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RESEARCH ARTICLE

THE DUCTILE CHARACTERESTICS OF HYBRID FERRO CEMENT SLAB.

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Abstract

This Paper Presents The Ductile Characteristics Of Hybrid Ferro Cement Slab Incorporating Polypropylene Fibers And Gfrp Sheet. A Total Of 9 Slabs Have Been Tested Under Two Point Flexural Loading. The Size Of The Slab Is 1000 Mm (Length) X1000 Mm (Width) X 60 Mm (Thickness). The Parameters Studied in This Investigation Includes the Number of Weld Mesh Layers, Polypropylene Fibers i.e. (0.3%) And Gfrp Sheet. Two Point Loading Test Was Conducted On Slabs And Parameters Such As Ultimate Moment Capacity, Ductility Ratio And Crack Pattern Were Observed.
To Extend The Principles Of Reinforced Concrete Design By Using Continuous Steel Reinforcement As The Main Reinforcement To Satisfy Ultimate Stress Limit State And Fibers As A Secondary Reinforcement To Control Cracking And Satisfy The Crack Width Limit State In Service. To Use Polypropylene Fibers Instead Of Steel Fibers, Differently From Most Prior Investigations Were Used. To Study the Influence of Self-compactingconcrete Mixture Used Instead Of Conventionally Vibrated Concrete.
From The Test Results It Is Observed That The Compressive Strength At 28 Days Curing Of Hybrid Ferro cement Slab With Polypropylene Fibers Content Of 0.3% Is Increased By 6.34% With Compressive Strength Of Conventional Concrete Plain.
From The Studies It Is Observed That the Deformation at Ultimate Load Are High In Case Of Ferro cements With Polypropylene Fibers. The Stiffness Of The Specimens With Zero Layer Weld Mesh Is Lower Than That Of The Specimens With Two Layers And Three Layers Bundled. Further, There Is Reduction In Number Of Cracks With Increase In Fiber Content.
From The Test Results It Is Observed That The Ultimate Load Carrying Capacity In Three Layer Weld Mesh Hfs With 0.3% Fiber Content Is Increased By 25% In Comparison With Double Layer Weld Mesh Of Ferro cement Slab Without Gfrp Layer.

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Chapter1:-

Introduction:-

General:-

Modern Structural Engineering tends to progress towards more economical structures through gradually improved methods of design and use of higher strength materials, such developments are particularly important in the field of reinforced concrete. The limiting features of ordinary reinforced concrete have been largely overcome by the development of Ferro cement, Ferro cement is a type of thin reinforced concrete section commonly constructed with hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size weld mesh. In its role as a thin reinforced concrete product and as a laminated cement-based composite, the ferro cement has found its place in numerous applications both in new structures and in repair and rehabilitation of existing structures.

Compared with the conventional reinforced concrete, ferro cement is reinforced in two directions; therefore, it has homogenous-isotropic properties in two directions. Benefiting from its usual high reinforcement ratio, ferro cement generally has a high tensile strength and a high modulus of rupture. In addition, since the specific surface of reinforcement in ferro cement is one to two orders of magnitude higher than that of reinforced concrete, larger bond forces develop with the matrix resulting in average crack spacing and width more than one order of magnitude smaller than in conventional reinforced concrete (Shah and Naaman 1997, Guerra et al 1978). Other appealing features of ferro cement include ease of prefabrication and low cost in maintenance and repair. Based on the abovementioned advantages, the typical applications of ferro cement are water tanks, boats, housing wall panel, roof, formwork and sunscreen (Nimityongskul et al 1980 and Kadir 1997).The renaissance of ferro cement in recent two decades has led to the ACI design guideline “Guide for the Design, Construction, and Repair of Ferro cement” (ACI Committee 549-1R-88 1993) and publications such as “Ferro-cement Design, Techniques, and Application” (Bingham 1974) and “Ferro cement and Laminated Cementations Composites” (Naaman 2000), which provide comprehensive understanding and detailed design method of contemporary ferro cement.

However, the rapid development in reinforcing meshes and matrix design requires continuous research to characterize the new material and improve the overall performance of ferro cement. Instead of cement mortar, self-compacting micro - concrete is used in this study in order to eliminate the external vibration and to overcome the difficulties and problems in the construction process. As a laminated composite, Ferro cement often suffers from severe spilling of matrix cover and delimitation of extreme tensile layer even at high reinforcement ratio, resulting in premature failure. Therefore, consideration of serviceability rather than strength limit would dominate composite design. Thus far, steel meshes have been the primary mesh reinforcement for ferro cement, but recently adding discontinuous short fibre to cementitious matrix has become in use (Sivakumar and Manu Santhanam 2007), which could bring significant improvement in ductility and shear capacity as well as moderate increase in tensile strength turns to be a logical andreasonable solution to solve serviceability problems. When concrete cracks, the randomly oriented fibres arrest the micro cracking, thus improving the strength, ductility and convert its brittle characteristics to a ductile one. In this study, the addition of polypropylene fibres also enhances the flexural strength and Impact resistance of HF slabs.

The development of new technology in the material science is progressing rapidly. In recent two or three decades, a lot of research was carried out throughout globe for how to improve the performance of concrete in terms of strength and durability qualities. Consequently concrete has no longer remained a construction material consisting of cement, aggregate, and water only, but it has become an engineered custom tailored material with several new constituents to meet the specific need of construction industry. The growing use of concrete in special architectural configurations and closely spaced reinforcing bars have made it very important to produce concrete that ensure proper filling ability, good structural performance, and adequate durability. In recent years a lot of research was carried out throughout the world for how to improve the performance of concrete in terms of its most important properties that is strength and durability. Concrete technology has under gone from macro to micro level study in the enhancement in strength and durability properties from 1980’s onwards. However till 1980’s the research study related to flow ability of concrete to strength and durability did not draw lot of attention of the concrete technologists.

This type of study has resulted in the development of Self Compacting Concrete (SCC), a much-needed revolution in concrete industry. Self-Compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self weight only. This SCC eliminates the need of vibration either external or internal for the compaction of concrete without compromising its engineering properties. Nowadays it is well known that the benefits of adding fibres to concrete.

Reduce cracks during plastic and hardening stage, reduce water seepage and protects steel in concrete from corroding and walls from dampening, Protects corner in precast slabs and concrete flooring. Increases abrasion resistance by over 40% there by increasing lift of roads, walkways, floors. Also reduces pitting of the floor.

A large number of civil infrastructures around the world are in a state of serious deterioration today due to carbonation, chloride attack, etc. Moreover many civil structures are no longer considered safe due to increase load specifications in the design codes or due to overloading or due to under design of existing structures or due to lack of quality control. In order to maintain efficient serviceability, older structures must be repaired or strengthened so that they meet the same requirements demanded of the structures built today and in future. Ferro cement over the years have gained respect in terms of its superior performance and versatility. Ferro cement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated in, mortar. In 1940 Pier Luigi Nervy, an Italian engineer, architect and contractor, used ferro cement first for the construction of aircraft hangars, boats and buildings and a variety of other structures. It is a very durable, cheap and versatile material.

Hybrid Ferro Cement Slab:-

Research efforts to improve materials and production processes used in ferro cement follow a number of parallel paths that deal with increasing strength, improving toughness, improving durability, increasing mechanical efficiency and decreasing material usage and production cost.

Ferro cement could be seen as a scaled down system of reinforced concrete construction with reinforcement distributed throughout the depth of the member. Improved elasticity, cracking, extensibility and impact characteristics are achieved by proper control of reinforcement parameters. While ferro cement can benefit from being considered an extreme boundary of reinforced concrete, it has and is still taking advantage from the rapid development in the field of composite materials including advanced laminated and hybrid composites and thus it must also continue to establish its own identity.

By concrete standards, ferro cement can be thought of a thin reinforced concrete construction with very high performance characteristic such as high tensile strength to weight ratio, ductility and impact resistance,these characteristics are required for earthquake prone area applications.For instance, a factory produced ferro cement element using self-compacting concrete .

Square weld mesh instead of woven wire mesh cost two to three times less than conventional ferro cement elements of equivalent performance. The increasing availability of fiber reinforced polymer is likely to lead further cost reduction. Applications of ferro cement in small size structures and structural elements have mushroomed in developing countries. In a way, Ferro cement is becoming an all-purpose material and its potential combinations with other materials is a testimony to its versatility. This may take the form of mechanized production of small size elements such as cement sheets and pipes to replace asbestos cement

The investigations by Naaman and Gurrero (1996) shows the addition of discontinuous fibres to the matrix of ferro cement can effectively increase its moment of resistance and significantly reduce the average crack spacing and width at ultimate loading and it also prevent the spalling of concrete. To improve the structural performance and reduce total cost of construction, a new ferro cement system performance is enhanced with polypropylene fibers, FRP laminates and which is termed as Hybrid Ferro cement system. Most of the past research work has focused on the potential use of ferro cement in structural applications as permanent formwork (Kadir 1997) secondary roofing elements, etc.

Very little research has been done on altering the inherent character and material properties of the ferro cement. This research work aims at to study the flexural response, deformation characteristics, ductile performance and energy absorption capacity under impact load of ferro cement slabs made up of self-compacting concrete and wrapped with GFRP sheets at the bottom face.

Chapter2:-

Literature Review:-

History Of Development:-

Joseph-Louis Lambot of France,in 1852:-

The initial definition of ferro cement can be drawn from a patent application submitted by Joseph-Louis Lambot of France, in 1852.The patent for "Ferro-cement", which translate into "iron-cement". His invention shows a new product which helps to replace timber where it is endangered by wetness, as in wood flooring, water containers, plant pots etc.., The new substance consist of a metal net of wire or sticks which are connected or formed like flexible woven mat. He Give this net a form which looks in the best possible way, similar to the article he want to create. Then he put in hydraulic cement or similar bitumen tar or mix, to fill up the joints.

Fig 1:-Lambots first boat at Brignoles museum France(Source :Google images)

Lambot built two rowboats in 1848 and 1849,in length respectively about 3.6m and 3m(12 and 9 foot), 1.3m(4ft) wide and 38mm (1.5in.) thick, and disclosed his patent at the paris exhibition in 1855 by showing one of the boats. The first boat is now at brignoles museum in France as shown in fig[1].

Joseph monier in 1867:-

He is working independently of Lambot, started building for the city of paris, France, flower pots and garden tubs made out of cement iron rods. Monier took a patent in July 1867,for "a system of movable casing and bowls made of iron and cement, applicable to horticulture", Monier's work also can be considered as the origin of reinforced concrete.

Dutch man, Mr. Boon in 1887:-

He built a small craft of ferro cement, the Zeemeuw (or seagull) and several barges of reinforced mortar to carry ashes and refuse on water canals. The Zeemeuw was reported to be still operating at the Amsterdam zoo in 1968.It is currently displayed in the lounge of the Vereeniging Nederland Cement Industries office in Amsterdam. During the first world war, ships and barges were built with reinforced concrete, and this was again attempted during the second world war due to shortages of materials, particularly steel. In effect, ferro cement was forgotten and replaced by reinforced and prestressed concrete.

Pier Luigi Nervi in 1940:-
A noted Italian engineer – architect, revived the original concept of "ferro cement" by proposing that Ferro cement be utilized to build fish boats. He pointed out the distribution of reinforcing meshes in concrete produces a material with approximately homogeneous mechanical properties, capable of resting high impacts. Following some preliminary test on slabs, he showed that ferro cement possesses exceptional elasticity, flexibility, strength, and resistance to cracking. In 1943 ferro cement received the acceptance by the Italian Navy. Shortly after the second world war, Nervi demonstrated the potential of ferro cement by building a 165 ton motor-sailor Irene using a ferro cement hull of thickness 35mm(1.4 in.) which is slightly less than that of the wood hull The Irene entirely satisfactory.

Nervi continued his pioneering by using ferro cement in some architectural work applications, such as a storage warehouse and the roof the exhibition hall of Turin(1948). Most of these structures are still standing today. The boats and structures built by Nervi were appreciated only two decades later, time at which the durability and serviceability of ferro cement could ascertained by the profession.

Ferro cement finally achieved wide acceptance in the early 1960's for boat building the united kingdom, New Zealand, Canada and Australia. In 1968, the Fisheries Department of the Food and Agriculture Organization(FAO) of the United Nations started ferro cement boat building projects in Asia, Africa, and Latin America. Other countries followed, including the soviet union, China, and several countries in south-east Asia. In 1972, the US National academy of science formed a panel to report on the application of ferro cement in developing countries. One of the recommendation of the panel was to establish a worldwide centre to collect, process, and disseminate information on ferro cement. Subsequently, in 1976, the International Ferro cement Information centre was established at the Asian institute of Technology (AIT) in Bangkok, Thailand. In 1975, the American concrete institute formed committee 549, Ferro cement. In 1991, the International Ferro cement Society was established (under the leadership of R. Pama) with headquarters at AIT in Bangkok.

Chapter 3:-

Experimental Programme:-

Objectives:-

1. To extend the principles of reinforced concrete design by using continuous steel reinforcement as the main reinforcement to satisfy ultimate stress limit state and fibres as a secondary reinforcement to control cracking and satisfy the crack width limit state in service.
2. To use polypropylene fibers instead of steel fibers, differently from most prior investigations were used.
3. To study the influence of SCC mixture used instead of conventionally vibrated concrete.
4. To study the experimental tests on simply supported HF slabs, in order to determine the ductility factor under the two point loading.
5. To analyze the nonlinear behavior of HF slabs by determining the load deflection response for the slabs tested.
6. To arrive at the analytical equations for moment of resistance, load deflection profile up to serviceability limit. Ductility factor of HF slabs from the experimental investigations carried out.

Advantages Of Ferro Cement Slabs:-
The construction of Ferro cement slabs has been found attractive in many developing countries because:

- Ferro cement is made of materials that are readily available in most countries.
- Ferro cement is suitable for a wide range of construction techniques, ranging from self-help construction for housing and agricultural structures to highly prefabricated industrial processes.
- At the low end, ferro cement requires a low level of technology and common labor skill, because of its light weight, it does not require heavy construction equipment or plants.
- Ferro cement can be fabricated in any desired shape, it is particularly suitable for shells and free form shapes.
- Ferro cement is durable and resistant to the environment like concrete and masonry, it is non-flammable, it is less prone to corrosion than steel, it is not sensitive to humidity and unlike wood, does not rot, and has longer life than fiber reinforced plastics.
- Ferro cement can be easily maintained and repaired after damage.
- Ferro cement is cost effective.
- The skills for ferro cement construction can be easily acquired.
- Ferro cement construction is less capital-intensive but more labour intensive.

- Ferro cement qualifies in terms of using fewer resources and nless energy, in being less polluting, and in generating less waste.

Disadvantages Ferro Cement Slabs:-
- It is difficult to fasten to ferro cement with bolts, screws, welding and nail etc.
- Large no of labors required.
- Cost of semi-skilled and unskilled labors is high.

Chapter 4
Preliminary Tests:-
Tests on Cement:-
Ordinary Portland cement 53 grade conforming to IS 12269-1987 is used and there properties are as follows:-
Table 1:- Test on cement

SL.NO	Characteristics	53 grade	As per IS 12269-1987 for 53 grade
1	Consistency of cement	35%	-
2	Specific gravity	3.09	3.15
3	Initial setting time	56 minutes	>30 minutes
4	Final setting time	268 minutes	<600
5	Fineness of cement	2.3%	<10%
6	Compressive strength 3 days	28.2 N/mm2	27 N/mm2
7	Compressive strength 7 days	38.6 N/mm2	37 N/mm2

Sieve Analysis of fine aggregates:-
The aggregate consists of well graded fine aggregate (sand) that passes a 4.75 mm sieve.
Table 2: sieve analysis of fine aggregate

IS Sieve Size	Wt. Retained On sieve(gm)	Cumulative Weight retained	Cumulative % retained	Cumulative % passing	Requirement IS 383-1970
4.75mm	66	3.32	3.32	96.68	90-100
2.36mm	176	8.84	12.16	87.84	75-100
1.18mm	330	16.58	28.74	71.26	55-90
600μm	226	11.36	40.10	59.90	35-50
300μm	1144	57.49	97.59	2.41	8-30
150μm	40	2.01	99.60	0.4	0-10
Pan	8	0.4	100.00	0.00	
TOTAL	1990		281.20		

Quantity Calculation:-
Mix design is defined as quantity of material per cubic metre of mortar (cement, fine aggregates) as shown in below
- Calculate the dry volume of materials required for $1m^3$ cement mortar. Considering voids in sands, we assume that materials consist of 60% voids. That is, for $1m^3$ of wet cement mortar, $1.6m^3$ of materials are required.
- Now we calculate the volume of materials used in cement mortar based on its proportions.Let's say, the proportion of cement and sand in mortar is 1:2.Then, the volume of sand required for 1:2 proportion of $1m^3$ cement mortar will be$1.6*2/(1+2)=1.067m^3$.
- Volume of cement will be calculated as $1*1.6/(1+2)=0.53\ m^3$
- Since the volume of 1 bag of cement is $0.0347\ m^3$, so the number of bag of cement will be calculated as: 0.53/0.0347=15.27 bag

Chapter 5:-

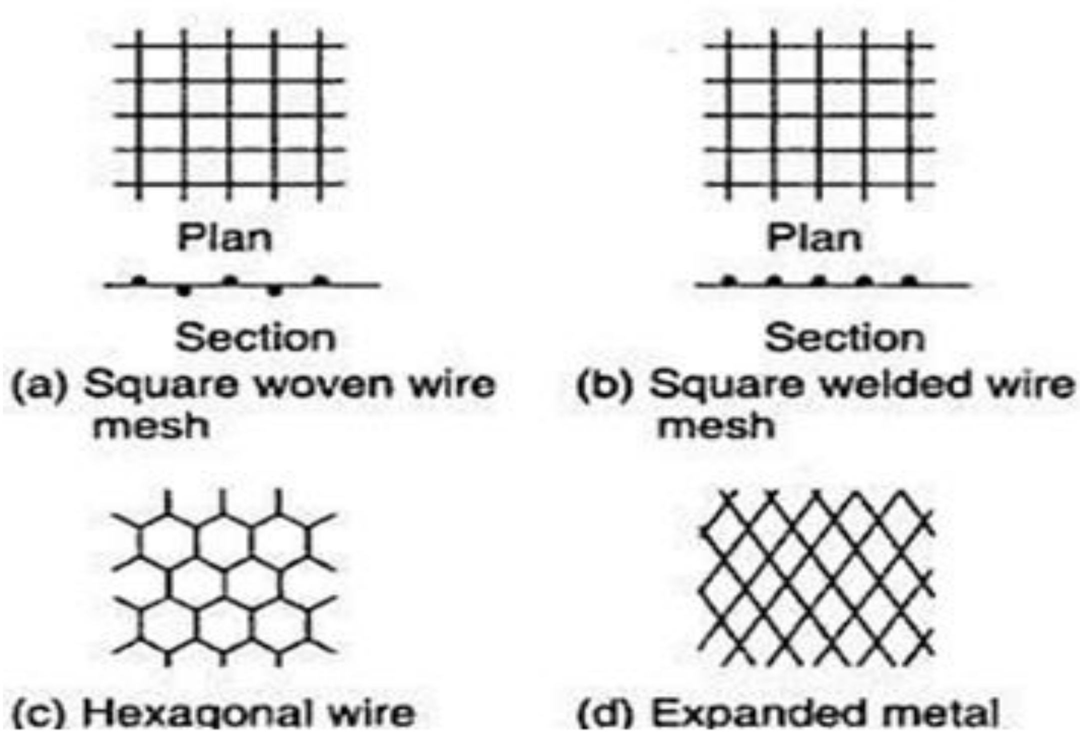
Materials:-

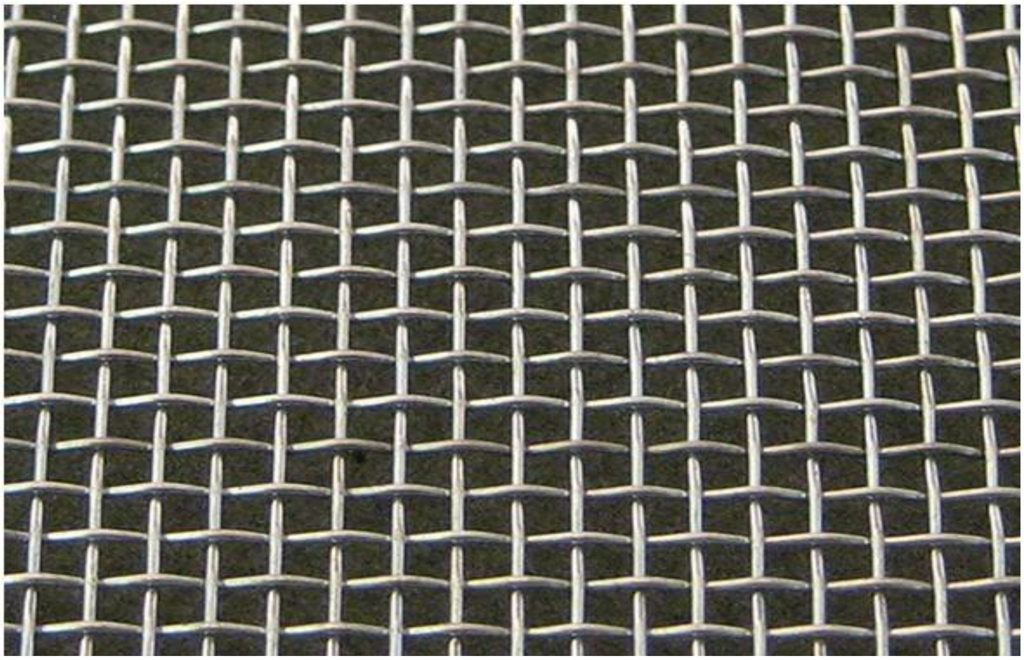
Constituents Of Ferro Cement:-

Ferro cement is a composite thin element which is constructed of building materials wire mesh, cement, fine aggregate (sand) water, polypropylene fibre.

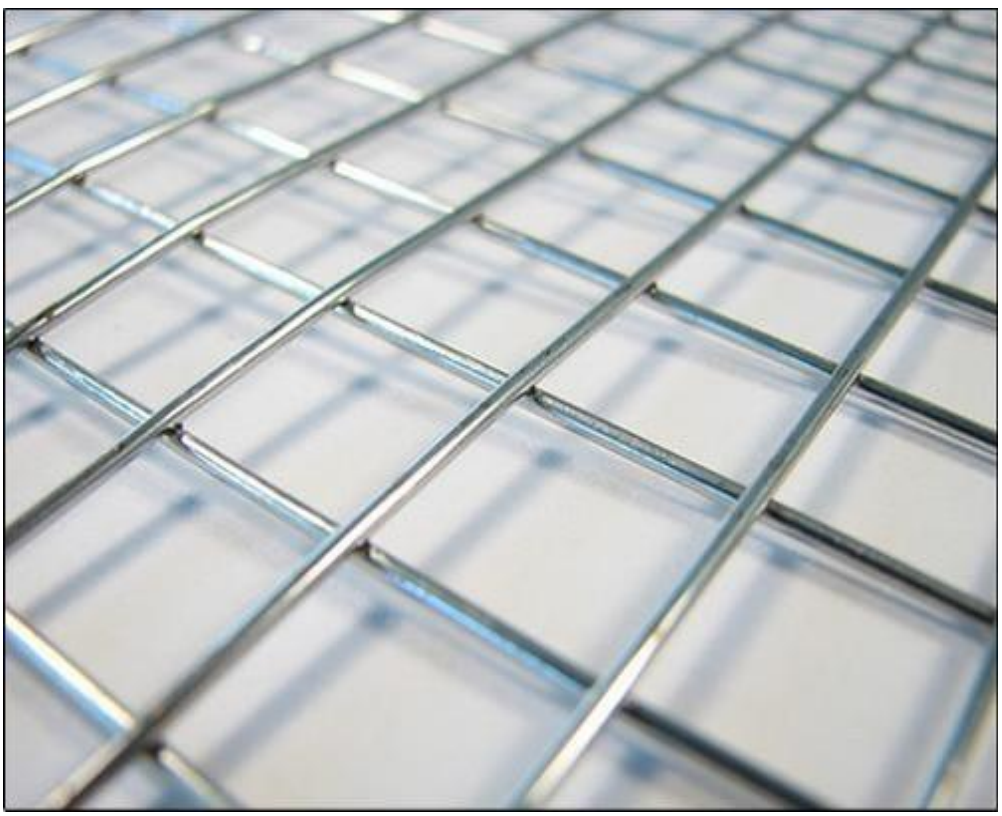
Wire mesh:-

One of the important constituents of ferro cement is wire mesh reinforcement. These generally consist of thin wires, (galvanized or un-galvanized) either woven or welded at their intersections. The mechanical properties of ferro cement depends on the type, quantity, Orientation and strength properties of mesh reinforcement. Different type of mesh reinforcement are available in the market, which are suitable of ferro cement construction. Some of them are listed below

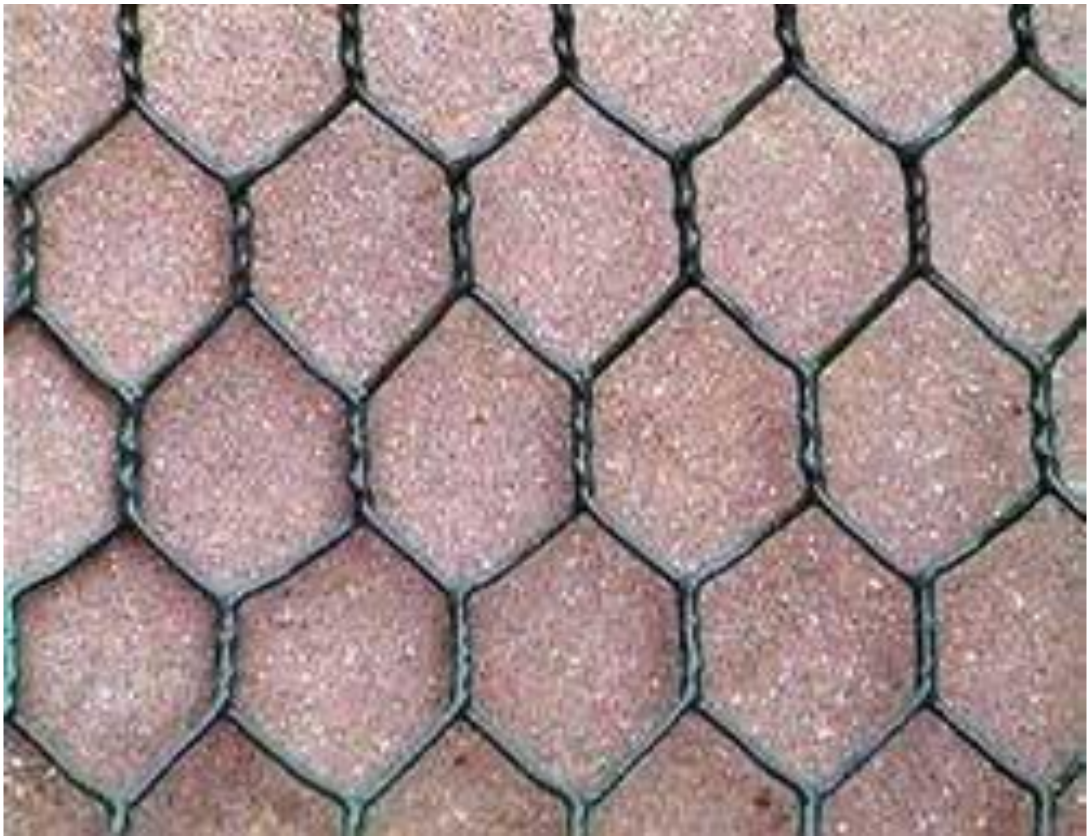




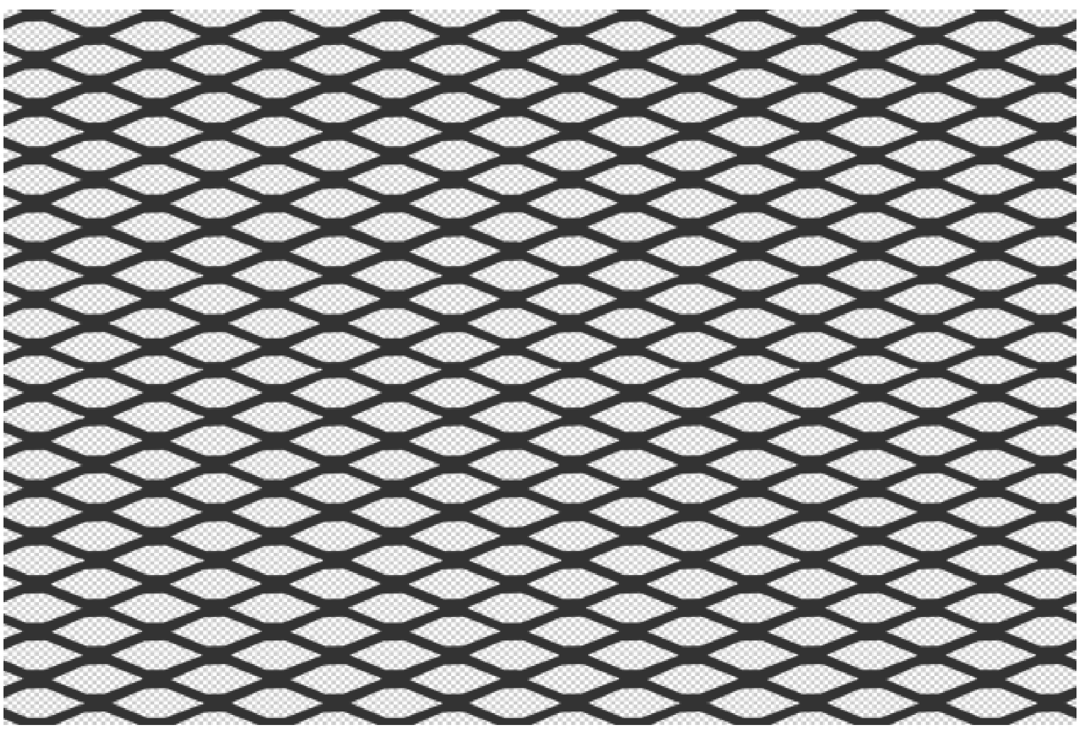
1.Squarewoven mesh



2.Square welded mesh



3.Hexagonal wire mesh.



4. Expanded metal mesh

Fig 2:- Types of wire mesh(Source: Google images)

1. **Woven wire mesh** is fabricated simply weaving the galvanized wires into desired grid sizes without welding them at the intersection. The grids are generally square. The mesh wires are not perfectly straight and some amount of waviness exists.
2. **Hexagonal wire mesh** also commonly known as chicken wire mesh is fabricated from cold drawn wires of diameter varying from 22-26 gauges and woven into hexagonal patterns with mesh opening varying from 10mm to 25mm. This is the cheapest, easiest to handle and most commonly used in ferro cement construction.
3. **Expanded metal mesh** which is sometimes used in ferro cement construction, is formed by slitting thin gauge sheets and expanding them in a direction perpendicular to the slits to produce diamond shape openings. This mesh has inherent advantages like good mechanical bond and ease of placing.
4. **Welded wire mesh** is fabricated in rectangular or square pattern by perpendicular intersecting wires (generally 2-3mm diameter) made of low to medium
5. **Tensile strength** steel (which are much stiffer than hexagon or woven wire mesh) and welded together at the intersections. Now we are using this kind of meshes in preparing ferro cement slabs.

Cement:-

Ordinary Portland cement of 53 grade that is commercially available in the market is satisfactory for ferro cement construction. But the type of cement should be selected according to the need or environment in which the structure is built. However other type of Portland cement can be used like sulphate resisting cement for ferro cement construction in marine environment.

Portland pozzolana cement has also been recommended for ferro cement as it provides good resistance to sulphate attack also competitive in price compared with ordinary Portland cement.

Sand:-

Only fine aggregate is used in ferro cement, Coarse aggregate is not used in ferro cement. Normally, the aggregate consists of well graded fine aggregate (sand) that passes a 4.75 mm sieve; and since salt-free source is recommended, sand should preferably be selected from river-beds and be free from organic or other deleterious matter. Good amount of consistency and compatibility is achieved by using a well- graded, rounded, natural sand having a maximum top size about one-third of the small opening in the reinforcing mesh to ensure proper penetration. The moisture content of the aggregate should be considered in the calculation of required water.

Water:-

In ferro cement, the water used for mixing cement mortar should be fresh, clinched fit for construction purposes; the water of pH equal or greater than 7 and free from organic matter—silt, oil, sugar, chloride and acidic material.

Admixtures:-

In numerous admixtures available, chemical admixtures is best suitable for ferro cement because it reduces the reaction between matrix and galvanized reinforcement. Chemical admixtures used in ferro cement cement serve one of the following purposes like water reduction, improvement in impermeability, air entrainment, which increases resistance to freezing and thawing. Here we are using Polycarboxylate Ether (PCE 811).

PolycarboxylateEther(PCE 811).'Polycarboxylate Ether' this liquid is commonly used for the purpose of enhancing the fluidity of concrete it also plays a vital role in boosting the strength it exalt the plasticity as well. Polycarboxylate ether increases the strength of concrete in a drastic manner. This chemical gives construction industry innovation solutions and totally new opportunities which are completely related to the field of concrete manufacturing. This chemical provides high fluidity to concrete at less levels of water. It also retains slump for the long time period. With water reducing property it also gives very remarkable strength and high workability to concrete.

Polypropylene fiber:-

Specific Gravity:-

0.90 – 0.91 gm/cm3, Because of its low specific gravity, polypropylene yields the greatest volume of fibre for a given weight. This high yield means that polypropylene fibre provides good bulk and cover, while being lighter in weight. Polypropylene is the lightest of all fibres and is lighter than water. It is 34% lighter than polyester and 20% lighter than nylon. It provides more bulk and warmth for less weight.

Applications:-

- Rcc&Pcc like lintel ,beam, slab, column, flooring and wall plastering
- Foundation, tanks, manholes, cover and tiles.
- Roads and pavement
- Hollow block and precast

Advantages:-

- ❖ Reduce cracks during plastic and hardening stage.
- ❖ Reduce water seepages and protect steel in concrete from corroding and walls from dampening.
- ❖ Rebound loss reduced by 50-70%. Result in saving of expensive mortar, cement and sand.
- ❖ Time taken for plastering is reduced and work is completed faster.
- ❖ Protect corners in precast slabs and concrete flooring.
- ❖ Increase abrasion resistance by over 40% there by increasing life of roads, walkways, floors. Also reduces pitting of the floor.

Properties of ferro cement composites (as per aci committee 549r-97):-

- ➢ Wire diameter 0.5 to 1.5 millimeters
- ➢ Size of mesh opening 6 to 35 millimeters
- ➢ Maximum use of 12 layers of mesh per inch of thickness
- ➢ Thickness 6 to 50 millimeters
- ➢ Ultimate tensile strength up to 34 MPa
- ➢ Allowable tensile stress up to 10 MPa
- ➢ Modulus of rupture up to 55MPa
- ➢ Compressive strength up to 28 to 69Mpa

Chapter6:-

Methodology:-

The experimental program includes preparing and testing of hybrid ferro cement slabs using point load method.

The variable parameters are as follows:-

1. Number
2. Percentage of welded square mesh reinforcement.
3. Percentage of polypropylene fibres in mortar.
4. Number of FRP layer wrapping.

Mix Proportion:-

Table 3:- Mix proportions

Cement sand Proportion	1: 2
Water cement ratio	0.45
Polypropylene fibres	0.3% by weight of cement
super plasticizer	0.5% by weight of cement

Variable Parameters:-

Table 4:- Variable parameters.

S.l no.	specimens	Thickness in mm	Wire mesh	FRP layers	Polypro-pyline fibers
1	A0	60	0	0	0
2	A2	60	2	0	0
3	A3	60	3	0	0
4	B0	60	0	0	0.30%
5	B2	60	2	0	0.30%
6	B3	60	3	0	0.30%
7	C0	60	0	1	0.30%
8	C2	60	2	1	0.30%
9	C3	60	3	1	0.30%

Test Specimens:-
A total of 9 specimens of Ferro cement slabs were cast and are tested. All the specimens have a dimensions of 1000mm*1000mm with a thickness of 60mm each. The thickness of slabs were kept constant and by varying numbers of layers of meshes, numbers of FRP layers and the slabs with and without polypropylene fibre totally accounts for 9 slab specimen. The specimens were designated as A0, A2,A3,B0,B2,B3,C0,C2,C3. Table4 shows the details of varying parameters used in ferro cement slabs in the present investigation work.

The supplementary specimens such as six numbers out of which three are with and another three without polypropylene fibres of size 70mm*70mm cubes were cast along with the ferro cement slab and are tested for compressive strength.

The slabs were cast using self compacting micro concrete, which gets compacted due to its own weight any external vibration. This concept is used for the construction of ferro cement slabs in order to overcome the problems and difficulties in the construction process.

The use of SCC in the construction of ferro cement slabs facilitates the easy placing of mortar without requirement of skilled labors, vibrators and improving the quality and speed of manufacturing ferro cement products.

Preparation Of Mortar:-
Mortar was prepared by calculating the exact amount of cement sand and water. At the first the cement sand were dry mixed. For addition of water, initially 75% of water is added to the dry mix and mixed thoroughly.

Admixture such as super plasticizer with dosage of 0.5% by weight of cement is added with remaining 25% of water and its added to the mixer and is mixed thoroughly for about ten minutes and polypropylene fibre with dosage of 0.3% by weight of cement is added to the mixture and mixed properly, Finally the mortar is prepared.

Fig 3:- Morter mix

The mesh pieces were cut down according to the size of panel leaving a cover of 50mm on both side of mesh of size (900*900mm) as shown in figure below

Fig 4:- Pieces of welded square mesh (spacing 20*20mm, 1.2mm diameter)

Properties Of Self Compacting Concrete:-

The SCC flows alone under its dead weight up to leveling, airs out and consolidates itself thereby without any entry of additional compaction energy and without a nameable segregation. The SCC owns over three key characteristics which are listed below. These characteristics were made possible by the development of highly effective water reducing agents (super plasticizers), those usually based on Polycarp boxy late ethers. The mixture composition of SCC deviates from conventional concrete. The powder contents of SCC are normally lying (in some cases even considerably) above those of conventional concrete.

1. **Filling Ability**: Ability of to fill a formwork completely under its own weight.
2. **Passing Ability**: Ability to overcome obstacles under its own weight without hindrance. Obstacles are e.g. reinforcement and small openings etc.
3. **Segregation resistance**: Homogeneous composition of concrete during and after the process of transport and placing.

An idea of SCC is a material that flows into formwork and compacted under the influence of its own self-weight without vibration and additional processing. Realization of self-compacting as the key feature of fresh concrete enabled at the same time application of technologically higher quality material with improvement of economic building conditions.

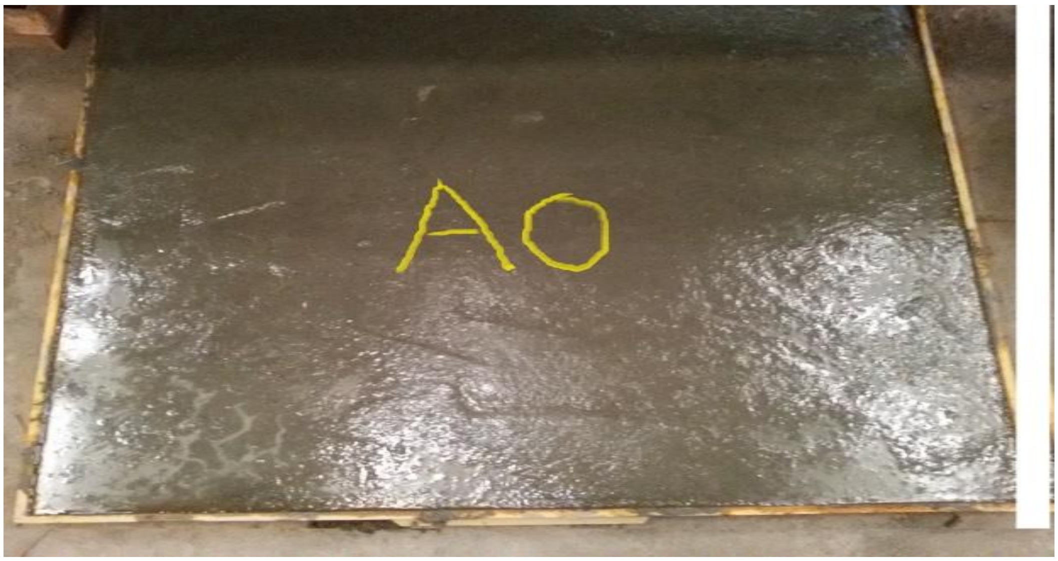
Uses And Advantages Of Self Compacting Concrete:-

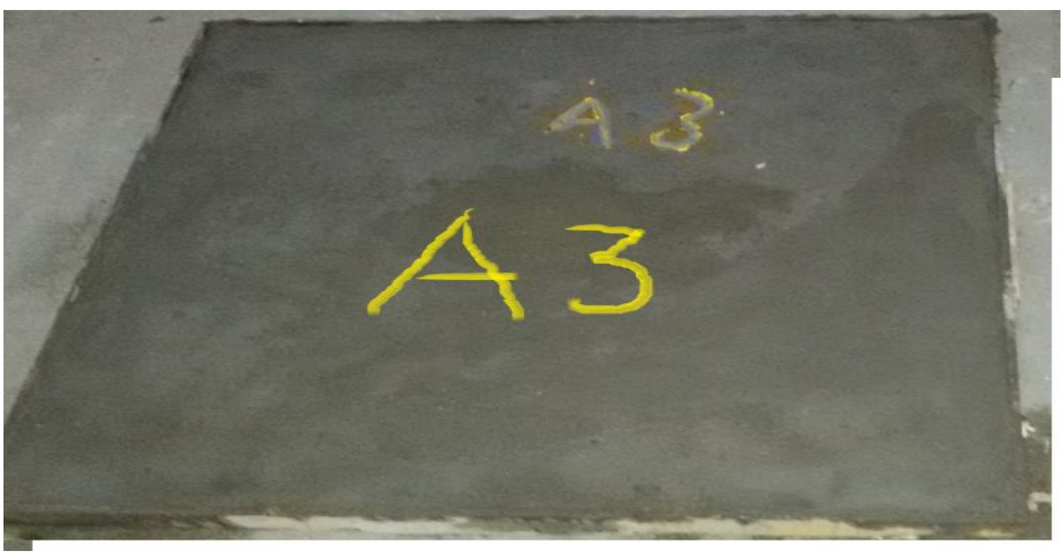
The main advantages of application of self-compacting concrete on site are as follows:

- No vibration of fresh concrete is necessary during placement into forms.
- Placement of concrete is easier.
- Faster and more efficient placement of fresh concrete is achieved. Total concreting time is reduced.
- Noise level on construction site is reduced.
- The number of working hours on the construction site can be increased and the night shift in urban zones is enabled.
- Energy consumption is reduced.
- Required number of workers on construction site is reduced.
- Safer and healthier working environment is obtained. Upon self-compacting concretehardening in structures:
- High quality of placed concrete is achieved, regardless of the skill of the workers.

- Good bond between concrete and reinforcement is obtained, even in congested reinforcement.
- High quality of concrete surface finish is obtained with no need for any subsequent repair.
- With a better final appearance of concrete surface, smooth wall surfaces and flat floor surfaces that need no further finishing are obtained.
- Improved durability of structures is achieved.

Casting:-
A wooden mould of size 1000mm*1000mm*60mm were oiled before casting to avoid sticking of mortar. Firstly at bottom mortar is placed for about 6mm thickness and above this the wire mesh of size 900mm*900mm to ensure minimum clear cover of 50mm on each side of the reinforcement is placed inside the mould care should be taken that the wire mesh should be strengthen to a plane surface by pressing with fingers and above this mortar is placed and another wire mesh is placed the procedure is continued for a three layer, two layer, and zero layer finally, the surface are being levelled to get a uniform surface finishes following fig 6 .shows casting slabs.






B0


B2


C0
C2

Fig 5:- casting slabs

Design Parameters:-

The arrangements of weld mesh used in this investigation were offive categories. Those are:

1. Placing a layer weld mesh across the cross section of slab attention zone with a clear cover of 3mm shown in Figure.
2. Placing the two layers of weld mesh across the cross section of slab at tension zone with a clear cover of 3mm and a spacing of3mm between the layers shown in Figure.
3. Placing the three layers of weld mesh across the cross section of slab at tension zone with a clear cover of 3mm and a spacing of 3mm between the layers shown in Figure.
4. Bundling the two layers of weld mesh with binding wire and placing near bottom with a clear cover of 3mm shown in Figure.
5. Bundling the three layers of weld mesh with binding wire and placing near bottom with a clear cover of 3mm shown in Figure.

These specimens are designed to study the influence of arrangements of weld mesh on the flexural behavior of the ferro cement slabs.

The thickness of the slab also plays a major role in the flexural strength and in the ductility. Hence, for the proposed experimental study and 60 mm thickness were chosen. HF slabs polypropylene fibers (Ronald 1996) were added as secondary reinforcing elements to control cracking in the compression face. Two different number of GFRP layers were considered to wrap at the bottom face of the slab. They are: 1.Specimens with single layer of GFRP wrapping at tension zone 2. Specimens with two layers of GFRP wrapping at the tension zone.

Curing And Application Of Gfrp Layers:-

The specimens cast were left in the moulds for a period of 24 hours. After 24 hours Specimens were demoulded from the mould carefully and immediately placed under water in a curing tank and were allowed to cure under water for a period of 28 days.

After the period of 28 days, the ferro cement slabs were taken out of the curing tank, dried and out of nine slabs for three slabs such as C0, C2&C3 at the bottom surface of the slab is made rough using of wire brush. GP resin twice by weight of the FRP sheets is being applied using the brush on the bottom surface of the slab and the sheets are pasted and are pressed along the edges of the slabs. FRP wrapped slabs are being kept for a period of 2 days and are allowed to get dried before the testing of slabs.

All the slabs were tested under monotonic loading in two point flexure to evaluate the following:
1. Deformation characteristics.
2. Ductility of Hybrid Ferro cement slabs
3. Modes of failure

Fig 6:- Application of GFRP layer.

Chapter7:-

Instrumentation And Loading Procedures:-

All the specimens were tested in a loading frame, which is fixed over a strong floor. The slabs were simply supported with an effective span of 800mm c/c. Two point loads were applied transversely at one third distances from support using a steel plate. Along with it, capacity proving ring was used for the load application. Dial gauge of sensitivity 0.01mm were used to measure the deflection of the slabs. The dial gauge were kept at mid span of the slab deflector meter to measure the deflection of the slab.

Fig 7:- Testing of slab specimens (structural lab)

The behavior of the slab was keenly observed from the beginning till collapse. The propagation of initial cracks due to the increase of load was also recorded. The loading was continued till the verge of collapse.

Measurement Of Deflections:-

The slabs were suitably instrumented for measuring deflection using dial gauge**.** Deflections under the loads of the central deflections were measured using 0ne dial gauge. The dial gauge have a least count of 0.01 mm, it was held in position by stands fit with magnetic base. The readings were taken at closer intervals. Figure9 shows the deflector meter attached to the slab.The load was gradually applied by screw gauge with a proving ring of capacity 25 kN. As the applied load was increased, each test slab was carefully inspected visually for the first crack formation to estimate first crack strength. The value obtained was confirmed using the load-deflection plot, where the first - crack strength would correspond to a sudden (but small) drop in the load readings. After the determination of the first-crack strength, the specimen was tested to failure to obtain its ultimate strength.

Ductility Performance:-

The ability of a member to deform without a significant loss of its strength is known as ductility.One method of quantifying ductility is by using the ductility factor as defined by the ratio of ultimate deflection to the deflection at yielding of tensile reinforcement and Ductility Index, based on the failure state, where the failure load may be considered as equal to 85% of the ultimate load in the descending part of the load- deflection curve, is also of interest in some cases, especially in seismic design.

The displacement factor based on yielding of steel and ultimate stage are shown in Table: 9. it can be seen that displacement ductility factor varied from 0.38 to 2.15 forferro cement slabs. From the test results, the slabs without the gfrp wrapping and fibre reinforcement exhibits lower ductility ratios. The gfrp wrapped slabs with 3 bundled layered reinforcement exhibits a higher displacement ductility ratio than those of fibre reinforced and conventional ferro cement slabs due to the fact that strengthening of tension zone on the slabs has better confinement which affect the ductility ratios.

The provision of gfrp layers in the tension zone and also the reinforcing of polypropylene fibres in the concrete has better confinement capacity than the conventional ferro cement slabs preventing the disintegration of concrete in the compression zone even after the concrete reaches failure thereby improving failure ductility. The number ofbundlenessoreinforcement of wire mesh also has effect on the ductility ratios due to increase in the volume

Chapter8:-

Results And Discussions:-

Test Results Of Cubes:-

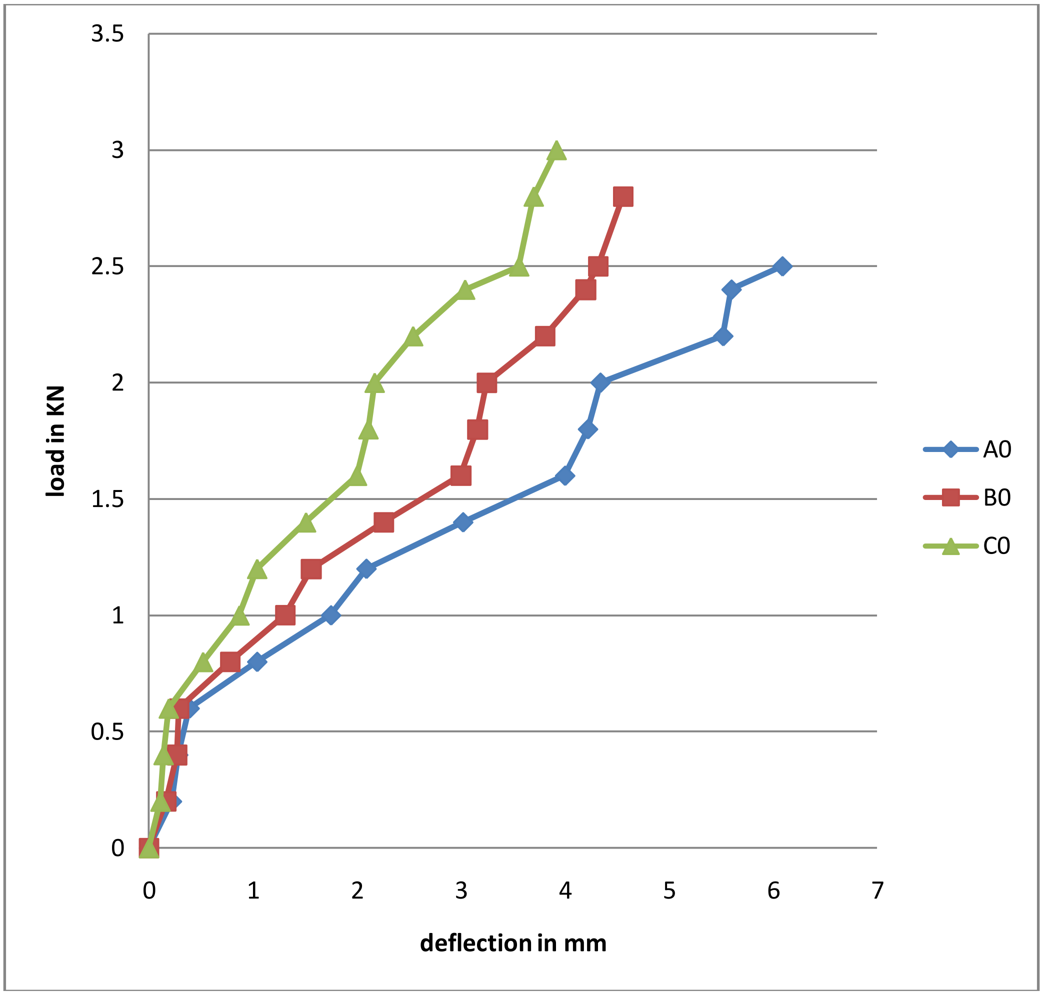
Table 5:- Test results on cubes

WITHOUT POLYPROPYLENE FIBRES				
Sl.NO	SIZE in mm	Load At failure (kg)	Compressive Strength(N/mm²)	Average
1	70*70	20,000	40.04	40.84
2	70*70	20,000	40.04	
3	70*70	21,200	42.44	
WITH POLYPROPYLENE FIBRES (0.3%)				
4	70*70	18,800	37.63	43.43
5	70*70	24,300	48.64	
6	70*70	22,000	44.04	

Test Results Of Slab Specimens:-

Table 6:- Slab thickness 60mm with zero layer of wire mesh.

Load (KN)	Deflection (mm) A0	Deflection (mm) B0	Deflection (mm) C0
0	0	0	0
0.2	0.22	0.165	0.11
0.4	0.28	0.27	0.14
0.6	0.39	0.29	0.19
0.8	1.04	0.78	0.52
1	1.75	1.31	0.87
1.2	2.09	1.56	1.04
1.4	3.02	2.26	1.51
1.6	4	3.0	2.0
1.8	4.22	3.16	2.11
2	4.34	3.25	2.17
2.2	5.52	3.81	2.54
2.4	5.60	4.2	3.04
2.5	6.09	4.32	3.56
2.8	6.30	4.56	3.70
3.0	6.40	4.66	3.92
1st crack	5.52	4.2	3.56
Max.load	3000	2800	3000



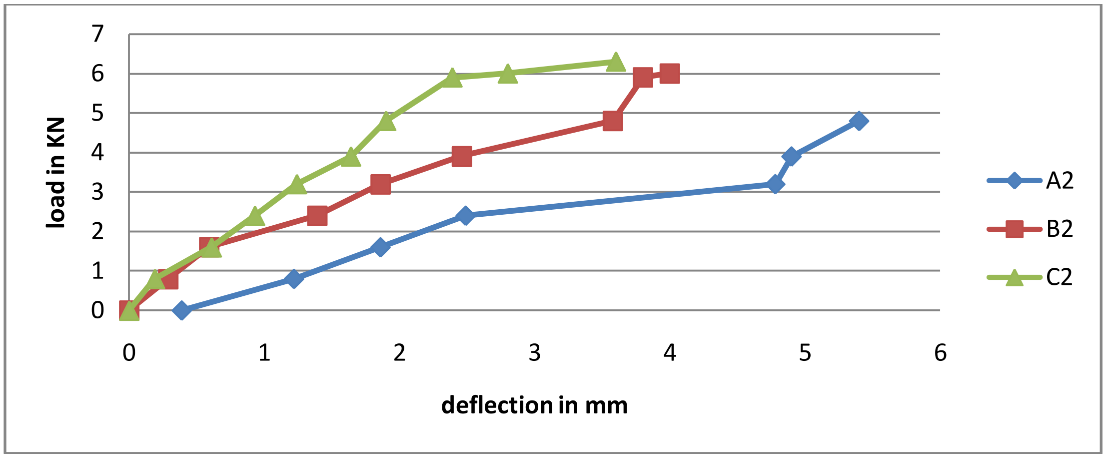
Graph 1:- Load v/s deflection (60mm zero layer)

A0: Slab specimen with zero layer wire mesh in the absence of polypropylene and Frp sheet.
B0: Slab specimen with zero layer wire mesh in the presence of polypropylene and in the absence of frp sheet.
C0: Slab specimen with zero layer wire mesh in the presence of polypropylene and Frp sheets.

Table 7:- Slab thickness 60mm 2 layers of wire mesh

LOAD (KN)	Deflection (mm)	Deflection (mm)	Deflection (mm)
	A2	B2	C2
0	0	0	0
0.8	0.39	0.29	0.19
1.6	1.22	0.59	0.61
2.4	1.86	1.39	0.93
3.2	2.49	1.86	1.24
3.9	4.78	2.46	1.64
4.8	4.90	3.58	1.90
5.9	5.4	3.80	2.39
6.0	5.8	4.0	2.80
6.3	6.1	4.2	3.60
1st crack	4.78	3.58	2.39
Max.Load	6400	7200	6400

A2: Slab specimen with two layer wire mesh in the absence of polypropylene and Frp sheet.
B2: Slab specimen with two layer wire mesh in the presence of polypropylene and in the absence of frp sheet.
C2: Slab specimen with two layer wire mesh in the presence of polypropylene and Frp sheets.

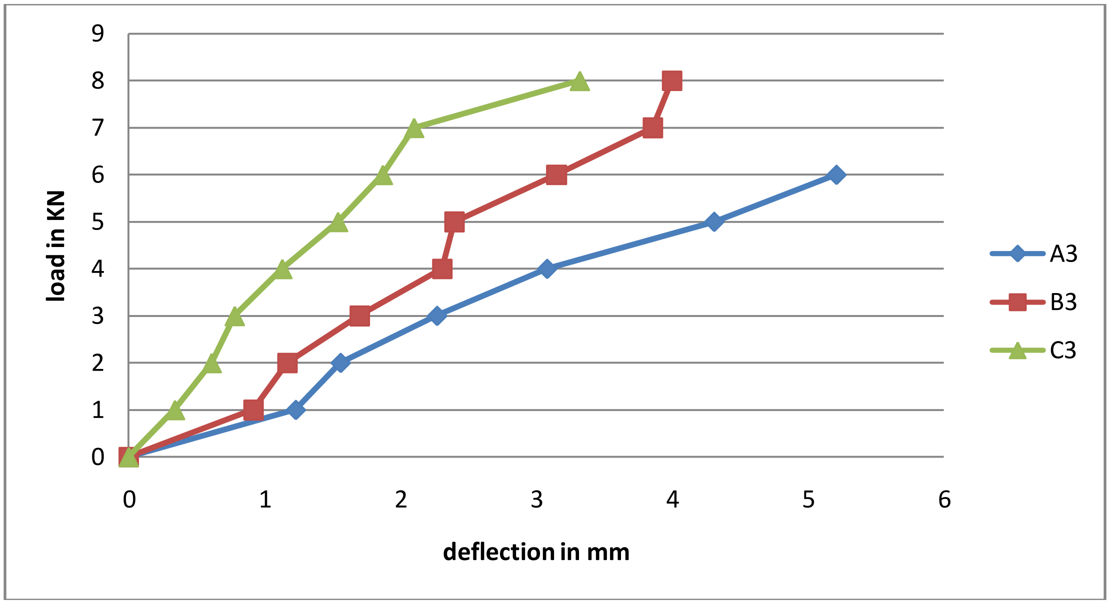


Graph 2:- Load v/s deflection (60mm 2 layer)

Table 8:- Slab thickness 60mm 3 layers of wire mesh

Load (KN)	**Deflection (mm) A3**	**Deflection (mm) B3**	**Deflection (mm) C3**
0	0	0	0
1	1.23	0.92	0.34
2	1.56	1.17	0.61
3	2.27	1.70	0.78
4	3.08	2.31	1.13
5	4.31	2.40	1.54
6	5.21	3.15	1.87
7	5.50	3.86	2.1
8	5.80	4.0	3.32
1st crack	4.31	3.15	3.32
Max.Load	8000	8000	8000

A3: Slab specimen with three layer wire mesh in the absence of polypropylene and Frp sheet
B3: Slab specimen with three layer wire mesh in the presence of polypropylene and in the absence of frp sheet
C3: Slab specimen with three layer wire mesh in the presence of polypropylene and Frp sheets.



Graph 3:-Load v/s deflection (60mm 3 layers)

Table 9:- Experimental result.

slab ID	load at (N)		deflection in mm			ductility factor(Md) = (d2/d1)
	yield load	ultimate load (Wu)	yield (d1)	ultimate (du)	0.85*Wu (d2)	
A0	2200	2500	5.52	6.09	2.12	0.38
A2	3900	5900	4.78	5.4	5.01	1.05
A3	5000	6000	4.31	5.21	5.10	1.18
B0	2400	2800	4.2	4.56	2.38	0.57
B2	4800	6000	3.58	4	5.10	1.42
B3	6000	8000	3.15	4	6.8	2.15
C0	2500	3000	3.56	3.92	2.55	0.72
C2	5900	6300	2.39	3.6	5.35	2.24
C3	7000	8000	2.1	3.32	6.8	3.23

Crack Pattern Of Slabs:-

Fig 8: Specimen A0

Fig 9:- Specimen A1.

Fig 10:-Specimen A2

Fig11:-Specimen B0.

Fig12:- Specimen B1

Fig13:- Specimen B2.

Fig 14:- Specimen C0.

Fig15:- Specimen C1.

Fig 16:- specimen C2.

Discussions:-

1 Table 5 shows that the compressive strength of hybrid ferro cement slabs without polypropylene fibres and with polypropylene fibres. From results it is observed that the compressive strength at 28 days curring of hybrid ferro cement slabs with polypropylene fibres content of 0.3% is increased by 6.34% with compressive strength of conventional concrete plain.

2 Table 6 shows the test results of ferro cement slabs specimen A0 with zero layer wire mesh in the absence of polypropylene B0 in the presence of polypropylene and in the absence of frpsheet.and C0 in the presence of polypropylene and Frp sheets.Graph1 shows the corresponding load deflection behavior of different three slabs from the test results it is observed that the ultimate load carriying capacity in flexure is 75% is more for B0 compared to A0 and 50% more for C0 compared to A0 slab.

3 Table 7 shows the test results of ferro cement slabs with double layer mesh the Graph2 shows the corresponding load v/s deflection behavior of HFS it is observed that the load carrying capacity is more in case of B0 and C0 compared to A0 in the same way Table 8 shows the test results of ferro cement slabs with three layer Graph3 shows the load deflection curve having more load carryting capacity of slab C0 compared to B0 ,A0 slabs.

4 From the test results it is observed that the ultimate load carrying capacity in three layer weld mesh HFS with 0.3% fibre content is increased by 25% in comparison with double layer weld mesh of ferro cement slab without GFRP layer.

5 By studying the crack patterns it is observed that the appearance of the first crack is slower in case of three layer weld mesh ferro cement slab with fibre and GFRP sheet in comparison with double layer weld mesh with 0.3% fibre content and without fibrous ferro cement slabs

Chapter9:-

Conclusions:-

1. The fibre reinforced ferro cement slabs shows a good load carrying capacity and Ductility characteristics. In the tension zone, concrete matrix crack occurs as fibre starts acting. The fibre carries the load across the crack, transmitting the load from one sided of the matrix to other and as the fibre is randomly distributed, the crack do not have very long paths, thereby loads bearing capacity of the \whole matrix is increased and multiple cracking is observed.
2. Increasing in numbers of layers from 2 to 3 significantly increases the load carrying capacity and ductility characteristics and capability to absorb energy of the slabs.
3. Presence of polypropylene fiber reduces the cracks and protects the corners of slab and increase the abrasion resistance, reduce the seepage of water.
4. Addition of super plasticizer will results in achieving self-compacting concrete and thus which reduce up to 6.34% of water. It also helps in placing of mortar which can easily flow by its own Wight without any vibration.
5. The compressive strength of cubes with presence of polypropylene fiber which increase about 6.34% as compared to conventional cube specimens.
6. The gfrp wrapped ferro cement slabs shows the higher ductility than that of the conventional ferro cement slabs due to the fact that, better confinement is being provided by the wrapping in the tension zone of the slabs. The wrapping acts as an external reinforcement and takes load in the tensile zone after the concrete fails.

Future Scope:-

1. Further investigation can be carried out by increasing the fiber content and also by using the different types of fibres such as steel fibres and carbon fibres.

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