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# Experimental Study on Flexural Behavior of Bendable Concrete

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**Abstract—** Bendable Concrete also known as Engineered Cementitious Composites abbreviated as ECC is class of ultra-ductile fiber reinforced cementitious composites, characterized by high ductility and tight crack width control. This material is capable to exhibit considerably enhanced flexibility. An ECC has a strain capacity of more than 3 percent and thus acts more like a ductile metal rather than like a brittle glass. A bendable concrete is reinforced with micromechanically designed polymer fibres. The aim of this study is to investigate the hardened property (i.e. Flexural Test) of ECC by addition of AR-Glass fibres in different proportion. The result is a moderately low fiber volume fraction (<2%) composite which shows extensive strain-hardening.

**Key words:***Bendable Concrete, ECC-Engineered Cementitious Composites, Deflection,*

## 1.Introduction:

Engineered Cementitious Composites Concrete (ECC) also called as Bendable Concrete or Conflexpave, is an easily moulded mortar-based composite reinforced with specially selected short random fibers usually polymer fibers. ECC acts more like a ductile metal than a brittle glass which then leads to a wide variety of application. The tensile strain capacity of ECC can reach 3-5%, compared to 0.01% for normal concrete. The compressive strength of ECC is similar to that of normal to high strength concrete. The aim of research work is to study ductile behavior of concrete, crack resistance capacity & concrete should give warning before its failure. Normal concrete is brittle in nature while ECC is ductile in nature, due to this property; it has wide applications & wide future scope in various fields.

### 1.1 OBJECTIVES OF THE INVESTIGATION:

- To check the behaviour of ECC-bendable concrete under compression, Split Tensile Test & Flexure Test.
- To find the deflection of ECC beams.

## 2. INGREDIENTS OF ECC CONCRETE:

Engineered cementitious composite is composed of cement, sand, fly ash, water, small amount of admixtures and an optimal amount of fibers. In the mix coarse aggregates are deliberately not used because property of ECC Concrete is formation of micro cracks with large deflection. Coarse aggregates increases crack width which is contradictory to the property of ECC Concrete.

### 2.1 CEMENT

The cement is called Portland slag cement (PSC) because of that Blast- furnace slag may also be used in some cements and The color of the cement is due chiefly to iron oxide. In the absence of impurities, the color would be white, but neither the color nor the specific gravity is a test of quality. Ordinary Portland cement 53 grade (Ultratech Cement) was use, the specific gravity is 3.15.

### 2.2 SAND [FINEAGGREGATE]

Fine aggregate / natural sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic materials. The most useful commercially are silica sands, often above 98% pure. Sand is used for making mortar and concrete and for polishing and sandblasting. Sands containing a little clay are used for making molds in foundries. The sand passed through of 4.75 mm sieve isused which was available locally.The specific gravity of sand is 2.60 and water absorption rate of 1.23%.

**2.3 SUPERPLASTISIZER**

VARAPLAST PC 432 is a ready to use admixture that is added to the concrete at the time of batching. The maximum effect is achieved when the VARAPLAST PC 432 is added after the additionof 50% -70% of the water.VARAPLAST PC 432 must not be added to the dry material. Thoroughly mixing is essential and a minimum mixing cycle, after the addition of VARAPLAST PC 432 of 60 seconds for forced action mixers is recommended. Theproperties of Varaplast PC 432 areshown inTable1.

Table 1: Properties of Varaplast PC 432

| S.NO | Charactertics | Proportion |
|---|---|---|
| 1 | Calciumchlo rideContent | Nil |
| 2 | Specificgrav ity | 1.08at30C |
| 3 | Airentrainm ent | Less than 1% additional air is entrained. |
| 4 | Settingtime | 1-4hours retardation depending ondosageandclimateconditions. |
| 5 | Chloridecont ent | Nil to BS5075 |
| 6 | Colour | Brown |

**2.4 FLY ASH**

Fly ash used was pozzocrete dirk 60.And specifications provided in Table 1.below. In RCC construction use of fly ash has been successful in reducing heat generation without loss of strength, increasing ultimate strength beyond 180 days, and providing additional fines for compaction. Replacement levels of primary class fly ash have ranged from 30-75% by solid volume of cementitious material.Class F fly ash is utilized so the acquisition cost is reduced. Only transportation cost is estimated. Theproperties of Fly ash areshown inTable2.

| S.NO | Charactertics | Proportion |
|---|---|---|
| 1 | ROS45micronsieve(max) | 18 |
| 2 | Lossonignition | 2.5 |
| 3 | Waterrequirement | 95% |
| 4 | Moisture content(max) | 0.5 |
| 6 | Lime reactivity(min) | 5 |
| 7 | $Sio_2+Al_2O_3+Fe_2O_3$ | 90min |
| 8 | $Sio_2$ | 50min |
| 9 | Cao | 5max |
| 10 | Mgo | 4max |
| 11 | $SO_3$ | 2max |
| 12 | $Na_2O$ | 1.5max |

Table 2: Properties of Fly ash

**2.5 AR Glass Fiber**

AR Glass fibers also known as an alkali resistance glass fiber. Generally, glass consist of quartz, soda, sodium sulphate, potash, feldspar and a number of refining and dying additive. Glass fibres are useful because of their high ratio of surface area to weight. However, the increased surface area make them much more susceptible to chemical attack. Humidity is an important factor in the tensile strength.Theproperties of AR Glass fibers are shown inTable3.

Table3: Properties ofAR Glass fibers

| S.NO | Charactertics | Proportion |
|---|---|---|
| 1 | Fibre | AR Glass |
| 2 | specific gravity | 2.68 |
| 3 | elastic modulus(Gpa) | 72 |
| 4 | tensile strength(Mpa) | 1700 |
| 5 | diameter(micron) | 14 |
| 6 | length(mm) | 12 |
| 7 | Aspects ratio | 857.14 |

**2.6 WATER**

Water fit for drinking is generally considered fit for making concrete. Water should be free from acids, oils, alkalis, vegetables or other organic Impurities. Soft waters also produce weaker concrete. Water has two functions in a concrete mix. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened.

**3. ECCMIXDESIGN**

Micromechanics are a branch of mechanics applied at the material constituent level that captures the mechanical interactions among the fiber, mortar matrix, and fiber–matrix interface. Typically, fibers are of the order of millimeters in length and tens of microns in diameter, and they may have a surface coating on the nanometer scale. Matrix heterogeneities in ECC, including defects, sand particles, cement grains, and mineral admixture particles, have size ranges from nano to millimeter scale.

**3.1 PROPORTION OF ECC CONCRETE**

| Mass of Cement kg/m3 | Mass of fly ash kg/m3 | Mass of fine aggregate kg/m3 | Mass of water kg/m3 | Water Cement ratio |
|---|---|---|---|---|
| 360 | 180 | 1080 | 144 | 0.40 |

### 3.2 Casting and Curing

Finally we have to choose the mix proportion was 1:0.5:2, AR Glass fiber 1%, 1.5%, 2% and superplasticizer dose was 500ml/bag and water to cementitious material ratio was 0.40. The casting was done according to IS:516 for mixing, mixed materialwastakenandfilled into cubes, beams and cylinders for different testing. Specimens were taken out after 24 hours and put for curing for durationsof 7,14, 28days.

### 3.3 Specimen Preparation

Add sand, cement, 50% of fly ash & 50% water & super plasticizer. Add slowly remaining quantity of fly ash, water & super plasticizer. Once the homogenous mixture is formed, add the AR glass fibers slowly. Mix all the constituents till the fibers are homogenously mixed in the matrix. Additionally, slight adjustment in the amount of HRWR is performed to achieve consistent rheological properties for better fiber distribution and workability. The mixtures are then cast into molds and demolded after 24 hr. After being demolded, ECC specimens are cured in curing room where the temperature is 25°C for 7 and 28 days respectively.

## 4. RESULT AND DISCUSSION

### 4.1 SLUMPTEST

Slump test is used to determine the workability of fresh concrete. Due to a huge slump may obtain if there is any disturbance in the process.It also mentioned that a slump more than 225mm will indicate a very runny concrete. The apparatus & equipment used for the slump test & the procedure of the test according to IS7320-1974.

### 4.2 Compression test result

According toIS:509-1959, the testingfor the specimensshouldbecarriedoutassoonaspossibleafte rtakingoutfrom the curingrank.Thespecimenneedto getmeasurementbefore testing. The lengthand height of specimen is measured and recorded. The axis of specimen is aligned with the centreof thrust of the seated plate. Plate is lowered until the uniform bearing is obtained. The force is applied and increased continuously at a rate equivalent to 20MPa compressive stresses per minute until the specimenfailed.Recordthemaximum force fromthe testing machine.The observation from our results shows that the increase in compressive strengthisupto28% incase ofadding 1% , 1.5% and2% fibrecontentin comparison ofconventional concrete. It shows that variationin compressive strength by adding fiber.

Fig. 1 Test on Cube

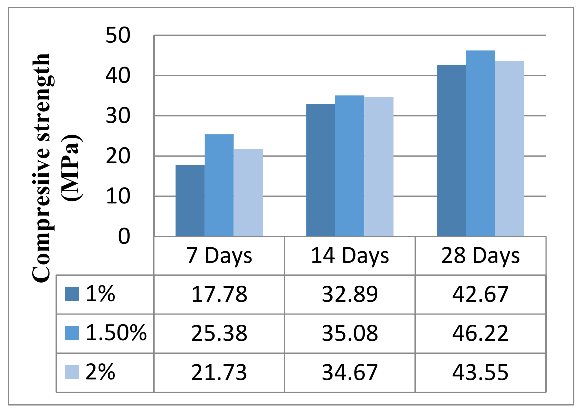


Fig.2 Compressive strength

### 4.3 Split tensile result

Normally concrete is very strong in compression but weak in tension. Indirect tensile test is used to indicate the brittle nature of specimens. Concrete is not elastic material. The stress strain behavior of concrete is straight line upto10-15% if it's ultimate strength. Split tensile test was performedon cylinder of size on universal testing machine according to IS: 5816-1999. The failure load to each cylinder was noted for finding split tensile strength.

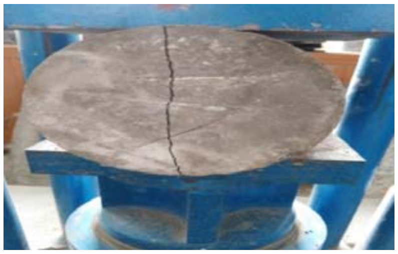

Fig.3 Test on cylinder

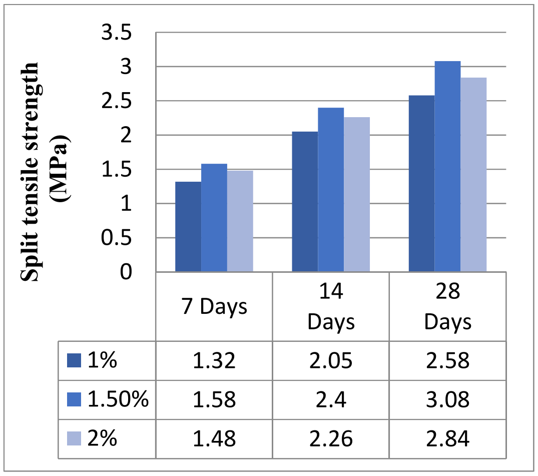


Fig.4 Split tensile strength

**4.4 FLEXURAL TEST**

The beam mould of size 100 X 15 X 10 cm (when size of aggregate is less than 40mm). The specimen shall be supported on 38mm diameter roller with 1000mm span for 150mm size specimen. The load shall be applied through two similar rollers mounted at the two points of the supporting span that is spaced at 40mm. The load is applied without shock at a rate of 4KN/minute for 150mm specimen. The load shall be increased until the specimen fails and the maximum load applied to the specimen during the test. The flexural test was performedon beams onuniversal testing machine according to IS: 516-1959. The failure load to each beam was noted for finding flexuralstrength. Table 4 shows theresults on flexural testing.

Flexuralstrength ofbeam canbecalculatedby followingformula,

$$f_b = PL / bd^2$$

Where,

P = Maximumloadin kNappliedtothe specimen

L = lengthofthe specimeninmm

d = depth measured in cm of the specimen at the point of failure

b = measuredwidthofthe specimenin mm

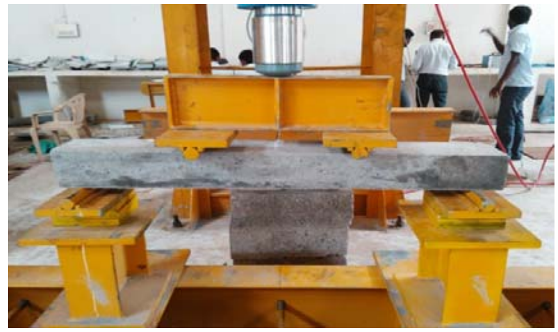

Fig. 5 Test on Beam

Table 4: Flexural strength result

| Fiber content (%) | First CrackStrengthon 14days (MPa) | | UltimateStrength on 14days (MPa) | |
|---|---|---|---|---|
| | Without reinforcement | With6mm reinforcement | Without reinforcement | With6 mm reinforcement |
| 1 | 6.1 | 10.6 | 7.8 | 11.7 |
| 1.5 | 6.5 | 10.25 | 7.3 | 11.9 |
| 2 | 6.3 | 10.50 | 7.8 | 11.7 |

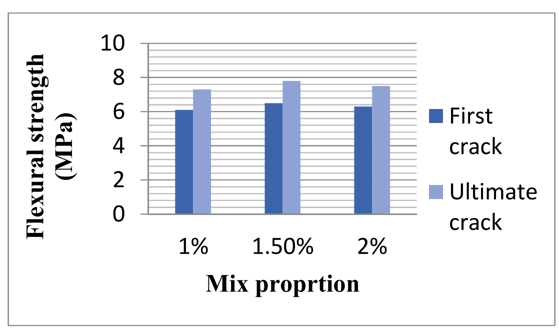


Fig. 6 Without reinforcement

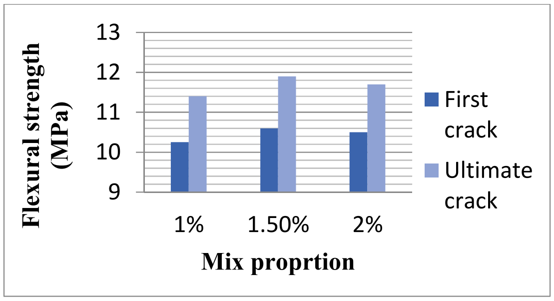


Fig. 7 With 6mm reinforcement

## 5. CONCLUSION

- ✓ According to test results, the beam is with standing high load and a large deformation without succumbing to the brittle fracture typical of normal concrete, even without the use of steel reinforcement.
- ✓ The significant properties of ECC Concrete are ductility, durability, compressive strength, and self-consolidation. Although the cost procured for the designing of ECC is normally higher than that of the normal concrete but it has numerous potential application.
- ✓ The percentage increase of compressive strength of various grades of AR glass fibre concrete mixes compared with 28 days compressive strength is observed 37%.
- ✓ The percentage increase of flexure strength of various grades of AR glass fibre concrete mixes compared with 28 days compressive strength is observed 5.19%.
- ✓ The result is a moderately low fiber volume fraction (<2%) composite which shows extensive strain-hardening, with strain capacity of about 3 to 5% compared to 0.01% of normal concrete.
- ✓ In failure pattern it is observed that the CC fails into two parts where as in ECC only crack is developed which reflects its ductile behavior.

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