFORMANCE FIBER REINFORCED CONCRETE USED IN NAGPUR FLYOVER

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Chapter No-01

INTRODUCTION

Technological advancement was made in the concrete field within the past two centuries. With the advent of chemical additives, a producer of concrete can influence the setting time, slump, and even air entrainment of a mix. For example, the use of super plasticizers (SP), which are also known as high range water reducers (HRWRs), can make concrete flow and consolidate due to its own self-weight. Other options, apart from the use of chemical admixtures, are available as well.

Concrete's weight can be reduced or enhanced with a change in aggregates. Lightweight aggregates may be necessary for specific applications. The use of such aggregates can reduce the unit weight of concrete, making slabs and wall sections thinner.

Heavyweight concrete containing steel and iron aggregates can create a unit weight in excess of 300 pounds per cubic foot. Such concrete is useful in nuclear reactor walls . Even though strength is always a concern as architects, engineers are pushing the boundaries of design continually with bridges that span longer distance, and with taller buildings. With these advanced, the concrete must be stronger, more flexible, and more durable.
The concrete industry for many years were aiming to develop high performance materials that can sustain the server environments. Attempts and efforts were made on maximizing the ultimate strength of the cement-based material besides the durability, which are the main important properties of the concrete based on design standpoint. These efforts were completed by producing a new class of portland cement-based material, which is known as Ultra-High Performance Concrete (UHPC). With this new technology, High-Performance Concrete (HPC) is no longer the strongest and most durable material properties compared to UHPC.

1.1 Background :-

The development of UHPC has taken quite a few years due to its complexity. To start with, the development of UHPC can be outlined back to about the 1930s. During this time, Eugene Freyssinet understood that if one were to apply pressure to concrete during the setting process, the result would be to increase the compressive strength of material. Later in the 1960s, applying pressure to the concrete was used in combination with a curing regimen that included a heat source and a water-saturated environment. In 1970s, compressive strength of 230 MPa (33 ksi) was achieved by using a vacuum mixing procedure. Also, a 510 MPa (74 ksi) was obtained by using a pressure of 50MPa.

UHPC was first recognized as Reactive Powder Concrete (RPC) due the fact that it contained only very fine materials . Ultra-High Performance concrete can be defined as a cement-based composite with a very high compressive strength of approximately 150 MPa (21.75 ksi) and high tensile strength 6.2 to 11.7 MPa (0.90 to 1.7 ksi) compared to the conventional concrete due to the existence of the short discontinuous steel fibers. If steel fibers are added to the paste in order to decrease brittleness and increase energy absorption capacity, the term Ultra-High Performance Fiber Reinforced concrete. The major principle of developing UHPC is to create a homogeneous and dense matrix. One of the main differences between UHPC and the conventional concrete is the removal of coarse aggregate particles to eliminate the effect of the interfacial transition zone between cement paste and aggregate, which contains the micro-cracking Therefore, aggregate materials used with UHPC are sand (not larger than 600 – μm) and quartz flour. Another requirement to produce strong paste is the use of large amount of cementitious materials .

Pozzolanic materials replacement, especially silica fume (SF) are required for the high strength and durability due to the pozzolanic reaction, which produce more calcium silicate hydrates (C-S-H) and accompanied with less voids. Several researches reported that the replacement ratio of portland cement by silica fume is up to 25% .

The low water to cementitious materials ratio (w/cm) is a must to obtain high strength and durability. With the new generation of HRWR of polycarboxylate base, one can reduce the w/cm up to 0.14 or less . Because of the large dosages of superplasticizer, UHPC mixes may take a while to set up. Therefore, to combat this potential problem, an accelerator may be employed to aid reduce the set time. Because of the high binder content, the UHPC tends to have a brittle failure in an explosive manner and a tendency toward micro cracking, which are related to the high autogenous shrinkage. Steel fibers are the only non-liquid or granular components in the mixture of UHPC. Even though fibers are not important for achieving a homogenous mixture, they are influential on the concrete in macro and micro level.

They improve the tensile and flexural strengths of concrete.

Normally, steel fibers are cylindrical in shape. Each fiber can have hooked or straight ends and experience the same principal modes of failure such as pullout and rupture . In general, fiber content influences the ductility of UHPC. As fiber content increases in UHPC mixture, there is an increase in ductility.

Typically, the diameter of most fibers is approximately 0.15 to 0.2 mm (0.006 to 0.008 in) and 13 mm long (0.5 inches). When they are added to the UHPC, the length of the fiber is usually the biggest concern. Fiber length can not only influence how effective the fiber is at holding tension cracks together, but the workability of a fresh concrete mixture as well. In general, when short fibers are added, the mix is more workable.

1.2 Motivation :-

UHPC possesses superior properties when compared to Conventional concrete. Higher strength allows for smaller section and longer spans. UHPC also has rheological properties similar to Self-consolidated Concrete (SCC).

Most UHPC mixture require rare and expensive constituent materials. Therefore, developing UHPC with locally available materials is the main motivation for conducting this research to increase the use for different applications.

UHPC is a new material and there is a lack of information and design codes for members cast with UHPC. The conducted research focuses on advancing our knowledge of UHPC, especially the mixture proportions so that it can be easier for individuals and ready-mix companies to produce UHPC with local materials and already existed techniques.

1.3 Research Objectives :-

The objectives of the research project are as follows:

1. To develop UHPC by using locally available materials in Arkansas and without using of superior approaches.

2. Investigate the effect of supplementary cementitious materials (e.g. silica fume; fly ash) on compressive strength.

3. Examine different curing regimen (e.g. moist curing, heat curing) on UHPC strength.

4. Inspect the effect of different steel fibers addition by fracture volume on compressive strength and modulus of elasticity of UHPC mixtures.

5. Develop modulus of elasticity equation for UHPC. The equation is developed based on the all possible date that collected from literature. The equation is also compared with research data that are conducted in this research

6. Examine the effect of two different mixers on UHPC compressive strength.

7. Investigate the cost of UHPC mixtures. This is conducted by a comprehensive study that considered different materials, several curing regimens.

8. Develop economical UHPC mixtures and the cost has been compared with most available commercial UHPC mixtures

Chapter No-02

LITERATURE REVIEW

2.1 General:-

The development in mineral admixtures (e.g., silica fume and fly ash) and chemical admixtures[e.g., high-range water reducer (HRWRA)] leads to the introduction of several types of high-quality concrete. These types of concrete typically include high-strength concrete, high-performance concrete, and fiber-reinforced concrete. The further advancement in concrete technology has resulted in a new type of concrete called Ultra-High Performance Concrete(UHPC). UHPC is a cement-based composite with a compressive strength of 150 MPa and tensile strength of 6.2 MPa . The age at which UHPC achieves these strengths has not been specified.

The benefits of using UHPC in the design of precast, pre-stressed concrete structures have been confirmed in a number of projects in United States, Germany, Canada, France, and Australia. In the United States, UHPC is mainly used for bridge applications that include precast, pre-stressed bridge girders, precast waffle panels, and as a jointing material between precast concrete deck panels and girders .In 1990s, UHPC was first known as reactive-powder concrete since it contained only very fine materials .

A typical UHPC mixture proportion consists of cement, supplementary cementitious materials (e.g., silica fume, fly ash, and slag cement), fine sand, quartz or glass powder, HRWR, steel fiber, and a low water content . Coarse aggregate is excluded in many UHPC mixture proportion. This exclusion reduces the micro-cracks that are present in the coarse aggregate and in the interfacial transition zone between the paste matrix and coarse aggregate. These micro-cracks can increase the permeability of concrete . In addition, when the concrete resists external loads, mechanical cracks tend to occur at the existing micro-cracks and propagate through the paste matrix and coarse aggregate which can lead to failure of the concrete. Therefore, the exclusion of coarse aggregate is necessary to improve the strength and durability of UHPC.

In terms of placement procedures, UHPC can reduce the time and the labor related to placement.UHPC tends to exhibit rheological behaviors similar to self-consolidating concrete. Therefore, the casting efforts are reduced, but additional form preparation is possibly needed The use of HRWR is one of main contributing factors to the high workability of UHPC while a low water content is necessary to achieve a high compressive strength . Researchers have found that the water to binder ratio (w/b) of UHPC can be decreased to 0.12; where binder is the total content of cement and supplementary cementitious materials.

However, the required water to cement (w/c) ratio for full hydration of cement is 0.32 . For conventional concrete with a typical w/c ratio of 0.4, the degree of hydration increases from 80% to 100%. For UHPC, the water content is so low that all the cement particles are not hydrated .UHPC is available as a premix in many markets. The premix requires special attention during mixing, casting, curing and testing. For example, a high-shear mixer is typically necessary for the mixing UHPC and a heat-curing technique can be used to achieve a high compressive strength. Ductal is a marketed form of UHPC that was developed by the participation of three companies: Lafarge, Rhodia, and Bouygues. Quartz powder with a diameter of 10 μm is used in the UHPC premix as a micro-filler material, and the premix also contains high tensile strength fibers (tensile strength of 2600 MPa) .

The use of these materials increases the cost of the premix. Commercially available UHPC is about 20 times more expensive than conventional concrete, which is about $100/yd 3 . This UHPC price includes the material costs of the proprietary blend and the fiber reinforcement, and the costs associated with the development and delivery of said material.

A potential solution to reduce the UHPC cost is to use a sand that has an average diameter of 150–600 µm or a natural sand as a filler material. However, the concrete's compressive strength can decrease when the diameter of the filler material increases. In this study, the authors investigate the effect of using a natural sand on the concrete's compressive strength.

The use of a local sand not only reduces the cost of UHPC but also eliminates the time and labor necessary to produce the ultra-fine sand which has an average diameter less than 600 µm. The optimal use of supplementary cementitious materials, typically including silica fume and fly ash, additionally reduces the concrete cost. It is anticipated that UHPC can replace conventional concrete in various structural applications, including precast and cast-in-place concrete applications, due to its improved structural durability and extended service life. Therefore, there is a need to develop UHPC using local materials, which enables engineers to use UHPC when necessary without significant increases in cost.

Ali Alaslam 2018 : Ultra-High Performance Concrete (UHPC) can enhance the durability and resilience of concrete structures. The use of local materials is a fundamental step to save energy and reduce the cost of concrete. The main focus of this research was to develop a UHPC with compressive strength of 150 MPa using locally sources materials. In this study, the effect of fine materials, binder type and content, type of mixer, steel fibers and curing regimes on concrete's compressive strength were investigated. The relationship between compressive strength and elastic modulus was also studied. This study synthesizes all relevant experimental data in the literature to propose a new equation for predicting the modulus of elasticity (MOE) at different ages. A number of UHPC mixtures were developed to verify the accuracy of the proposed equation. With an error of ±10%, the proposed equation provides a reasonable prediction for the UHPC mixtures containing local materials. The final part of the dissertation focuses on developing economical UHPC mixtures by reducing the amount of binder content by using of ash. Costs were compared with the UHPC mixtures that are available in the market, indicating $283/m3 compared to approximately $200/m3 with current products.

N.M Azmee 2018: Over the last twenty years, remarkable advances have taken place in the research and application of ultra-high performance concrete (UHPC), which exhibits excellent rheological behaviors that include workability, self-placing and self-densifying properties, improved in mechanical and durability performance with very high compressive strength, and non-brittleness behavior. It is the 'future' material with the potential to be a viable solution for improving the sustainability of buildings and other infrastructure components. This paper will give an overview of UHPC focusing on its fundamental introduction, design, applications and challenges. After several decades of development, a wide range of commercial UHPC formulations have been developed worldwide to cover an increasing number of applications and the rising demand of quality construction materials. UHPC has several advantages over conventional concrete but the use of it is limited due to the high cost and limited design codes. This paper also aims to help designers, engineers, architects, and infrastructure owners to expand the awareness of UHPC for better acceptance.

Bassam Tayeh 2019: This study aims to review the research studies available in literature that examines the mechanical properties and optimum mixing ratios of ultra-high performance fiber-reinforced concretes (UHPFRCs). In addition to a comparison between mechanical properties of UHPFRC, high-performance concrete (HPC), and normal strength concrete (NSC). The studies included in this review were compiled under different headings and explained concisely. Subsequently, the best UHPFRC mixture was determined to be obtainable with 2% to 3% steel fiber content and a water/cement ratio of < 0.2. Additionally, the UHPFRCs that were subjected to curing at 90 °C for 28 days yielded compressive, tensile, and flexural strengths that were 49% better than the samples cured at 20 °C. The review elucidates the key points of producing the best UHPFRC material for future applications.

Hongzhuan Zhang 2019: Ultra-high performance concrete (UHPC) is a new type of concrete with higher strength and durability developed on the basis of the research of high performance concrete. In order to improve the toughness and flexural performance of concrete, steel fibers are added to make it have broader engineering application advantages.

UHPC, which combines high-strength concrete and steel fiber reinforced concrete, is not simply to pull high-performance concrete to high-strength direction. It is based on the study of cementing effect of cement, coagulation of various coarse and fine aggregates, admixtures, admixtures and other hydraulic cementitious materials. Due to the high self-weight and brittleness and low strength of ordinary concrete, especially the low tensile strength, it can't meet the application requirements of super-large structure and assembly structure. Some foreign experts call the removal of coarse aggregate UHPC with fibers as UHPC. In fact, UHPC is a kind of fiber reinforced UHPC mortar. It has super-high, low brittleness and excellent durability, which can't reach the effect of ordinary concrete. In order to improve the performance of UHPC and promote its practical application, this paper studies the influence of UHPC composition material selection, mix design and maintenance mode selection on concrete performance, combining with the actual situation of relevant raw materials in China.

Josniya Jose et al 2020: Retrofitting has become a proven method for improving the load carrying capacity of existing concrete structural elements subjected to high mechanical loading, ageing or aggressive environments. Ultra-High Performance Fiber Reinforced Concrete (UHPFRC)is a relatively new generation of cement-based retrofitting material with a very high compressive strength and low permeability attributed to its tightly packed microstructure, also displaying excellent bonding ability with normal structural concrete. It has the potential to eliminate various problems caused by other retrofitting methods like FRPs or externally bonded steel plates as a result of the mismatch of stiffness with parent concrete. This study presents an overview of UHPFRC focusing on its properties, design, applications and challenges. The performance of UHPFRC concrete mix is greatly influenced by the type and degree of packing of its constituents in the cementitious matrix, necessitating the need for optimisation. Strength properties are very much higher when compared to that of conventional concrete alongside with increased durability aspects. The retrofitting technique showed an enhancement in the load carrying capacity of deteriorated structures. Therefore, UHPFRC can be considered as a practical solution to improve the sustainability of buildings and other infrastructural components. However, as a retrofit, there are some concerns regarding the loss of ductility. This broadens the need for methods to improve its ductility. This paper presents the state-of-art review of existing literature that deals with the retrofitting/rehabilitation of structures using UHPFRC. Altogether, the paper aims to expand the awareness regarding UHPFRC which was otherwise hindered, owing to limited design codes.

Murugan M 2020: The development in mineral admixtures and chemical admixtures leads to the development of several types of high quality concrete. These types of concrete typically include high strength concrete, high performance concrete and fiber reinforced concrete. The further advancement in concrete technology has resulted in a new type of concrete called Ultra-High performance concrete(UHPC).UHPC was first known as reactive-powder concrete since it contained only very fine materials. The main objective of this paper is to study the UHPC and its cost efficiency in India. . UHPC is exhibited to possess very high strength, elastic modulus, ductility and brilliant durability properties. The reported results are in the range of: compressive strength > 150 MPa, flexural tensile strength > 25 MPa, modulus of elasticity > 50 GPa. UHPC has many advantages over conventional concrete but is still in limited practice due to limited design codes and high cost As far as the constituents are concerned, steel fibers, finer silica sand and silica sand amounted for nearly half of the total cost. Despite the higher cost of UHPC, it has the advantage of having longer lifespan.

Tomas Vavrinik 2013: This paper describes experimental investigations of various mechanical properties of Ultra High Performance Fiber Reinforced Concrete (UHPFRC). The UHPFRC is a modern cementitious composite containing a large amount of cement, both reactive and nonreactive very fine particles, chemical admixtures and short high strength steel fibers. This type of concrete has superior durability and excellent mechanical properties. In this paper an UHPFRC containing 2% of fibers by volume with a compressive strength exceeding 150MPa is presented. In this study detailed descriptions of the measurements of compressive strength, bending strength, direct tensile strength, fracture energy and modulus of elasticity are given. The study provides a comparison of the above mentioned UHPFRC properties with high performance concrete, fiber reinforced concrete and conventional structural concrete. The results indicate excellent performance of UHPFRC in all categories. The biggest difference to ordinary concretes can be seen in tensile behavior, where its response in tension exhibits strain hardening accompanied with multiple cracking followed by tensile softening. The direct tensile strength of the studied material is 10MPa and its fracture energy is 5 times higher than that of conventional fiber reinforced concrete. It is believed, that such type of material is the future of concrete industry, it will allow executing higher, more effective structures with excellent durability.

H.J.H. Brouwers 2015: This paper presents a method to develop Ultra-High Performance Fibre Reinforced Concrete (UHPFRC). Towards an efficient utilization of binders and fibres in UHPFRC, the modified Andreasen & Andersen particle packing model and the hybridization design of fibres are utilized. Particularly, the UHPFRC with ternary fibres is appropriately designed and tested. The flowability, mechanical properties and flexural toughness of the designed UHPFRC are measured and analyzed. The results show that, based on the optimized particle packing and hybrid macro and micro fibres, it is possible to produce UHPFRC with a relatively low binder amount (about 620 kg/m3) and low fibre content (Vol. 2%). Moreover, due to the mutual effects between the utilized fibres, the hybrid fibre reinforced UHPFRC shows an improved flowability and better mechanical properties. Nevertheless, the flexural toughness of UHPFRC is dominated by the hooked steel fibres. Due to the specific characteristics of UHPFRC, the JSCE SF-4 standard is found more suitable than ASTM C1018-97 to be used to evaluate the flexural toughness of UHPFRC.

Nasir Hassan 2022: Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) is a cement-based composite with exceptional mechanical and durability properties. This analytical study examines the impact of the mix design proportions, the curing temperatures, and the curing ages on the mechanical properties of the composite. In this study, more than 100 previously conducted studies on the development of the mechanical properties of UHPFRC were analyzed. Regression analyses from the collected data were carried out to develop various equations for predicting different mechanical properties of the composite from its mix compositions, curing conditions, and ages. The mechanical properties of the composite were found to be highly dependent on the curing temperature at its early ages and its compositions at later ages. The findings of this study demonstrate that UHPFRC is an exceptionally suitable material for structures subjected to aggressive environments and it is a good choice for cast-in-situ applications.

Chapter No-03

MATERIALS USED

3.1.Introduction:

Ultra-high-performance concrete is a new type of concrete that is being developed by agencies concerned with infrastructure protection. UHPC is characterized by being a steel fibre-reinforced cement composite material with compressive strengths in excess of 150 MPa, up to and possibly exceeding 250 MPa. UHPC is also characterized by its constituent material make-up: typically fine-grained sand, fumed silica, small steel fibers, and special blends of high-strength Portland cement. Note that there is no large aggregate. The current types in production (Ductal, Taktl, etc.) differ from normal concrete in compression by their strain hardening, followed by sudden brittle failure. Ongoing research into UHPC failure via tensile and shear failure is being conducted by multiple government agencies and universities around the world.

3.2. Material Used :

3.2.1. Silica Sand :

Silica sand, also known as quartz sand, white sand, or industrial sand, is made up of two main elements: silica and oxygen. Specifically, silica sand is made up of silicon dioxide (SiO_2).The most common form of SiO_2 is quartz – a chemically inert and relatively hard mineral. SiO_2 grades at a 7 out of 10 on Mohs hardness scale, making it ideal for use as filtration media and abrasive blasting sands.Although quartz is often white or colourless, it can come in a wide range of shades. The colour of each sand deposit depends largely on the variety of minerals and rock detritus that make up the resource.

In order to be considered a silica sand the material must contain at least 95% SiO_2 and less than 0.6% iron oxide. If the sand does not meet this criteria, it will qualify as what’s often called ‘regular’ sand.

Fig no 3.1: Silica sand

3.2.2. Micro Silica :

Silica fume, also known as microsilica, (CAS number 69012-64-2, EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

It is sometimes confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5). However, the production process, particle characteristics and fields of application of fumed silica are all different from those of silica fume.

Fig no 3.2: Silica Fume

3.2.3. Cement Opc-53 :

This grade was introduced in the country by BIS in the year 1987 and commercial production started from 1991. Advent of this grade in the country owes it to the improved technology adopted by modern cement plants. OPC 53 Grade cement is required to conform to BIS specification IS:12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/sqcm.

53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure. Being a high strength cement, it provides numerous advantages wherever concrete for special high strength application is required, such as in the construction of skyscrapers, bridges, flyovers, chimneys, runways, concrete roads and other heavy load bearing structures. Not only is this grade of cement stronger than other grades / types, it is also more durable. Further, by substituting lower grade cement with OPC 53, overall savings can be obtained through reduced quantity of cement that would be required to be used. A savings of 8-10% can be achieved with the use of 53 Grade OPC in place of any other grade.

53 Grade cement attains higher early strength as compared to any other grade of cement but because of early gain, does not increase much after 28 days. In addition, due to faster hydration process, the cement releases heat of hydration at a much faster rate initially and therefore, the chances of micro cracking of concrete is much greater. Thus, during initial setting period of concrete, the higher heat of hydration can lead to damage arising out of micro cracks with in the concrete structure, which may not be visible on the surface. The situation can be worsened when construction supervisors / masons tend to increase the quantity of cement in concrete with a wrong notion that such increases are better for both strength and durability of concrete. Grade 53 should therefore be used only where such application is warranted for making the concrete of higher strength, where good supervision and quality assurance measures are in place and where proper precautions are taken to relieve the higher heat of hydration through a proper curing process.

The physical and chemical characteristics of OPC 53 Grade Deccan Cement very comfortably surpasses the stringent standards specified by BIS, including compressive strength which is remarkably higher than the prescribed standards.

Fig no 3.3: Cement OPC 53Grade

3.2.4. Steel Fibres :

Steel fibre-reinforced shot crete (SFRS) is shot crete (spray concrete) with steel fibres added. It has higher tensile strength than unreinforced shot crete and is quicker to apply than weldmesh reinforcement. It has often been used for tunnels and road constructions.

Fig no 3.4: Steel Fibre

3.2.5. Superplasticizer :

Superplasticizers (SPs), also known as high range water reducers, are additives used for making high-strength concrete or to place self-compacting concrete. Plasticizers are chemical compounds enabling the production of concrete with approximately 15% less water content. Superplasticizers allow reduction in water content by 30% or more. These additives are employed at the level of a few weight percent. Plasticizers and superplasticizers also retard the setting and hardening of concrete.

According to their dispersing functionality and action mode, one distinguishes two classes of superplasticizers:

1. Ionic interactions (electrostatic repulsion): lignosulfonates (first generation of ancient water reducers), sulfonated synthetic polymers (naphthalene, or melamine, formaldehyde condensates) (second generation), and;
2. Steric effects: Polycarboxylates-ether (PCE) synthetic polymers bearing lateral chains (third generation).

Superplasticizers are used when well-dispersed cement particle suspensions are required to improve the flow characteristics (rheology) of concrete. Their addition allows to decrease the water-to-cement ratio of concrete or mortar without negatively affecting the workability of the mixture. It enables the production of self-consolidating concrete and high-performance concrete.

The polymers used as plasticizers exhibit surfactant properties. They are often ionomers bearing negatively charged groups (sulfonates, carboxylates, or phosphonates...). They function as dispersants to minimize particles segregation in fresh concrete (separation of the cement slurry and water from the coarse and fine aggregates such as gravels and sand respectively). The negatively charged polymer backbone adsorbs onto the positively charged colloidal particles of unreacted cement, especially onto the tricalcium aluminate (C_3A) mineral phase of cement.

Fig no 3.5: Superplastisizer

3.2.6. Water:

The water-cement ratio of the fresh concrete mix is one of the main, if not the most important, factors determining the quality and properties of hardened concrete, as it directly affects the concrete porosity, and a good concrete is always a concrete as compact and as dense as possible. A good concrete must be therefore prepared with as little water as possible, but with enough water to hydrate the cement minerals and to properly handle it.

A lower ratio leads to higher strength and durability, but may make the mix more difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers. A higher ratio gives a too fluid concrete mix resulting in a too porous hardened concrete of poor quality. For higher-strength concrete, lower w/c ratios are necessary, along with a plasticizer to increase flowability.

Chapter No-04

METHODOLOGY

4.1 General:- This Chapter Shows my design of Ultra high performance fiber reinforced concrete, and its mix proportions.

Material Properties

Sr.No	Materials	Specific Gravity	Water Absorption
1	Cement OPC 53Grade	3.150	
2	Silica Fumes	2.170	
3	Silica Quartz Sand	2.788	0.52
4	Admixture	1.100	
5	Water	1.000	

Table No. 4.1 Material Used in UHPFRC

Design Stipulation

1	Grade of Concrete	M 100+
2	Characteristic compressive strength at 28 days	100 MPa
3	Type of Cement	OPC 53 Grade Ultratech Cement
4	Max^{m} Nominal Size of fine Agg	2.0 MM
5	Water- Cement Ratio	As Per Design
6	Water-Binder Ratio	As Per Design
7	Workability	200MM
8	Type of fine Agg	Manufactured sand (Silica Quartz Sand)
9	Chemical Admixture Used	Fosroc Chemical Ltd. AuraCast 270M (PCE Based HWRA)

10	Mineral Admixture Used	Silica Fumes
11	Steel Fiber Used	0.20mm Dia. 12mm Length Straight Steel Fiber

Table No 4.2 Design Stipulation of UHPFRC

Source of Materials

Sr.No	Materials	Source
1	Fine Agg. (Manufactured Sand)	Silica Quartz Sand
2	Cement	Ultratech Cement OPC 53G (Confirming to IS:269-2015)
3	Mineral Admixture (Silica Fumes)	Apple Chemie(AC-McroSil-Si9+) (Confirming IS 15388)
4	Water	Base Camp Borewell Water,Khadgaon (ph 6.5-8.0)
5	Chemical Admixture (PCE Based)	Fosroc Chemical Ltd.AuraCast 270M (PCE Based HWRA)
6	Steel Fiber	Precision Drawel Pvt.Ltd.

Table No 4.3 Source of Materials

UHPFRC Mix Proportions

Trail No 1

Materials	**Mix Proportions -1**	**Mix Ratio**
Cement	720	1
Silica Fumes	220	0.3056
Silica Quartz Sand	780	1.0833
Water	179	0.2486
Admixture	35	0.0486
Steel Fiber	470	0.6528
W/c Ratio	0.1904	0.0003
Fresh Density	2404	
Flow Observed	**180mm**	**Temp (C^o) 23.6**

Table no 4.4 Trail Mix 1

Trail No 2

Materials	**Mix Proportions -1**	**Mix Ratio**
Cement	750	1
Silica Fumes	250	0.3333
Silica Quartz Sand	720	0.96
Water	190	0.2533
Admixture	35	0.0467
Steel Fiber	470	0.6528
W/c Ratio	0.1904	0.0003
Fresh Density	2415	
Flow Observed	**190mm**	**Temp (C^o) 23.6**

Table no 4.5 Trail Mix 2

Trail No 3

Materials	**Mix Proportions -1**	**Mix Ratio**
Cement	780	1
Silica Fumes	270	0.36
Silica Quartz Sand	685	0.9133
Water	200	0.2667
Admixture	40	0.0533
Steel Fiber	450	0.6
W/c Ratio	0.190	0.0003
Fresh Density	2425	
Flow Observed	**190mm**	**Temp (C°) 23.6**

Table no 4.6 Trail Mix 3

The above mentioned three different trial mix were made in accordance to achieve a proper mix proportion for UHPFRC in terms of its strength to be achieved, the achieved results are as mentioned in the tables so given

- Trial mix 01 – this trial mix proportion couldn't give the desired strength to the concrete
- Trial mix 02 –this – this trial mix proportion has proven to givethe desired strength to the concrete
- Trial mix 3 –this – this trial mix proportion has proven to givethe desired strength to the concrete

Fig no 4.1 Cube casting

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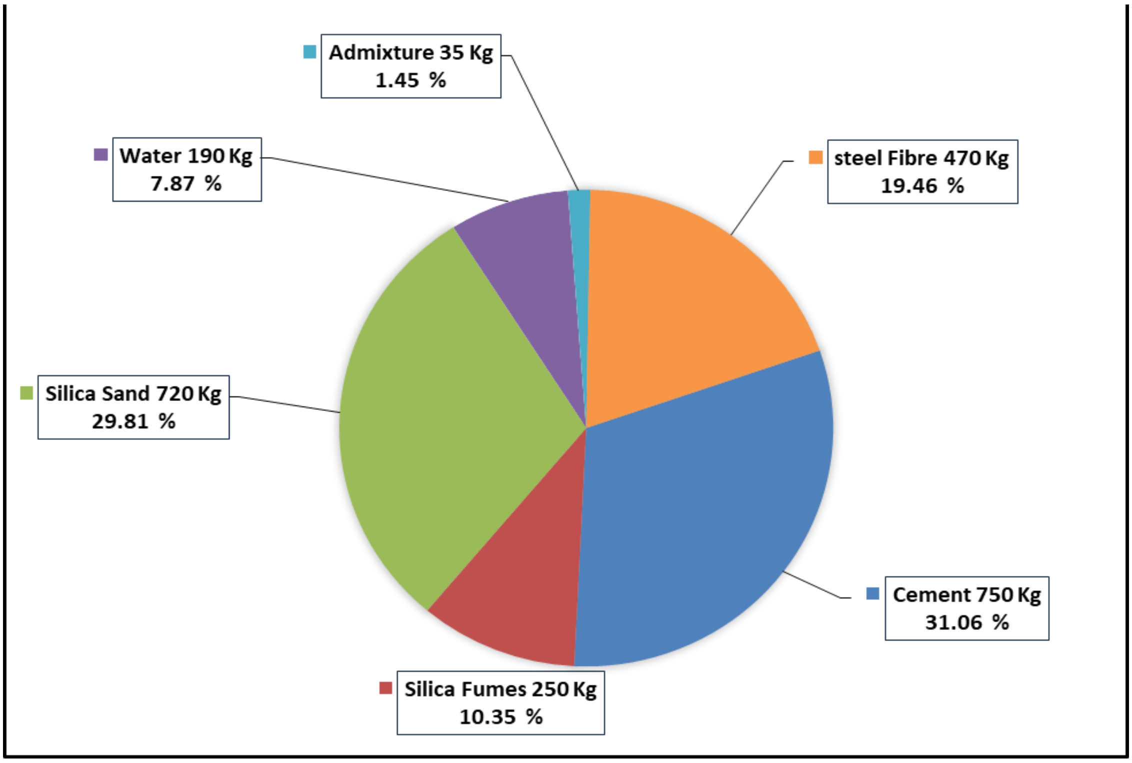

Fig 4.2 Pie chart of material proportion.

4.2 Tests For Uhpfrc Mixes :

4.2.1 Compressive Strength Test : A compression test is a method for determining the behavior of materials under a compressive load. Compression tests are conducted by loading the test specimen between two plates, and then applying a force to the specimen by moving the crossheads together. During the test, the specimen is compressed, and deformation versus the applied load is recorded. The compression test is used to determine elastic limit, proportional limit, yield point, yield strength, and (for some materials) compressive strength.

- **Compressive strength of concrete formula:** compressive strength formula for any material is the load applied at the point of failure to the cross sectional area of the face on which load was applied

Compressive strength = Load /cross sectional area

Fig no 4.3. concrete mould.

- **Apparatus for compressive strength of concrete**

  a) Concrete mould

  b) Trowel

  c) Compressive testing machine

- **Procedure for compressive test of concrete:**

  a) Mix the cement and sand with trowel for the period of one minute on non porous plate.Ensure that the cement should not have any lumps in it.

  b) Clean the mould with the dry cloth and apply the mould oil for easy removal of mortar cube after drying.

  c) Now pour the mortar in steel cube mould. Prod the mortar for 20 times in 8 second with the help of tamping rod to eliminate the entrained air.

  d) Place the mould at room temperature for 24 hours

  e) After 24 hrs dismantling the steel mould from mortar cube.Keep the test specimen submerged under water for the stipulated time/steam curing. This process is called as curing.

Fig no 4.4.Compression testing machine

- **Steam curing :** Steam curing at atmospheric pressure is a method used to raise concrete strength at early ages. The steam curing method is based on the application of hot water vapor at a temperature between 40 °C and 100 °C for a limited period. The highest temperatures and the longest curing period are determined based on the characteristics of the target concrete, the cost, and the production cycle. This study presents the effect of steam curing regime application on concrete properties. Steam curing has a negative effect on the microstructure of concrete, and this effect increases with higher temperatures. The curing period and the pre-curing period in addition to the cooling period influence the properties and the strength of concrete.

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Fig no 4.5. Steam curing.

Fig no 4.6 Cube before test.

Fig no 4.7 Cube after test.

4.2.2. Flow Test : The flow test is performed to measure workability of concrete. As name suggests, in this test the workability of concrete is measured by examining the flowing property of concrete. The flow test is a simple laboratory test. This test works on the principal of a jolting of the standard mass of concrete and measured by flow of concrete. The flow of concrete indicates the workability of the fresh concrete.

Fig no 4.8 Flow test.

Chapter No-05

TEST RESULTS

5.1.Results of Test Performed on Fresh Concrete:-

The proposed study is being carried out to develop UHPFRC and this shows the result of the tests so performed on it .

5.1.1.Compressive strength test results:-

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-01					Vol^{m} of Mould : 70.6 cc	Mould Size-70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^{2})**	**Avg. N/mm^{2}**	**Age In days/Test Date**	**Remark**
1	2642	2.642	362.0	36.20	**31.80**	**1 Day** **05-May-23**	**04/05/23 Casting Date**
2	2542	2.542	304.0	30.40			
3	2288	2.288	288.0	28.80			

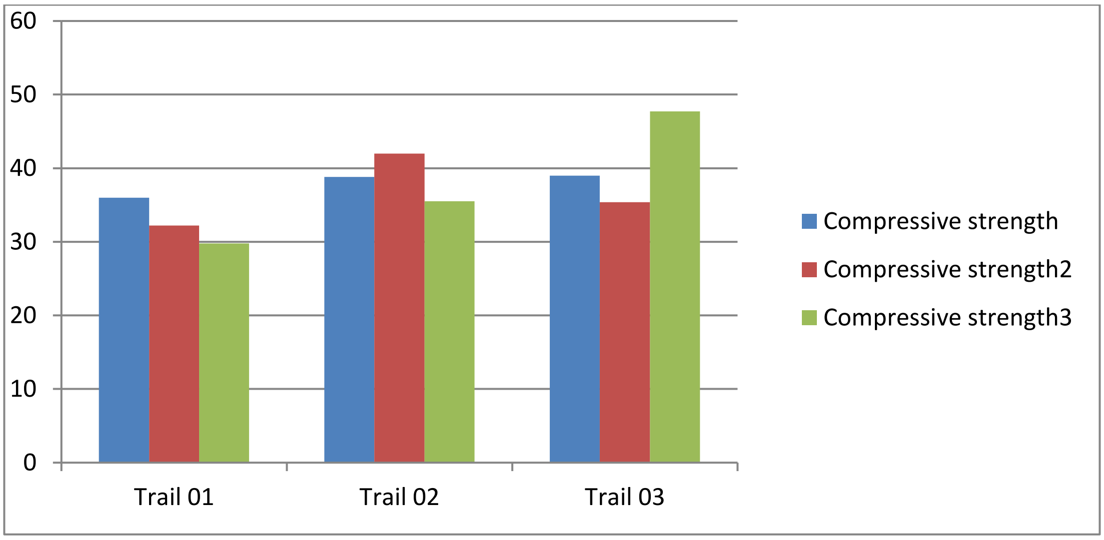
Table No 5.1. Compressive test 1st day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-02					Vol^{m} of Mould : 70.6 cc	Mould Size-70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^{2})**	**Avg. N/mm^{2}**	**Age In days/Test Date**	**Remark**
1	2642	2.642	388.0	38.80	**38.77**	**1 Day** **05-May-23**	**04/05/23 Casting Date**
2	2542	2.542	420.0	42.00			
3	2288	2.288	355.0	35.50			

Table No 5.2. Compressive test 1st day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-03					Volm of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm²)**	**Avg. N/mm²**	**Age In days/Test Date**	**Remark**
1	2642	2.642	362.0	36.20	**31.80**	**1 Day** 05-May-23	**04/05/23 Casting Date**
2	2542	2.542	304.0	30.40			
3	2288	2.288	288.0	28.80			

Table No 5.3. Compressive test 1st day result



Graph No 5.1. Compressive strength 1st day result.

The graph thus shows the 3rd day strength of all the trial mixes.In all the three trials of 1stday the compressive strength of trail 01 of load 362KN was highest,of trial 02 the compressive strength of load 420KN was highest ,and for trial 03 the

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-01					Volm of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm²)**	**Avg. N/mm²**	**Age In days/Test Date**	**Remark**
1	2399	2.399	425	42.50	**42.70**	**3 Day** 07-May-23	**04/05/23 Casting Date**
2	2544	2.544	455	45.5			
3	2511	2.511	401	40.10			

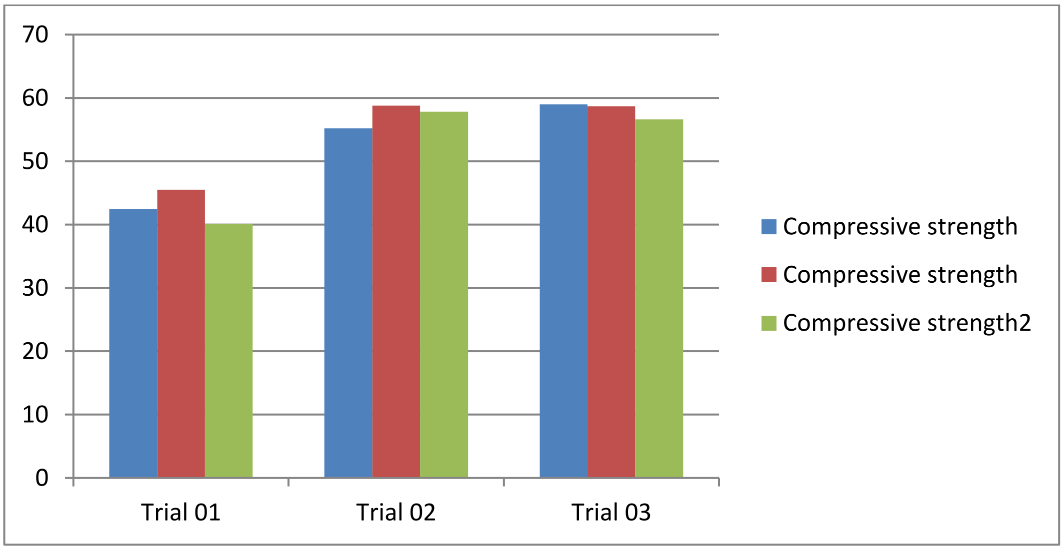
Table No 5.4. Compressive test 3rd day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-02					Vol^m of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	Weight	Density	Load (Kn)	Strengh (N/mm^2)	Avg. N/mm^2	Age In days/Test Date	Remark
1	2642	2.642	552	55.20	57.27	3 Day 07-May-23	04/05/23 Casting Date
2	2542	2.542	588	58.80			
3	2512	2.512	578	57.80			

Table No 5.5. Compressive test 3rd day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-03					Vol^m of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	Weight	Density	Load (Kn)	Strengh (N/mm^2)	Avg. N/mm^2	Age In days/Test Date	Remark
1	2544	2.544	590	59.00	58.10	3 Day 07-May-23	04/05/23 Casting Date
2	2566	2.566	587	58.70			
3	2535	2.535	566	56.60			

Table No 5.6. Compressive test 3rd day result



Graph No 5.2. Compressive strength 3rdday result.

The graph thus shows the 3rd day strength of all the trial mixes

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-01					Vol^m of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2366	2.366	699	69.90	**65.03**	**7 Day**	**04/05/23 Casting Date**
2	2633	2.633	622	62.20		**11-May-23**	
3	2601	2.601	630	63.00			

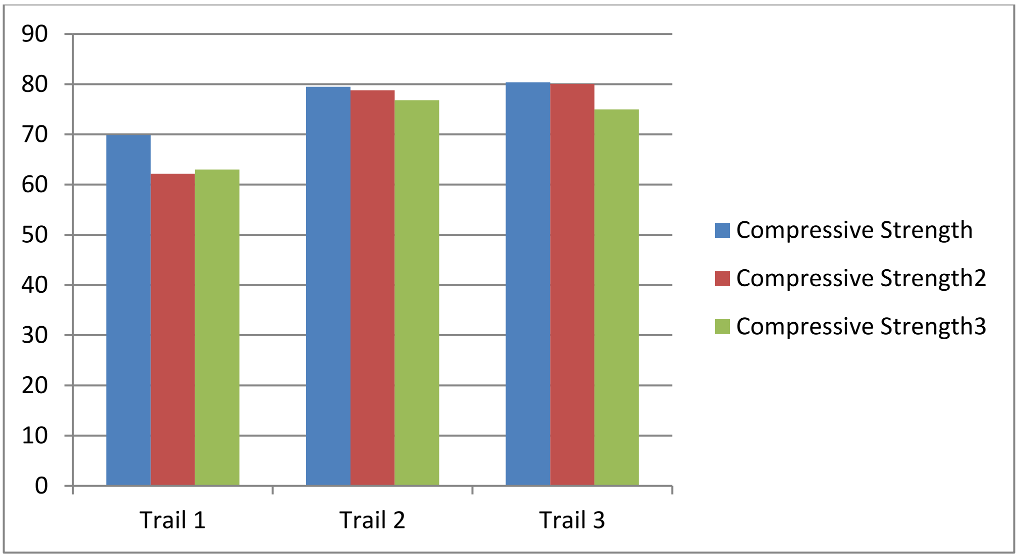
Table No 5.7. Compressive test 7th day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-02					Vol^m of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2510	2.51	795	79.50	**78.37**	**7 Day**	**04/05/23 Casting Date**
2	2568	2.568	788	78.80		**11-May-23**	
3	2601	2.601	768	76.80			

Table No 5.8. Compressive test 7th day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-03					Vol^m of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2633	2.633	804	80.40	**78.50**	**7 Day**	**04/05/23 Casting Date**
2	2644	2.644	801	80.10		**11-May-23**	
3	2621	2.621	750	75.00			

Table No 5.9. Compressive test 7thday result



Graph No 5.3. Compressive strength 7th day result.

The graph thus shows the 7th day strength of all the trial mixes and proved to give us the desired strength so required and as mentioned above

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-01					Volm of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2544	2.544	801	80.10	**76.37**	**28Day**	**04/05/23 Casting Date**
2	2512	2.512	725	72.50		**02-june-23**	
3	2577	2.577	765	76.50			

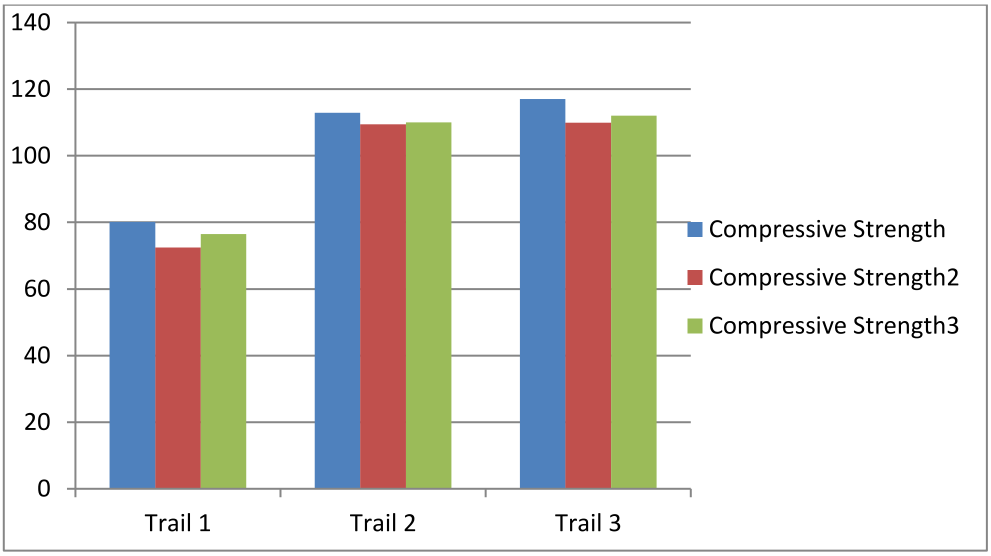
Table No 5.10. Compressive test 28th day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-02					Volm of Mould : 70.6 cc	Mould Size- 70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2510	2.51	1129	112.9	**110.80**	**28 Day**	**04/05/23 Casting Date**
2	2568	2.568	1095	109.50		**02-june-23**	
3	2601	2.601	1100	110.00			

Table No 5.11. Compressive test 28th day result

A-11	COMPRESSIVE STRENGTH OF CONCRETE. Trial ID-03					Vol^m of Mould : 70.6 cc	Mould Size-70.6mm
Sr. No.	**Weight**	**Density**	**Load (Kn)**	**Strengh (N/mm^2)**	**Avg. N/mm^2**	**Age In days/Test Date**	**Remark**
1	2631	2.631	1170	117	112.97	28 Day	04/05/23 Casting Date
2	2605	2.605	1099	109.9		02-june-23	
3	2612	2.612	1120	112.00			

Table No 5.12. Compressive test 28thday result



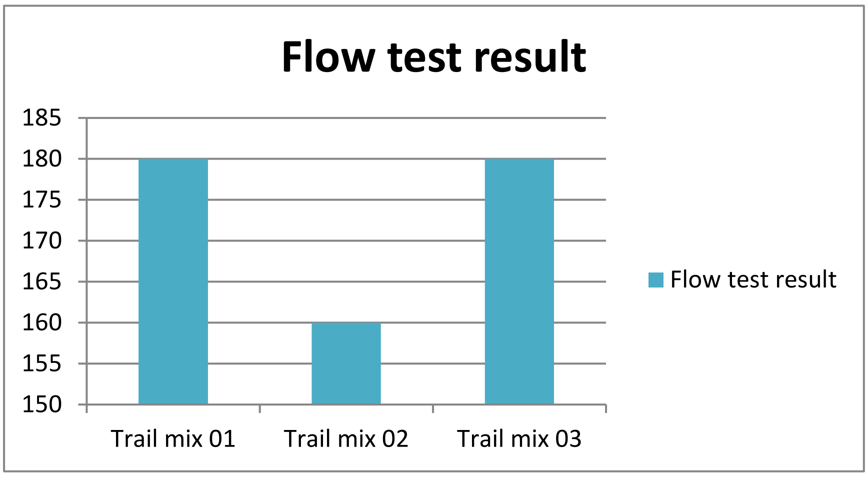
Graph No 5.4. Compressive strength 28th day result.

The graph thus shows the 28th day strength of all the trial mixes and proved to give us the desired strength so required and as mentioned above.

5.1.2.Flow table test results:-

Sr.no	Trail mix	Superplasticizer content (%)	Flow Observed(mm)
1	Trail mix 01	1.45	180
2	Trail mix 02	1.44	160
3	Trail mix 03	1.64	180

Table No 5.13 Flow table test result



Graph No 5.5 Flow test result

The graph thus shows the flow of concrete in mm i.e. 180mm obtained in 1&3.

Chapter No-06

CONCLUSION

The following conclusions can be drawn:

1. UHPFRC mixtures were successfully developed using locally available materials found at Nagpur Maharashtra. The use of Silica sand was efficient in producing UHPFRC mixtures having compressive strength of 112.97 MPa. In 28 days

2. UHPFRC mixtures were mixed by pan and drum rotating mixers. Mixtures batched in a pan mixer had compressive strengths 8% higher than mixtures batched in a drum mixer.

3. When Silica fumes was used as a Mineral admixture, the highest compressive strength in the research project was achieved 112.97 (MPa).

4. Mixtures with 470 kg/m^3 of binder content achieved a strength of 57 MPa without steel fibre and 112.97 MPa with steel fibre

5. Longspan pvt.ltd a Pune based company charges 41,000 rs/m^3 and according to our experiment by using locally available material the cost for 1m^3 of UHPFRC is reduced to Rs 8000/- only.

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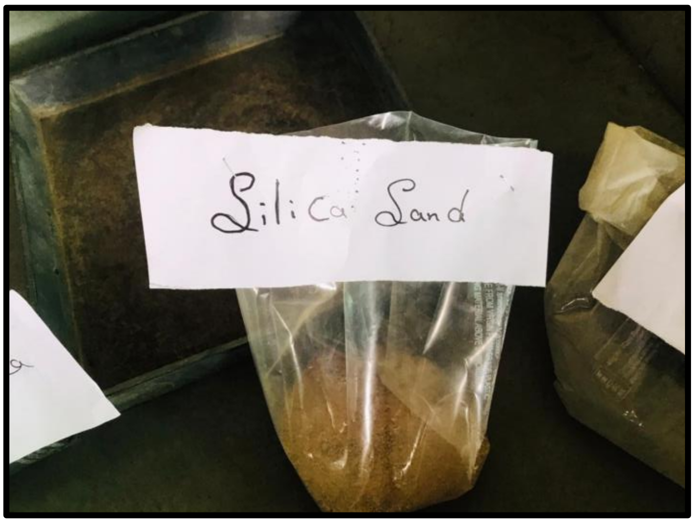
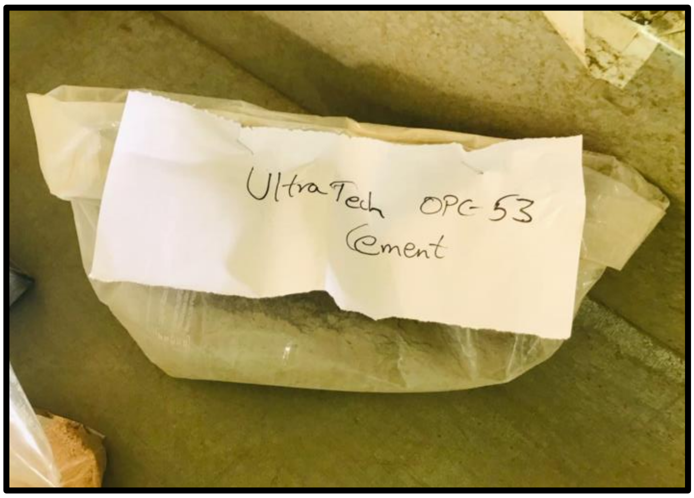
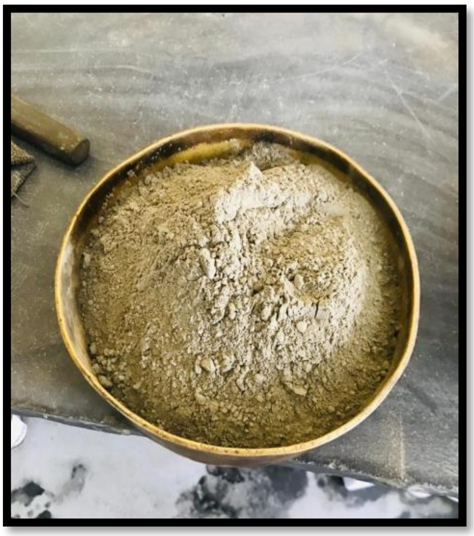
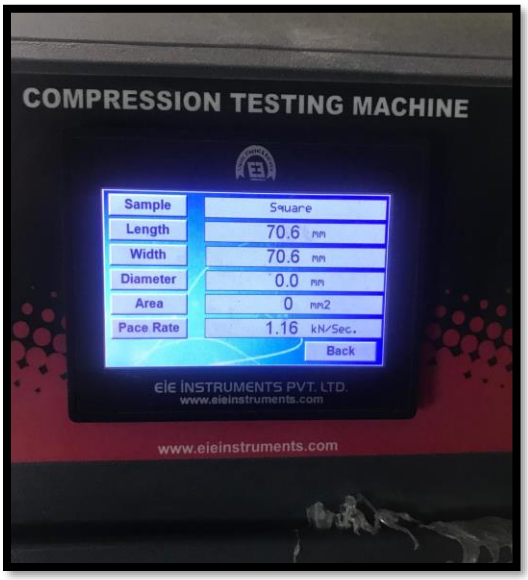
PHOTO GALLERY








COMPRESSION TESTING MACHINE
Sample
Square
Length
70.6 mm
Width
70.6 mm
Diameter
0.0 mm
Area
0 mm2
Pace Rate
1.16 kN/Sec.
Back
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Chapter No-07

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