Experimental Investigation on Bendable Concrete

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Abstract - *As we know concrete is widely used in today's construction industry, but the main problem with traditional concrete is that it cannot take much tensile stresses. The Flexible concrete is a superior substitute for this problem. Flexible concrete is a special type of concrete that can take bending stresses.*

Bendable concrete also known as "Engineered Cementations Composites" (ECC) is a class of ultra-ductile fiber reinforced cementitious composites, characterized by high ductility and tight crack width control. In this concrete, we eliminate the coarse aggregate. Instead of that, we use fibers such as silica fiber, steel fibers, Asbestos fiber, polyvinyl alcohol fibers etc. to provide flexibility to concrete. It also acts as a reinforcement material in the concrete. It is 500 times more resistant to cracking and 40% lighter in weight. This material can bring the insurrection because of its some special quality such as flexibility, self-healing, lighter weight, etc. In several countries such as Japan, Korea, U.S.A, etc., the flexible concrete is used in many structures.

The main aim of this project work is to investigate the flexural strength, the hardened property of concrete by addition of different percentages of fibers i.e., 0%, 0.5%, 1%, 1.5%, 2% with conventional concrete design according to Indian standard. Cubes, Beams and Cylinders were casted with variation in proportion and are tested. The testing includes Compressive strength, Flexure strength, and Split tensile strength. The results obtained have indicated that this material can be used as a substitute for conventional material for all future constructions.

***Key Words*: Bendable concrete, Ductility, flexibility, self-healing, lighter weight, Compressive strength, Flexure strength, and Split tensile strength.**

1. INTRODUCTION

Conventional concrete are almost unbendable and have a strain capacity of only 0.1% making them highly brittle and rigid. This lack of bend ability is a major cause of failure under the strain and has been a pushing factor in the development of an elegant material namely, bendable concrete also known as Engineered Cementations Composites. Therefore the ECC acts more like a ductile material. Now we are improving the ductile property of normal concrete by using natural and artificial fibers like jute fiber and nylon fiber in place of coarse aggregate and cement partially replaced by fly ash. Experimental Study on Bendable Concrete by Using Admixture and Fiber, this paper suggests the need for developing a new class of FRCs which has the strain-hardening property but which can be processed with conventional equipment

However, coarse aggregate are not used in ECC (hence it is mortar rather than concrete). The powder content of ECC is relatively high. Cementations materials such as fly ash, silica fume, blast furnace slag, silica fume, etc., may be used in addition to cement to increase the paste content. Additionally, ECC uses squat amounts, typically 2% by volume, of short, discontinuous fibers.

Fig -1: Behavior of ECC under flexural loading

The figure represents the behavior of ECC under flexural loading and it can be seen that the beam can deform well without direct failure. The different ingredients in ECC work together to share the applied load. ECC has proved to be 50 times further flexible than traditional concrete and 40 times lighter, which could even manipulate design choices in skyscrapers. Additionally, the excellent energy absorbing properties of ECC make it especially fitting for critical elements in seismic zones.

1.1 Making of Engineered Cementations Composites

ECC is through with ingredients typically found in concrete, including cement, sand, fly ash, and super plasticizer. However, no coarse aggregates are employed, and no air entrainment is essential. In-stead, micro-fibers are added. The type, size and amount of all ingredients and their mixing sequence are carefully controlled, so that the resulting composite maintains self-consolidating characteristics during casting and ductile behavior after hardening. ECC mix design also includes a normal concrete mix design for comparison.

Fig -2: Making of ECC

Figure shows self-consolidating casting from a ready-mix truck for the bridge link-slab project mentioned above. The components in an ECC mix design have been tailored using a body of knowledge (broadly known as micromechanics) on how the fiber, mortar matrix and the interface between them interact under mechanical loading. As a result, brittle fracture failure is eliminated. Instead, multiple micro cracks form when the composite material is overloaded beyond the elastic state (pseudo-yielding), and the propagating micro cracks maintain very tight crack width in accordance with the tailored nature of the bridging fibers. The whole inelastic deformation process of ECC can be likened to the "give" built into the human skeleton due to the presence of muscles and ligaments. A human skeleton with only bones would be significantly more brittle. The design of ECC is analogous to the design of a well-engineered structure that employs knowledge of load carrying behavior of structural elements such as beams, columns and connections, as well as the interactions between these elements. In ECC, the design of the composite with fiber, matrix and interface is at much smaller length scales, but conceptually equivalent.

1.2 Self-Healing Property of ECC

For the most part, the self-healing process simply takes advantage of materials previously present in conventional concrete, explains. Even in ordinary concrete a significant percentage of the cement grains stay behind unused and dormant because they are never hydrated. Cracks in the concrete description these residual cement grains to the air and water in the surrounding environment. Under the right conditions, the unhydrated grains counter chemically with water and the carbon dioxide in the air to form strong compounds known as calcium carbonates. The fractures in conventional concrete are generally so large that even when calcium carbonates do form they provide virtually no benefit. However, when the cracks are small adequate no more than 50 μm these compounds can accumulate in such a way as to fill the cracks, thus repairing the concrete and exit behind nothing but a scar. Most important of all, the self-healing concrete recovers its essential properties, counting its ductility, its stiffness, and its ability to resist the intrusion of such corrosive agents as water and road salt,

In general, the self-healing concrete consists of the similar Portland cement, water, sand, and chemical admixtures that are already present in conventional concrete. The difference is that the chemical, mechanical, and geometric properties and proportions of these ingredient are fine-tuned to promote the self-healing process, Li says.

1.3 Structural Applications

ECC have create use in a number of large-scale applications, these include:

1. The Mitaka Dam near Hiroshima was repaired using ECC in 2003. The surface of the then 60-year-old dam was strictly damaged, showing evidence of cracks, spalling, and some water leakage. A 20 mm-thick layer of ECC was applied by spraying over the 600 m2 Surface area.

2. Also in 2003, an earth retain wall in Gifu, Japan, was repaired using ECC. Ordinary Portland cement possibly will not be worn due to the severity of the cracking in the original structure, which would have caused reflective cracking. ECC was intended to reduce this danger; after one year only micro cracks of tolerable width were observed.

3. The 95m (GlorioRoppongi high-get higher apartment buildings in Tokyo contain a total of 54 ECC coupling beams (two per story) intended to moderate earthquake damage. The properties of ECC (high break tolerance, high energy absorption, and ability to deform under shear) give it superior properties in seismic resistance applications when measure up to ordinary Portland cement. Related structures include the 41-story Nabeaure Yokohama Tower (four coupling beams per floor)

4. The 1 km (0.62 mi) long Mihara Bridge in Hokkaido, Japan was open to traffic in 2005. The steel-reinforced road bed contains virtually 800 m3 of ECC material. The tensile ductility and tight crack direct behaviour of ECC led to a 40% reduction in weight and 50% reduction in cost.

5. Similarly, a 225-mm thick ECC bridge deck on interstate 94 in Michigan was completed in 2005. 30 m3 of material was worn, delivered on-site in standard mixing trucks. Due to the exclusive mechanical properties of ECC, this deck also used less material than a proposed deck made of ordinary Portland cement. Mutually the University of Michigan and the Michigan Department of Transportation are monitoring the bridge in an effort to verify the theoretical superior durability of ECC; after four years of monitoring, concert remained undiminished.

1.4 Advantages of Bendable Concrete

- It is more stronger, more durable, and lasts longer than the conventional concrete.
- It has more resistance to cracking.
- It does not emit that amount of harmful gases as compared to conventional concrete
- The use of steel reinforcement is reduced.

- It can be used as precast concrete.
- The crack width can be reduced.
- The flexural strength of the concrete can be increased.
- If used in the pavements, the life span of the pavement is more and durable
- Used in the coupling beams.
- ECC is green construction material
- ECC is 37% a smaller amount exclusive, consumes 40% less energy, and produce 39% less carbon dioxide than regular concrete.
- ECC incorporates elevated volumes of industrial wastes including fly-ash, sands and wastes from metal casting processes, wasted cement kiln dust from cement production
- Reduced emission of Greenhouse gases.
- Applicable in earthquake resistant structures.
- Used in the construction of jointless bridges

2. LITERATURE REVIEW

Victor Li (2012), Yu Zhu et al (2012),Jun Zhang, Zhenbo Wang and Xiancunju (2013), Yu Zhu et al.[4] (2014),Tahir Kemal Erdem (2014), Zhou & Pan [2014], Gandhiya [2015], Ian et al [2016], Zhang et al[2017], Gabriel Arce,[10].

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. Fly ash
3. Fine Aggregates
4. Jute and Coir Fiber
5. Water

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.

3.2 Fly Ash

Fly ash is a consequence from burning pulverized coal in electric power generating plants. Throughout combustion, mineral impurities in the coal fuse in suspension and float out of the combustion chamber with the exhaust gases. As the merged material rises, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is together from the exhaust gases by electrostatic precipitators or bag filters. The fine powder does be similar to Portland cement but it is chemically different. Fly ash chemically reacts with the consequence calcium hydroxide released by the chemical reaction between cement and water to form additional Cementations products that improve many desirable properties of concrete. Two types of fly ash are frequently used in concrete: Class C and Class F. Class C are often high-calcium fly ashes with carbon satisfied less than 2%; whereas, Class F are generally low-calcium fly ashes with carbon contents with a reduction of than 5% but sometimes as high as 10%. In general, Class C ashes are twisted from burning sub-bituminous or lignite coals and Class F ashes bituminous or anthracite coals. Concert properties along with Class C and F ashes be different depending on the chemical and physical properties of the ash and how the ash interact with cement in the concrete. Countless Class C ashes when exposed to water will react and become hard just like cement, but not Class F ashes. In this project we have replaced 30% of Cement with class C fly ash.

3.2.1 Physical properties

Table -1: Physical properties of fly ash

Fineness	Retained on 45 micron sieve
Specific gravity	1.90 - 2.96
Shape	Spherical glassy shaped
Color	Depends upon the chemical composition
Constituents	Mineral

3.2.2 Chemical properties

The chemical composition of fly ash depends upon the type of coal used and the methods used for combustion of coal.

Table -2: Chemical properties of fly ash

S no	Description Property	Average Range of Values (%)
1	SiO_2	**44-58**
2	Al_2O_3	**21-27**
3	Fe_2O_3	**4-18**
4	CaO	**3-6**
5	MgO	**1-25**
6	SO_3	**0.3-1.7**

3.3 Fine aggregate

Fine aggregate is an accumulation of grains of mineral issue derived from the disintegration of rocks. It is distinguished from the gravel only by the size of the grains or particles. But it is separate from clays which contain organic materials. Frequently commercial sand is obtained from river beds or from sand dunes originally formed by the action of winds. The most commercial used are silica sands, often above 98% pure. Beach sands usually have smooth, spherical to avoid particles from the abrasive action of waves and tides and are free of organic matter. Sand is used for making mortar and concrete and for also used for polishing and sand blasting.

3.4 Jute fiber

Jute is a kind of fiber obtained from plants known as white corchorus capsular is. It is a natural fiber popularly known as “Golden fiber”. The manufacturing of jute fiber involves hand harvesting of the source plant, drying in the field for defoliation, retting for periods up to a month, stripping and sun drying in the field.

3.4.1 Properties of jute fiber

Table -2: Chemical properties of fly ash

Length	1.5-4mm
Diameter	0.015-0.02mm
Tenacity	3 – 4 g/denier
Elongation	1.7%
Density	1.46 g/cc
Specific gravity	1.5
Moisture content	13.5%
Color	White, Yellow, Brown,

3.5 Coir fiber

Coir or coconut fiber is a expected fiber extracted from the husk of coconut and used in products such as floor mats, doormats, brushes and mattresses.

Coconuts, harvested after about six to 12 months on the palm, contain pliable white fibers. Brown fiber is obtain by harvesting completely full-grown coconuts when the nutritious layer nearby the seed is ready to be processed into copra and desiccated coconut. The fibrous stratum of the fruit is then estranged from the hard shell (manually) by driving the fruit down onto a spike to split it (de-husking).

Fig -3: Shows the coir

3.5.1 Physical properties of Coir

Table -3: Physical Properties of Coir

Length	0.6mm
Diameter	0.1-1.5mm
Density	1.40 g/cc
Tenacity	10
Breaking	30%
Elongation	27.4%
Tensile strength	210 MPa
Specific Gravity	0.87

4. Testing on Materials

Material testing is a test done to determine the properties of a substance in comparison with a standard or specification and to test the behavior of building materials. The following are the tests based on the standard or specification.

4.1 Tests on cement

- Fineness test
- Specific Gravity of Cement 3.14
- Determination of Normal Consistency of Cement

Table -3: Normal Consistency of Cement

S No	Percentage of water	Amount of water added in ml	Penetration depth of needle
1	26	78	16
2	28	84	5

- Determination of Initial & Final Setting time of Cement
  - Initial setting time =48 minutes
  - Final setting time = 600 minutes

4.2 Tests on fine aggregate

- Particle Size Distribution:

- Fineness modulus of a given sample of fine aggregate is 1.04

- Bulking Of Sand

4.3 Tests on Fly Ash

The fineness test of the fly Ash is carried out by using the sieve size of 90 microns such that it is fine enough to be used as the admixture for the replacement of cement.

The specific gravity of the fly ash is carried out by using the Lechartliers flask. The procedure is similar to that of the specific gravity of cement test.

5. Methodology

5.1 Mix Design

The mix design of grade M20 was used. The mix design for ECC concrete is essentially based on micromechanics design basis. Micromechanics are a branch of mechanics applied the material constituent level that captures the mechanical interactions among the fiber, mortar template and fiber matrix interface. Typically, fibers are of the order of millimeters in length and ten of microns in diameter, and they may have a surface coating on the nanometer scale. Template heterogeneities in ECC, including defects, sand particles, cement grains, and mineral admixture particles, have size vary from nano to millimeters scale. Therefore the ideal mix proportion given in the literature of ECC. This concrete was used as the guidelines to determine the proportion of various constituents in the concrete. The volume fraction of using jute and coir fiber was varied as 0%, 0.5%, 1%, 1.5%, 2%, added in total volume of concrete mix. The ideal mix proportion which was taken as reference is shown in table.

Table 4 -: Normal Consistency of Cement

Mix Designation	Cement (Kg/m3)	Fly Ash (Kg/m3)	Fine Aggregate (Kg/m3)	W/C Ratio
M20	620	266	1330	0.40

5.2 Calculation of materials quantities

Volume of moulds

- Cement concrete cube mould(150*150*150mm) - 0.15*0.15*0.15 =0.003375m3

- Cement concrete cylinder mould (150mm dia,300mm height) = 0.0053028m3

- Cement concrete beam mould (150*100*100mm) = 0.005m3

Quantities of materials for preparation of bendable concrete

- **Quantities of materials for one cube**

Mix ratio = 1:1.5

Size of fine aggregate = passing from IS Sieve 1.18 mm

Water cement ratio = 0.4

Volume of mould = 0.003375m3

Unit weight of cement = 1440kg/m3

- **Quantity of material for 1 cubic meter:**

Cement = 1/2.5 * 1.54 * 1440*1 = 887.04kg

Sand = 1.5*887.04=1330.56kg

Fly ash = 30% of cement

=0.3*887.04

=266.112kg

Cement after 30% replacement with fly ash=620.928kg

- **For 1 cube:**

For 1 cube mould required cement = 0.003375*620.928=2kg

For 1 cube mould required fly ash = 1kg

For 1 cube mould required sand = 1.5*3= 4.5kg

For 1 cube mould required jute and coir

For 0.5% =0.015kg, 1% = 0.030kg, 1.5 = 0.045kg, 2% =0.06kg

- **For 1 cylinder**

For 1 cylinder required cement= 0.005301*620.928 =3.3kg

For 1 cylinder required fly ash = 1.5kg

For 1 cylinder required sand = 1.5*4.8= 7.2kg

For 1 cylinder required jute and coir

For 0.5% = 0.024kg, 1% = 0.048kg, 1.5% = 0.072kg, 2% = 0.096kg.

- **For 1 prism**

For 1 prism mould required cement = 0.005*620.928=3.1kg

For 1 prism mould required fly ash = 1.3kg

For 1 prism mould required sand = 1.5*4.4= 6.65kg

For 1 prism mould required jute and coir

For 0.5% = 0.022kg, 1% = 0.044kg, 1.5% = 0.066kg, 2% = 0.088kg.

5.3 Testing on specimens

5.3.1 Compressive strength

Compressive strength of a concrete is a evaluate of its ability to resist static load, which tends to crush it. Most frequent test on hardened concrete is compressive strength test. It is because the test is easy to perform. Additionally, many desirable characteristic of concrete are qualitatively related to its strength and the consequence of the compressive strength of concrete in structural design. The compressive strength gives a good and clear indication that how the strength is affected with the increase of fiber volume dosage rate in the test specimens.

This test was performed to find the enlarge and differences of strength according the cement to sand ratio in concrete.

5.3.2 Flexural Strength Test

Flexural strength of a concrete is a determine of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture'. Concrete specimens for flexural strength were cross sectional area of 100mm width with 100mm depth and length of 500mm concrete beam. The specimen is subjected to bending, by means of four-point loading waiting it fails. The task of this test was performed to find the increase and differences of strength according the increasing percentage of fiber in the concrete, in both pre-crack and post-crack behavior, as fundamental to assess and evaluate the effects of the additional of fibers on the behavior of concrete. The Flexural strength test be conducted in the concrete technology laboratory after the concrete specimens be cured. The test procedure be carried out accordance with IS: 516-1959.

5.3.3 Split tensile strength

This method covers the determination of the splitting tensile strength of cylindrical concrete specimens.

6. Results and Discussion

In this chapter Results and Observations of tests carried out in previous chapter is presented, analyzed and discussed.

6.1 Compressive strength of cubes at 7 days

The result of compressive test of the cubes shows the increase in the strength of cubes with the change in the percentage of the fibers is shown in table.

Table 5-: Compressive Strength (N/mm2) of Cubes at 7 Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average compressive strength(N/mm2) of cubes at 7days
0%	22	26	24
0.5%	20.4	24	22.2
1%	24.36	27.2	25.78
1.5%	26	25.56	26.67
2%	05.62	25.94	26.22

Table 5 and Chart 1 represents the 7 days strength of cubes for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.2 Compressive strength of cubes at 14 days

Table 6-: Compressive Strength (N/mm2) of Cubes at 14 Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average compressive strength(N/mm2) of cubes at 14days
0%	27	29	28
0.5%	28.4	29.6	29
1%	29.3	31.6	30.45
1.5%	34.66	35.8	35.23
2%	30.48	30.7	30.59

Table 6 represents the 14 days strength of cubes for different percentages of fibres and the strength has increasing with increasing in the percentage of fibre till 1.5% and there is a decrease in the strength at 2%.

6.3 Compressive strength of cubes at 28 days

Table 7-: Compressive Strength (N/mm2) of Cubes at 28 Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average compressive strength(N/mm2) of cubes at 28days
0%	35.3	34.04	34.67
0.5%	32.6	34.8	33.7
1%	35.8	37.08	36.44
1.5%	39.48	39.62	39.44
2%	35.52	33.8	34.66

Table 7 represents the 28 days compressive strength of cubes for different percentages of fibers and the strength will be increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.4 Split tensile strength of cylinders at 7 days

Table 8-: Split tensile Strength (N/mm2) of Cubes at 7Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split tensile strength(N/mm2) of cubes at 7days
0%	0.51	0.46	0.5
0.5%	1.2	1.26	1.23
1%	1.82	1.7	1.76
1.5%	2.32	2.14	2.23
2%	1.81	1.89	1.85

Table 8 represents the 7 days tensile strength of cylinders for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.5 Split tensile strength of cylinders at 14 days

Table 9-: Split tensile Strength (N/mm2) of Cubes at 14 Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split tensile strength(N/mm2) of cubes at 14days
0%	0.82	0.68	0.75
0.5%	1.54	1.72	1.63
1%	2.23	2.01	2.12
1.5%	3.06	3.38	3.22
2%	2.41	2.31	2.36

Table 9 represents the 14 days tensile strength of cylinders for different percentages of fibers and the strength will be increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.6 Split tensile strength of cylinders at 28 days

Table 10-: Split tensile Strength (N/mm2) of Cubes at 28 Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split tensile strength(N/mm2) of cubes at 28days
0%	0.74	1.18	0.96
0.5%	2.84	2.76	2.8
1%	2.96	2.84	2.9
1.5%	4.96	3.94	4.1
2%	3.64	3.74	3.69

Table 10 represents the 28 days tensile strength of cylinders for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.7 Flexural strength of beams at 7 days

Table 11-: Flexural strength (N/mm2) of cubes at 7days Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split Flexural strength (N/mm2) of cubes at 7days
0%	5.6	4.4	5
0.5%	7.7	7.3	7.5
1%	8.87	8.36	8.75
1.5%	9.28	10.72	10
2%	9.66	9.34	9.5

Table 11 represents the 7 days flexural strength of beams for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.8 Flexural strength of Beams at 14 days

Table 12-: Flexural strength (N/mm2) of cubes at 14days Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split Flexural strength (N/mm2) of cubes at 14days
0%	7.62	8.38	8
0.5%	8.94	8.56	8.75
1%	9.37	9.71	9.54
1.5%	11.68	11.32	11.5
2%	10.56	10.64	10.6

Table 12 represents the 14 days flexural strength of beams for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.10 Flexural strength of beams at 28 days

Table 13-: Flexural strength (N/mm2) of cubes at 28days Days

Percentage of fibers by weight of cement	Sample 1 (N/mm2)	Sample 2 (N/mm2)	Average split Flexural strength (N/mm2) of cubes at 28days
0%	10.06	9.44	9.75
0.5%	12.23	13.07	12.65
1%	13.36	13.64	13.5

1.5%	15.93	15.79	15.86
2%	14.39	14.11	14.25

Table 13 represents the 28 days flexural strength of beams for different percentages of fibers and the strength has increasing with increasing in the percentage of fiber till 1.5% and there is a decrease in the strength at 2%.

6.10 Comparison of average compressive strength for different percentages of fibers

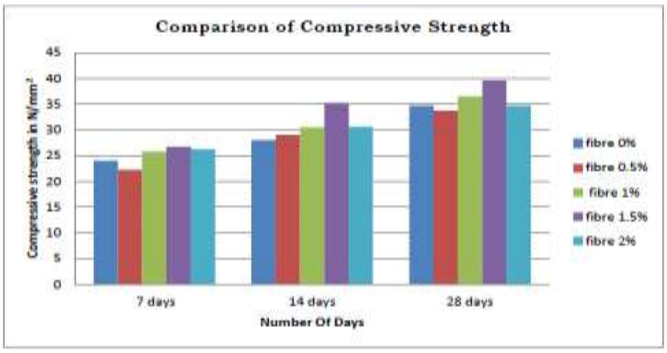

Chart -1: Comparison of Average Compressive Strength for Different Percentages of Fibres at 7, 14 And 28 Days

6.11 Comparison of average split tensile strength for different percentages of fibres

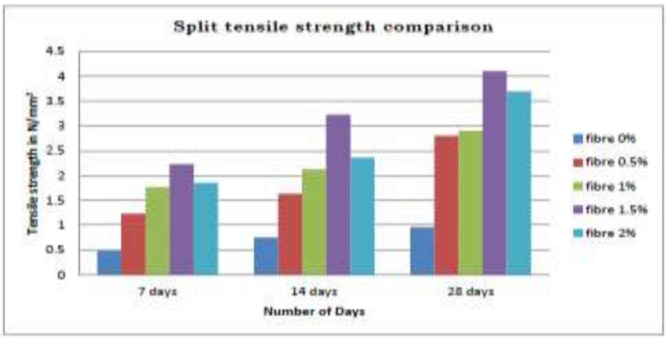

Chart -2: Comparison of Average Split Tensile Strength for Different Percentages of Fibres at 7, 14 And 28 Days.

6.12 Comparison of average flexural strength for different percentages of fibers

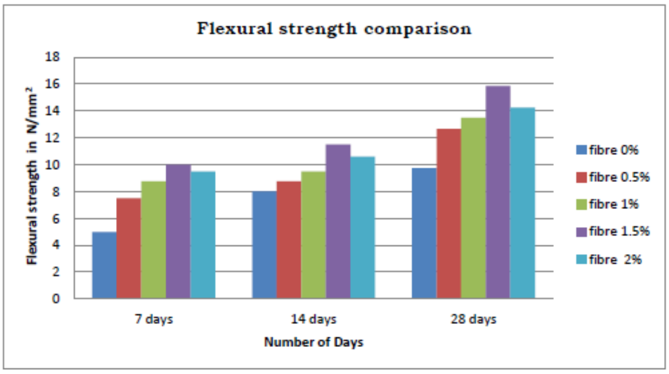

Chart -3: Comparison of Average Flexural Tensile Strength for Different Percentages of Fibres at 7, 14 And 28 Days.

Result: From the above tests that are carried out for various percentages of fibres, it is clear that addition of fibres with 1.5% (both jute & coir) by the weight of cement gives the maximum strength values of compressive, split tensile and flexural strength.

6.13 Comparison of compressive strength of bendable concrete of 1.5% fibres with convention concrete of grade M20.

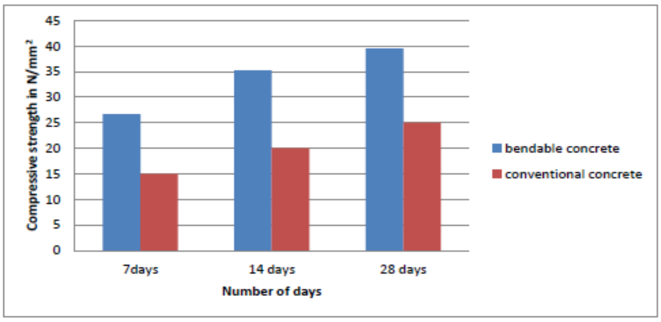

Chart -4: Comparison of Compressive Strength of Bendable Concrete of 1.5% Fibers with Convention Concrete of Grade M20.

6.14 Comparison of split tensile strength of bendable concrete with 1.5% of fibers with conventional concrete of grade M20.

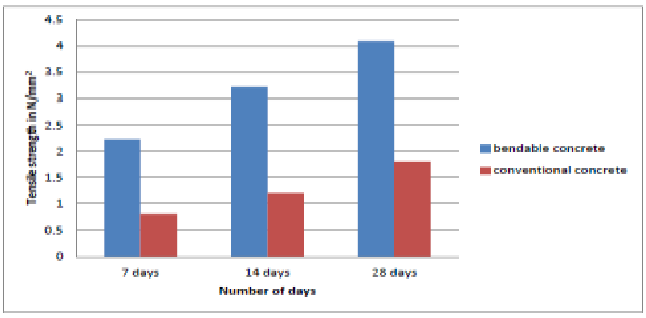

Chart -5: Comparison of Split Tensile Strength of Bendable Concrete of 1.5% of Fibers with Conventional Concrete of Grade M20.

6.15 Comparison of flexural strength of bendable concrete of 1.5% fibres with conventional concrete

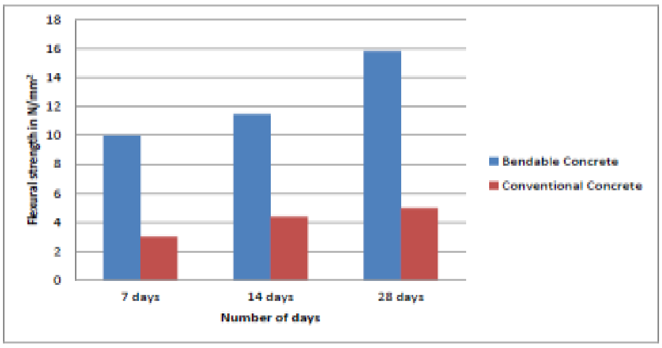

Chart -6: Comparison of Flexural Strength of Bendable Concrete of 1.5% Fibers with Conventional Concrete of Grade M20.

7. COST ANALYSIS

A cost analysis involve the process of reporting take apart elements in a cost proposal such as labor, equipment and materials that make a product or service, as well as its proposed profit. It is used for cost evaluation purpose when there is a lack of competition or comparable offers in the market place. Often referred to as cost assistance analysis or cost effectiveness analysis, a cost analysis refers specific skills to perform and it is useful tool for various aspects of business planning.

7.1 Cost analysis of conventional concrete

Table 14-: Flexural strength (N/mm2) of cubes at 28days Days

Sl. No.	Materials	Quantity (Kg)	Cost/ Kg	Total Cost(R)
1	Cement	562	7	3934
2	Fine Aggregate	843	4	3372
3	Coarse Aggregate	1686	5	8430
4	Water	252.9	3	758.7
Total				16494.7

7.2 Cost analysis of bendable concrete

Sl. No.	Materials	Quantity (Kg)	Cost/ Kg	Total Cost(R)
1	Cement	620	7	4340
2	Fine Aggregate	266	4	1330
3	Coarse Aggregate	1330	5	5320
4	Jute	8.86	250	2215
5	Coir	8.56	200	1772
6	Water	354.4	3	1063.2
Total				14977

8. CONCLUSION AND FUTURE SCOPE

8.1 Conclusion:

Based on the experimental investigations carried out the following conclusions are made:

- The significant properties of bendable concrete are ductility, durability, compressive strength and self-consolidation.
- Although the cost procured for designing of ECC is normally higher than that of the normal concrete but it has numerous potential applications.
- In this project the compression, split tensile and flexural strength measurements of bendable concrete are done. The values are compared with conventional cubes, cylinders and prisms. Therefore, it is proved that the bendable concrete has more strength than conventional concrete.
- Due to the flexibility nature, bendable concrete is more resistant to the cracks and acts with more efficiency in seismic regions.
- It was found that the addition of both jute and coir (1.5%) has improved the flexural behavior of ECC specimens.
- On comparing the 7 days, 14 days and 28 days tests, better results were obtained in the 28 days strength.
- The cost incurred on the jute and coir fibres is less when compared to other artificial fibres,
- The good workability of concrete is achieved.

8.2 Future scope

- Further tests can be carried on the bendable concrete by replacing of jute and coir with the other fibres.
- By adding the super plasticizers the water cement ratio can be reduced which improves the workability and strength.
- Further investigation can be carried by replacing of cement with other admixtures like GGBS, silica fumes, etc.
- These advancements may change the properties of the concrete which results in change in strength of concrete.

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