AN EXPLORATORY STUDY ON STRENGTH CHARACTERISTICS OF FLEXIBLE CONCRETE USING SLAG AND MICROFIBERS

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Abstract - *Concrete used in construction compiles of cement, coarse aggregates, fine aggregates comes with many disadvantages such as low tensile strength, brittleness and heavy weight compared to its strength. To overcome the drawbacks of conventional concrete a new and unique construction material known as FLEXIBLE CONCRETE has been introduced. Its engineering name is Engineered Cementitious Composite (ECC). It has ductility property which lacks in conventional concrete; hence flexible concrete does not break and only bends. Other than ductility property it also has self-healing property and are resistant to cracking. Microfibers are used as reinforcement and to eliminate the usage of coarse aggregates in order to get flexibility. Silica sand can be used as fine aggregates to increase Strength and flexibility. To all this flexible concrete reduces the cost of project and hence are economical to use. The test is conducted using slag partially incorporated with cement as cementitious materials and micro fibers such as polypropylene, glass, hooked steel, polyester as reinforcement.*

Key Words: *Flexible Concrete, Conventional Concrete, Ductility, Strength, Fibers Compressive quality, Flexure quality, and tensile quality.*

1. INTRODUCTION

Concrete could be a well-known word in concrete business. Concrete is wide victimization as artefact that could be a combination of binding material, fine combination, coarse combination and water. Concrete strength in the main depends on the water-cement magnitude relation. Concrete victimization is a binding material from quite a hundred and fifty years. Because it was low in price and attributes the high strength characteristics. As Concrete could be a structural material utilized in varied constructions like atomic energy plants , Dams, Water tanks, Towers, Tunnels etc., inserting the contemporary concrete needs practiced operatives victimization slow, heavy, noisy, expensive, energy-consuming and infrequently hazardous mechanical vibration to confirm adequate compaction to get the total strength and sturdiness of the tough concrete.

1.1 CEMENT

The Ordinary Portland Cement (OPC) has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Fly ash, ground granulated blast furnace slag, rice husk ash, high reactive metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. Additionally it is well understood that the use of supplementary cementitious materials as part of binders is required for production of good strength concrete.

1.2 FLEXIBLE CONCRETE

As we probably aware cement is generally utilized in the present development industry, yet the principle issue with conventional cement is that it can't take a lot of ductile stresses. The Flexible cement is a prevalent substitute for this issue. Adaptable cement is an exceptional kind of cement that can take bowing anxieties. Bendable cement otherwise called "Engineered Cementations Composites" (ECC) is a class of ultra-flexible fiber strengthened cementitious composites, described by high pliability what's more, close break width control. In this solid, we dispense with the coarse total. Rather than that, we use strands, for example, steel fibers, GGBS, micro fibers, slag and so forth to give adaptability to concrete. It additionally goes about as a fortification material in the solid. It is multiple times more impervious to splitting and 40% lighter in weight. This material can bring the revolt due to its a few uncommon quality, for example, adaptability, self-mending, lighter weight, and so forth. In a few nations, for example, Japan, Korea, U.S.A, and so on, the adaptable cement is utilized in numerous structures.

The fundamental point of this task work is to explore the strength characteristics of concrete by varying the percentages of fibers with regular solid plan as per Indian norm. Solid shapes, Beams and Cylinders were casted with variety in extent and are tried. The testing incorporates Compressive quality, Flexure quality, and tensile quality. The outcomes got have shown that this material can be utilized as a substitute for traditional material for every future development. This article portrays the applications and advantages of an as of late created brilliant structure material to be specific Engineered cementitious composite (ECC), otherwise called adaptable or bendable cement. Customary cements have a strain limit of just 0.1 percent and are profoundly weak and unbending. This absence of bendability is a significant reason for disappointment under strain and has been a pushing factor in the improvement of a rich material which is fit to display an upgraded adaptability. An ECC has a strain limit of in excess of 3 percent and in these manner demonstrations more like a flexible metal as opposed to like a weak glass. A bendable cement is made out of the considerable number of elements of a customary solid short coarse totals or squashed stones and is strengthened with ECC is a green development material. The potential advantages like condition cordiality, cost viability, and also been compared with conventional concrete to know the difference and to get the best results

2. LITERATURE REVIEW

[1] Balaji R (June 2018) carried out an Experimental Study on ECC Concrete using Recron fibers, Poly Vinyl Alcohol Fibers, fly ash incorporated with cement. ECC remains safe to use at tensile strains from 3% to 5%. It is also called as bendable concrete reinforced with micromechanically designed polymer fibers. The Recron fibers, Poly Vinyl Alcohol Fibers, fly ash are partially incorporated with cement as supplementary materials to increase the flexibility of concrete in different percentages and it shows different values of strength in each mix from this study.

[2] Brinila Bright B N (April 2018) carried out an Experimental Investigation on Bendable Concrete Using Natural and Artificial Fibers (Jute and Nylon). Engineering cementitious composite (ECC), also called strain hardening cement-based composites (SHCC) or more popularly as bendable concrete It has wide applications and wide future scope in various fields. Fly ash is also known as pulverized fuel ash. Two fiber volume fractions 0%, 0.5%, 1% and 1.5% were considered. For these purpose concrete cubes, cylinders, and prisms are experimentally investigated in ths study.

[3] S.Nandhini (2017) carried out an Experimental Investigation of Engineered Cementitious Composite. This study suggests the need for developing a new class of FRCs which has the strain-hardening property. It is demonstrated that ECC can be designed based on micromechanical properties with strain hardening capacity of about 3 to 5% compared to 0.01% of normal concrete. The main objective of the study is to increase the tensile properties if flexural member with the application of poly vinyl alcohol fibers of moderately low fibre volume fraction about 2% composite which shows extensive strain-hardening.

[4]Anu T Eldho , Divyasasi in (2016) carried out an Experimental Study On Evaluation of Mechanical Properties of Engineered Cementitious Composites. This paper investigates the mechanical properties of M40 grade Engineered Cementitious Composite (ECC) with recron and multifilament polypropylene fibre and durability property of conventional concrete and ECC. The values of compressive strength, split tensile strength, flexural strength and modulus of elasticity were measured. M40 grade ECC has higher compressive strength, tensile strength, flexural strength and modulus of elasticity as compared with M40 grade conventional concrete.

[5] Sagar Gadhiya (2015) gave a Review On Bendable Concrete. An ECC has a strain capacity of more than 3% and thus acts more like a ductile metal rather than like a brittle glass. A bendable concrete is reinforced with micromechanically designed polymer fibers. In this paper literature survey of fresh and mechanical properties of different ECC mixtures are evaluated by incorporating supplementary cementitious material, i.e., fly ash and different aggregate type considering various parameters, i.e., types of fibers, compressive strength, flexural strength and deflection.

[6] Maulin Bipinchandra Mavani (2012) carried out an Experimental Study to Investigate about Fresh/Mechanical/Durability Properties and Structural Performance of Engineered Cementitious Composite (ECC).

3. MATERIALS USED

Collection of material is one of the most important in construction because without material we can't proceed for any type of construction like building construction, pavement construction etc. Before starting the project check for the availability of resources or materials. The following are the some materials we use regularly in our constructions.

1. Cement
2. Coarse aggregates
3. Fine Aggregates
4. GGBS
5. Fibers

3.1 CEMENT

Cement is a binder or a powdery substance made by calcining lime and clay, mixed with water to form mortar or mixed with sand, gravel to make concrete. Broadly, the raw materials which are used for manufacture of cement consist of lime, silica, alumina and iron oxides.

There are different types of cement, namely Ordinary Portland cement, Portland pozzolana cement, Rapid hardening cement, Quick setting cement, Sulphate resisting cement, Low heat cement, Hydrophobic cement, Air entraining cement, Expanding cement, High alumina cement, Blast furnace slag cement, White cement, Colored cement.
The solid used for the assessment was Ordinary Portland Cement (OPC) with brand JAYPEE concrete attesting to IS: 455-1989.

PROPERTIES	TEST VALUES	STANDARD VALUES(IS:455-1989)
Specific Gravity	2.94	2.90 – 3.15
Standard Consistency(percent)	32	
Initial Setting Time (min)	190	>30
Final Setting Time (min)	235	>600
Finess	2.5	<10
Characteristic compressive strength	46.94	

Table -1: properties of cement

3.2 COARSE AGGREGATE

The coarse absolute used, was from a developed quarry satisfying the essentials of IS 383: 1970. In this preliminary program aggregates of only 20 mm size are used.The limits express gravity, mass thickness, water ingestion and fineness modulus were settled. The coarse sums are used particularly in standard concrete.

3.3 FINE AGGREGATE

The fine absolute used in the current preliminary program is standard sand insisting to zone – II as per 383:1970. It is unblemished, dormant and freed from normal issue, buildup and earth.

3.4 GGBS

The effect more blazing slag is a reaction of the iron putting away up industry. Iron mineral, coke and limestone are overseen into the radiator and the subsequent fluid slag coasts over the fluid iron at a temperature of about 1500oC to 1600oC. The fluid slag has a synthesis of about 30% toI40% SiO2Iand about 40% CaO, which is close to the substance structure of Portland concrete. After the fluid iron is tapped off, the stay fluid slag, which incorporates dominatingly siliceous and aluminous progression is then water-doused rapidly, achieving improvement of a cleaned beat. This cleaned beat is dried and ground to the key size, which is known as ground granulated blast radiator slag(GGBS). The production of GGBS requires insignificant additional criticalness as isolated and the essentialness required for the making of Portland concrete.

The chemical composition of blast furnace slag is similar to that of cement clinker.

- CaO : 30%-45%
- SiO_2 :17%-38%
- Al_2O_3 :15-25%
- Fe_2O_3 : 0.5%-2.0%
- MgO : 4.0-17.0%
- MnO_2 :1.0-5.0%
- Glass : 85-98%

Physical Properties:

- Colour off- white powder
- Bulk density (loose) 1.0-1.1 tons/m3
- Bulk density (vibrated) 1.2-1.3 tons/m3
- Relative density 2.85-2.95
- Surface area 400-600m2 /kg

Fig 1: GGBS

3.4.1 EFFECT OF GGBS ON CONCRETE

- **Effect on Setting Time:** Setting times of concrete containing slag increases as the slag content growths. A progression of slag content from 35 to 65% by mass can create setting time by as much as 60 minutes. This deferral can be supportive, particularly in monstrous pours and in gurgling conditions in which this property prevents the improvement of cold joints in exceptional pours.
- **Effect on Bleeding:** The rate and proportion of spilling in solid slag or in slag concrete is normally not as much as that of in concrete containing no slag. Considering the all around higher fineness of slag. The higher fineness of slag in like way expands the air-entraining head required, wandered from standard cement. In any case, slag not under any condition like fly junk doesn't contain carbon, which may cause insecurity and air difficulty in concrete.
- **Effect on Workability:** It is normally comprehended that GGBS particles are less water absorptive than Portland strong particles and along these lines GGBS concrete is more down to earth than Portland strong cement. For comparing value, a reduction in water content up to 10% is conceivable.
- **Effect on Creep:** "It has been spoken to that under important conditions; the grouch of GGBS concrete looked like that of Portland (Concrete society 1991). Different specialists quick and dirty that GGBS concrete had comparative or lower creep with substitution levels going from 30% to 70%.
- **Effect on Drying Shrinkage:** The majority of the investigations in the making proclaimed that the use of GGBS would chop down the drying shrinkage potential under unequivocal conditions.
- **Effect on Elastic Modulus**: It is ordinarily perceived that the impact of GGBS substitution on the versatile modulus of cement is immaterial (concretesociety, 1991).

- **Effects on permeability of Hardened Concrete :**Wire of granulated slag's in strong glue helps in the distinction in epic pores in the glue in to littler pores, acknowledging diminished penetrability of the cross area and of the solid (Malhotra 1987). RoseI(1987) showed that huge decrease in weakness is developed as the substitution level of the slag increments from the 40 to 60% of through and through cementitious material by mass.

3.5 FIBERS

Strands are the one whose length is more than its expansiveness and are get as characteristic or manufactured materials. Manufactured strands can regularly be delivered efficiently and in huge sums contrasted with characteristic filaments. The most regularly utilized designing material fiber is carbon filaments, glass strands, and silica filaments.

3.5.1 NECESSITY OF FIBER REINFORCED CONCRETE

- It collects the flexibility of the strong.
- It lessens the air holes and water voids the typical porosity of gel.
- It collects the sturdiness of the strong.
- Fibers, for example, graphite and glass have staggering protection from creep, while the corresponding isn't genuine for most gums. Along these lines, the heading and volume of strands influence the shock execution of re-bars/ligaments.
- Reinforced solid itself is a composite material; where the fortification goes about as the sustaining fiber and the solid as the framework. It is in this manner principal that the direct under warm worries for the two materials be comparable with the target that the differential deformations of concrete and the fortification are confined.

3.6 TYPES OF FIBERS USED IN FLEXIBLE CONCRETE

1. Polypropelene fiber
2. Polyester fiber (Recron 3s)
3. Steel fiber
4. Glass

3.6.1 POLYPROPELENE FIBER

Polypropylene strands are hydrophobic, that is they don't adjust water. Thusly, when set in a solid framework they need basically be blended long enough to make sure about scattering in the solid blend. The blending time of fibrillated or tape strands ought to be kept to a base to keep up a key decent ways from conceivable pounding of the filaments such a polypropylene fiber proposed by makers for clearing applications is the orchestrated fibrillated fiber. The length of fiber prescribed is normally annexed to the clear most over the top size of all out in the blend. Makers suggest that the length of the fiber be more indisputable than two fold the partition across of the total.

Fig 2: Polypropylene Fiber

S.NO	PROPERTIES	TEST DATA
1	Diameter (D) mm	0.0445
2	Length (L) mm	6.20
3	Aspect Ratio (L/D)	139.33
4	Tensile Strength(MPa)	308
5	Specific Gravity	1.33

Table 2: Properties of Cement

3.6.2 POLYESTER (RECRON 3S)

Reliance Industry Limited (RIL) has pushed Recron 3s strands with the goal of improving mortar and cement. The modulus of versatility of Recron 3s is high as for the modulus of adaptability of the solid or engine folio. The Recron 3s strands help increment in flexural strength. Recron 3s strands are ordinary inviting and nonhazardous. They reasonably disseminate and separate in the blend. Essentially 0.2%-0.4% by the hugeness of concrete Recron 3s is acceptable for getting the above focal core interests. Thusly it pays for itself, at any rate acknowledges net development with reduced work cost and improved properties. The fiber type considered for the examination is polyester.

Fig 3: Polyester (Recron 3s)

Properties	Test Values
Cut length	12mm
Effective diameter	30microns
Specific gravity	1.35

Tensile strength	About 6000kg/cm^2
Melting point	>250^{0}C
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	Good
Young's modulus	>5000 MPa

Table3: Physical Properties of Polyester Fiber

3.6.3 STEEL FIBERS

Steel strands have used in concrete since the mid 1900s.The early fibers were round and smooth and the wire was cut or cut to the vital lengths. The use of straight, smooth strands has by and large disappeared and current fibers have either cruel surfaces, trapped closes or are wrinkled or undulated through their length. Present day financially open steel fibers are produced using drawn steel wire, from cut steel or by the break down extraction process which produces strands that have a bow shaped cross region.""As per IRC:SP:46-1997 steel strands have corresponding breadths (considering cross-a sectional area) of from 0.15 mm to 2 mm and lengths from 7mm to 75 mm. Edge extents generally run from 20 to 100. (Point extent is described as the extent between fiber length and its proportionate separation over, which is the broadness of a drift with a district identical to the cross-sectional area of the fiber). Steel fibers have high unbending nature (0.5–2GPa) and modulus of adaptability (200GPa), a bendable/plastic weight strain brand name and low killjoy. Concretes containing steel fiber have seemed to have impressively improved security from influence and more unmistakable malleability of disillusionment in weight, flexure and bend.

Fig 4: Steel Fibers

S.No	Particulars	Principles
1	Shape	Corrugated
2	Length	30mm-50mm
3	Thickness	0.7mm
4	Aspect ratio	42
5	Density	78500N/m^3
6	Maximum Tensile strength	828 mpa
7	Appearance	Bright & clean

Table 3: Properties of Steel Fiber

3.6.3.1 BENEFITS OF USING STEEL FIBERS IN CONCRETE

The use of steel fiber in cement can improve its different properties. The advantages of utilizing steel strands in concrete are as indicated by the going with:

1. Steel Fibers are typically appropriated all through a given cross-section whereas strengthening bars or wires are set precisely where required
2. Steel strands are ordinarily short and positively dispersed as separated and unsurprising supporting bars of wires.
3. It is commonly preposterous to accomplish at an amount zone of help to zone of solid utilizing steel strands when stood apart from utilizing a plan of fortifying bars of wires.
4. Steel Fibers are typically added to concrete in low volume estimations (a great part of the time under 1%), and have been demonstrated to be powerful in lessening plastic shrinkage separating.

3.6.4 GLASS

Glass is an unmistakable material made by dissolving a blend of materials, for example, silica, soft drink junk, and CaCO3 at high temperature followed by cooling where hardening happens without crystallization. Glass is broadly utilized in our proceeds with through made things, for example, sheet glass, compartments, valuable stone, and vacuum tubing. Glass is a perfect material for reusing. The utilization of reused glass spares bundle of vitality and the expanding comprehension of glass reusing speeds up base on the utilization of waste glass with various structures in different fields. One of its indispensable duties is the improvement field where the waste glass was reused for solid creation. The usage of glass in architectural concrete still needs improvement. A continuous report have shown that waste glass that is squashed and screened is a solid, ensured and compelling choice to sand utilized in concrete. During the most recent decade, it has been seen that sheet glass squander is of tremendous volume and is developing a little bit at a time in the shops, headway areas and current workplaces.

Utilizing waste glass in the solid progression division is profitable, as the creation cost of solid will go down. The extent of waste glass is a tiny bit at a time reached out during the time by virtue of an ever-making utilization of glass things. The greater parts of the waste glasses have been dumped into landfill regions.

Fig 4: Glass

4. TESTING OF MATERIALS

Material testing is a test done to decide the properties of a substance in correlation with a norm or particular and to test the conduct of building materials. Coming up next are the tests depend on the norm or detail.

4.1 TESTS ON SAND

- Sieve analysis test

4.2 TESTS ON AGGREGATES

- Shape test
- Aggregate Impact test
- Soundness Test
- Crushing test
- Los angels Abrasion test
- Specific Gravity test
- Water absorption test

4.3 TESTS ON CEMENT

- Fineness test
- Consistency test
- Setting time test
- Soundness test
- Strength test
- Heat of Hydration Test
- Specific gravity test

Tests	Result
Specific Gravity of Cement	3.2
Fineness of Cement	5.5%
Consistency of Cement	29%
Initial Setting Time of Cement	40min
Specific gravity of C.A	2.75
Water absorption of C.A	0.67%
Specific gravity of F.A	2.68
Water absorption of C.A	1.2%

Table 4: Results of Preliminary Tests on Cement and Aggregates.

4.4 TESTS ON GGBS

Test results of specific gravity of GGBS is shown in Table

Weights in Gm	Trial 1	Trial 2
Empty bottle (W1)	137 gm	137 gm
Bottle + water (W2)	409.62 gm	409.55 gm
Bottle+ kerosene (W3)	353.5 gm	353.4 Gm
Bottle+kerosene+ GGBS (W4)	398.720 gm	399.8 Gm
GGBS (W5)	64 gm	64 gm
S.G	2.7	2.72

Table 5: Specific Gravity of GGBS

Specific gravity of GGBS:

$$= W5 \times (W3-W1)/(W2-W1)\times(W5+W3-W4)$$

Average specific of GGBS = 2.7

4.5 TESTS ON CONCRETE

- Slump Cone test
- Compression Strength test
- Flexural strength test
- Split Tensile Test

5. METHODOLOGY

5.1 MIX DESIGN

The mix structure of assessment M30 was used. The mix structure for ECC Concrete is on a very basic level established on Micromechanics plan premise. Micromechanics are a piece of mechanics applied at the material constituent level that gets the mechanical associations among the fiber, mortar system, and fiber–cross section interface. Usually, strands are of the solicitation for millimeters long and numerous microns in estimation, and they may have a surface covering on the nanometer scale. Lattice heterogeneities in ECC, including deserts, sand particles, solid grains, and mineral admixture particles, have size spans from nano to millimeter scale. From this time forward the ideal mix degree given in the composition of ECC-ECC Concrete was used as the guidelines to choose the degree of various constituents in the strong. The volume part of using fiber was contrasted as 0.2% and 0.4%, incorporated hard and fast volume of strong mix. The ideal Mix degree which was taken as reference is

Ratio adopted for mix design of flexible concrete = cement: GGBS: Sand

= 1: 0.1: 0.8

Total = 1+0.1+0.8 = 1.9

5.2 QUANTITY REQUIRED FOR 1M^3

CEMENT
Part of cement in total = 1/1.9
Unit weight of cement = 1440 kg/m^3
Dry concrete to wet concrete = 1.52
Volume = 1m^3
Unit weight of cement = 1440 kg/m^3
Cement
= (Part of cement in total)×(dry concrete to wetconcrete)×(volume)×(unit weight of cement)
= (1/1.9)×(1.52)×(1)×(1440)
= 1152 Kg/m^3.
GBS is taken as 10% of cement
GGBS
= 10% of cement
= 0.1×1152
=115.2 Kg/m^3
Sand is taken as 80% of cement Sand
= 80% of cement
= 0.8 × 1152
= 921.6 Kg/m^3
Water cement ratio adopted is 0.35 W/C = 0.35
W = (1152+115.2)×0.35
W = 443.52 Litres

MATERIALS	QUANTITY (KGS)
Cement	1152
GGBS	115.2
Sand	921.6
Water	443.52

Table 6: Materials Required for 1cu.m of Flexible Concrete

Quantity Required For 6 Cubes
Casting For 6 Cubes (150 × 150 × 150 MM)
Volume of 1cube = 150 × 150 × 150 = 3.375 × 10^{-3}mm^3

MATERIALS	QUANTITY (KGS)
Cement	25.6
GGBS	2.56
Sand	20.52
Water	9.85

Table 7: Materials required for 6 cubes

Quantity Required For 6 Beams
Casting For 6 Beams (100 × 100 × 500 MM)
Volume of 1cube = 100 × 100 × 500
= 5 × 10^{-3}mm^3

MATERIALS	QUANTITY (KGS)
Cement	38.016
GGBS	3.80
Sand	30.41
Water	14.63

Table 8: Materials Required for 6 Beams

Quantity for 6 Cylinders
Volume of 1cylinder = □/4×150^2×300= 5.30×10^{-3}

Table 9: Materials Required for 6 Cylinders

MATERIALS	QUANTITY(KGS)
Cement	40.29
GGBS	4.02
Sand	32.20
Water	15.50

Proportioning of Fibers

CUBES:

1. 0.2%
= 0.2% of total weight of materials
= 0.2 % of (25.6+2.56+20.52+9.850)
=0.1170 Kg
= 117 Grams
Each Fiber = 29.25grams

2. 0.4%
= 0.4% of total weight of materials
= 0.4 % of (25.6+2.56+20.52+9.850)
= 0.2341 Kg
= 234grams
Each Fiber = 58.53grams

Fibers	Quantity (Grams)		
	Cubes	Beams	Cylinders
0.2%	117	173.7	184
0.4%	234	353.8	386

Table 10: Proportioning of fibers

6. RESULTS AND DISCUSSIONS

6.1 RESULTS OF TEST ON FLEXIBLE CONCRETE

6.1.1 COMPRESSIVE STRENGTH

Mix Notation	Compressive Strength (MPa)		
	3rd day	7th day	28th day
CC	20.89	27.33	38.02

Table 11: Compressive Strength of Nominal Mix at Different Ages

6.1.2 FLEXURAL STRENGTH

Mix Notation	Flexural Strength (MPa)		
	3rd day	7th day	28th day
CC	2.87	3.05	4.21

Table 12: Flexural Strength of Nominal Mix at Different Ages

6.1.3 TENSILE STRENGTH

Mix Notation	Tensile Strength (MPa)		
	3rd day	7th day	28th day
CC	2.22	2.82	4.21

Table 13: Tensile Strength of Nominal Mix at Different Ages

6.2 RESULTS OF TESTS ON FLEXIBLE CONCRETE

6.2.1 COMPRESSIVE STRENGTH

Mix Notation	Compressive Strength (MPa)		
	3rd day	7th day	28th day
FC(0.2)	28.88	33.77	41.9
FC(0.4)	32	43.20	44.44

Table 13: Compressive Strength Of Flexible Concrete at Different Age

6.2.2 FLEXURAL STRENGTH

Mix Notation	Flexural Strength (MPa)		
	3rd day	7th day	28th day
FC(0.2)	13	14	17.6
FC(0.4)	15	12	24.09

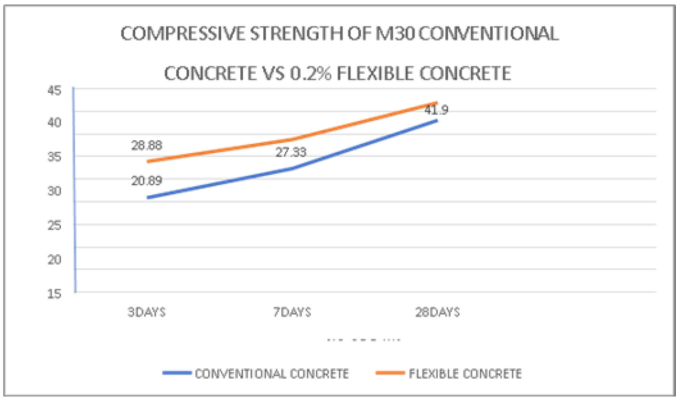
Table 14: Flexural Strength of Flexible Concrete at Different Ages

6.2.3 TENSILE STRENGTH

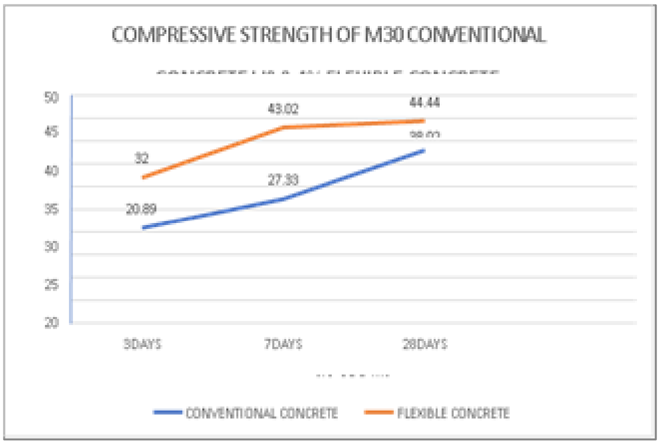
Mix Notation	Tensile Strength (MPa)		
	3rd day	7th day	28th day
FC(0.2)	3.0	3.42	4.66
FC(0.4)	4.16	4.74	5.53

Table 15: Tensile Strength of Flexible Concrete at Different Ages

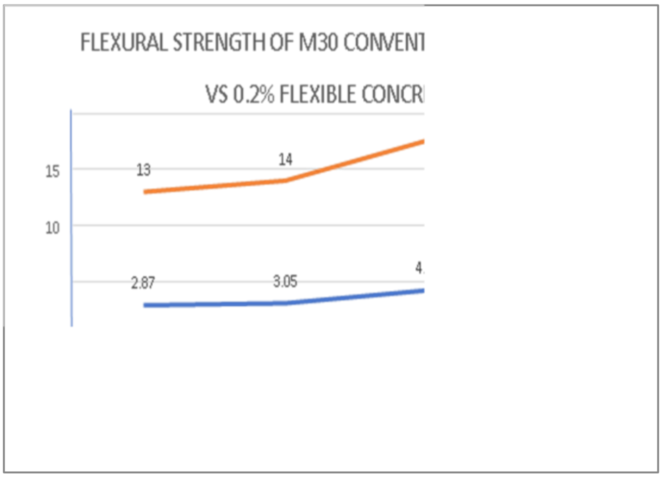
6.3 GRAPH REPRESENTATION OF RESULTS



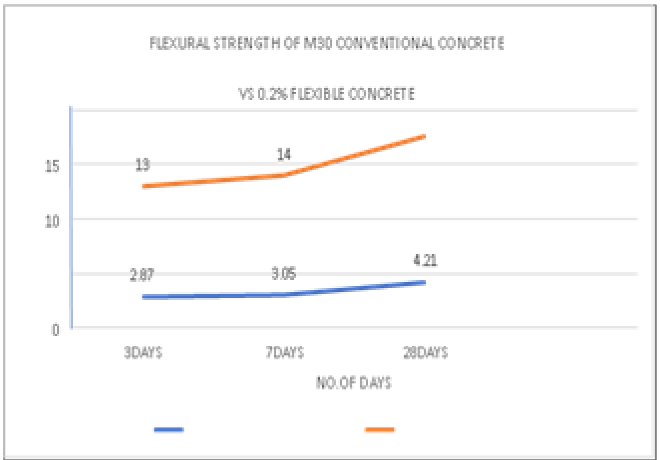
Graph 1: Compressive Strength CC vs FC (0.2)



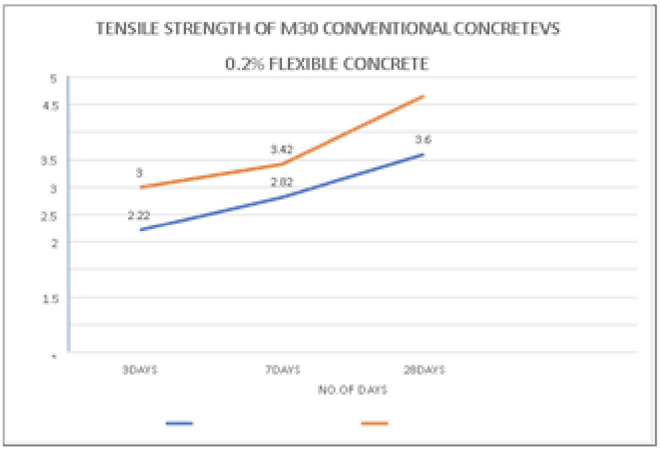
Graph 2: Compressive Strength CC vs FC (0.4)



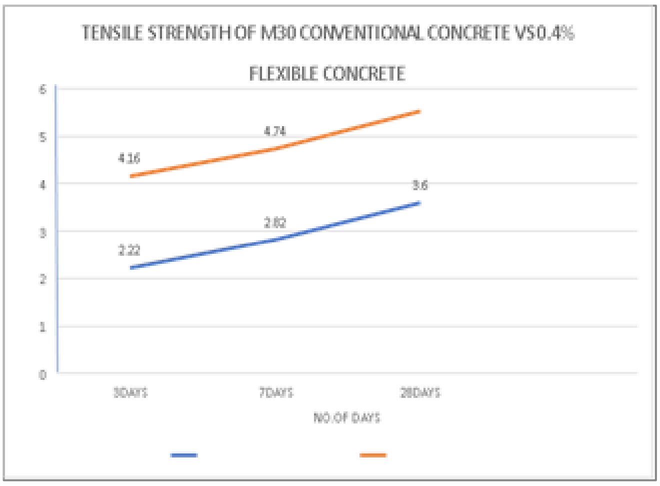
Graph 3: Flexural Strength CC vs FC (0.2)



Graph 4: Flexural Strength CC vs FC (0.4)



Graph 5: Tensile Strength CC vs FC (0.2)



Graph 6: Tensile Strength CC vs FC (0.4)

6.4 COST ANALYSIS

- Total cost of Conventional Concrete M30 grade = 13,841.94 Rs.
- Total Cost of Flexible Concrete M30 grade with 0.2% fiber in Rs. = 14,271.66
- Total cost of Flexible Concrete M30 grade with 0.4% fiber in Rs. = 15097.36

7. CONCLUSIONS AND FUTURE SCOPE

7.1 CONCLUSIONS

1. From the investigations, it is concluded that the flexible concrete with the mix FC(0.4) has the best result and stated as best mixes when compared to CC.
2. Fracture controlled failure is exhibited by the ECC under flexural loading, and a bend is obtained because of crack controlling nature.
3. Workability aspect of polypropylene fiber, recon fiber, steel fiber and glass is an appreciable issue as satisfactory workability is obtained.
4. The compressive strength of ECC with 0.4% content of

fiber is greater than ECC with 0.2 % of fiber content.

5. The flexural strength of Flexible concrete which is having 0.4% volume of fiber is greater when compared with 0.2% volume of fiber.
6. The tensile strength of Flexible concrete with 0.4% of volume is greater than bendable concrete with 0.2% volume of fiber.
7. The partial replacement of cement with GGBS gave effective results regarding strength and cracking . Hence replacement of cement more than 10 % can also be adopted.
8. The adoption of volume of fiber can be increased in order to get better results regarding strength, cracking, ductility etc.
9. The strength of Flexible concrete in all aspects is more than Conventional concrete.
10. The synthetic fibers are cheaply available and hence can be used in flexible concrete and the fibers may be altered in order to reduce the cost.

7.2 FUTURE SCOPE

1. Since Flexible concrete is light in weight, it can be used in sky scrapers and heavy buildings. It can be used in Earthquake resistant structures and joint less bridge.
2. ECC is the upcoming advancement in technology which will replace the conventional concrete in countries which are more prone to natural disasters.
3. In India, it is still a new material and requires proper research for its use.

REFERENCES

1.IS: 456-2000 – plain and reinforced concrete – code of practise.
2.IS: 10262 : 2009 – Concrete mix proportioning – Guidelines.
3.IS: 9013 – 1978 – Method of making, curing and determining compressive strength of accelerated- cured concrete test specimens.
4.Text Book of Concrete Technology by MS . Shetty.
5.All about Flexible Concrete and Bendable Concrete – Civil Digital.
6.Balaji R (June 2018) "Experimental Study on ECC Concrete" International Journal of Recent Scientific Research Vol. 9, Issue, 6(D), pp. 27489-2749.
7.Brinila Bright B N (April 2018)[2] "carried out an Experimental Investigation On Bendable Concrete Using Natural and Artificial Fibers (Jute and Nylon)". International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 04Apr-2018 e-ISSN: 2395-0056p-ISSN: 2395-0072.
8.S.Nandhini (2017) "Experimental Investigation of Engineered Cementitious Composite". International Journal of Innovative Research and Advanced Studies (IJIRAS) Volume 4 Issue 4, April 2017, ISSN: 2394-4404. PP370 – 376.
9.Anu T Eldho, Divyasasi in (2016) "Experimental Study On Evaluation of Mechanical Properties of Engineered Cementitious Composites". International Journal of Scientific & Engineering Research, Volume 7, Issue 10. PP 5-9.
10. Sagar Gadhiya(2015) "BENDABLE CONCRETE: A REVIEW".www.ijscer.com Vol. 4, No. 1, February 2015. ISSN 2319 – 6009. PP 141-147.
11.Ganesh S. Ghodke, Nilesh S Daphal, Yogesh S.Bandgar, Dattatray S.Gadekar. "Bendable Concrete by Using Admixture and Fiber" International Journal for Technological Research in Engineering (May-2017). PP 1743-1746.

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