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Evaluation and Testing of Bendable Concrete Slab with Partial Replacement of Cement by Industrial and Agricultural by product and Polyvinyl Alcohol as Fiber

S. Suseendar[1], M. Lenin sundar[2], Ms. Geethu Mohan[3]
[1]*M.E-structural engineering, Sri Krishna College of technology, Coimbatore*
[2]*Professor, Sri Krishna College of technology, Coimbatore*
[3]*Assistant Professor, Sri Krishna College of technology, Coimbatore*

Abstract: Bendable Concrete also known as Engineered Cementitious Composite (ECC) is an ultra-ductile concrete with strain-hardening and multiple-cracking behavior in tension and flexure. Bendable concrete mixtures are evaluated by incorporating supplementary cementitious materials such as rice husk ash, palm oil fuel ash, silica fume and PVA fiber. Ductile property of normal concrete can be improved by using PVA fibers in place of coarse aggregate. In the present work bendable concrete is high in flexural strength compared with conventional concrete. In flexure, concrete is weak bendable concrete shows effective results on flexural values by partial replacing cement with polyvinyl alcohol fiber and rice husk ash, palm oil fuel ash and silica fume is partially replaced with cement by percentages of 20% and compare the results of hardened concrete properties as compressive strength, split tensile strength, flexural strength. For these purpose concrete cubes, cylinders, beams and slabs are experimentally investigated. This paper also focuses on significant pattern of cracks developed during testing of specimens.

Keywords: Engineering Cementitious Composites ECC, PVA fiber, Rice husk ash, palm oil fuel ash, silica fume, ECC concrete.

I. Introduction

The recently developed smart building material namely Bendable concrete also known as Flexible concrete or Engineered Cementitious Composite (ECC) was developed by Professor Victor Li at the University of Michigan. Conventional concretes are almost unbendable and have a strain capacity of only 0.1% making them highly brittle and rigid. This lack of bendability is a major cause of failure under strain and has been a pushing factor in the development of an elegant material namely, bendable concrete. It contains cement, sand, water, binder material, polyvinyl alcohol fibres and admixtures. Polyvinyl alcohol (PVA) fiber is considered as one of the most suitable polymeric fibers to be used as the reinforcement of engineered cementitious composites. Ductile property of normal concrete can be improved by using PVA fibers in place of coarse aggregate and cement partially replaced by rice husk ash, palm oil fuel ash, silica fume. Additionally, ECC uses low amounts, typically 2% by volume, of short, discontinuous fibers. ECC incorporates super fine silica sand and tiny Polyvinyl Alcohol-fibers covered with a very thin (nanometer thick), slick coating. Thus an ECC deforms much more than a normal concrete but without fracturing. The different ingredients of ECC work together to share the applied load. ECC has proved to be 50 times more flexible than traditional concrete, and 40 times lighter, which could even influence design choices in skyscrapers. Additionally, the excellent energy absorbing properties of ECC make it especially suitable for critical elements in seismic zones.

II. Need of the Project

In the present experimental work, the ECC is prepared by using the polyvinyl alcohol fiber in it. The performance of a polyvinyl alcohol fiber is introduced in the Engineered Cementitious Composite ECC. In the present paper, mechanical properties of PVA fiber reinforced ECC under tension, compression, and flexure are studied, by testing different types of specimens, Cement is partially replaced by rice husk ash, palm oil fuel ash, silica fume. Compare the results of hardened concrete properties as compressive strength, split tensile strength, flexural strength. 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.

III. Materials And Methods

3.1 Cement:

Ordinary Portland cement (OPC) – 53 grade (Ultratech Cement) was use.

3.2 Sand:

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. soil containing more than 85% sand-sized particles.. Sand is used ingredients of mortar and concrete and for polishing and sandblasting. The weight varies from 1,538 to 1,842 kg/m3, depending on the composition and size of grain. The fine aggregate obtained from river bed. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.68. The grading zone of fine aggregate was zone III as per Indian Standard specifications.

3.3 Rice Husk Ash:

Rice Husk Ash (RHA) which is an agricultural by-product has been reported to be a good pozzolan by numerous researchers. After collection, the Rice Husk was burnt under guided or enclosed place to limit the amount of ash that will be blown off. The ash was ground to the required level of fineness and sieved through 600 μm sieve in order to remove any impurity and larger size particles.

3.4 Palm Oil Fuel Ash:

Palm oil fuel ash (POFA), a by-product from the palm oil industry is disposed of as waste in landfills. It not only occupies land but also creates environmental pollution and health hazards. These problems can be reduced to a large extent by using POFA in concrete. It can be used as a supplementary cementing material upto a certain replacement level of cement without causing any adverse effect on strength and other properties of concrete.

3.5 Silica Fume:

Silica fume is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. Silica fume, although finer than OPC and it does not typically have higher water demand as compared to OPC in concrete

3.6 Super Plastisizer:

Super plasticizer used was Melamide Formaldehyde.

3.7 Polyvinyl Alcohol Fiber:

PVA fibres have some structural strength and can also be used for shrinkage control. While they cannot replace reinforcing steel, they improve the mechanical properties of cured concrete, boosting its strength. Polyvinyl alcohol fibre (PVA) is an ideal environment-friendly cement reinforced material. It will develop the flexural property of concrete and mortar. This product can be widely used in civil and industrial buildings, walls, roofing, flooring and roads, bridges, tunnels, reinforcement for embankment slopes.

3.8 Proportioning of Concrete:

The initial mix proportion was 1:3, PVA fiber 2% and super plasticizer 2% and water/cement ratio was 0.5.

Materials used in trial 1 is (cement + 20% of RHA +fine aggregate + PVA fiber + super plasticizer).

Materials used in trial 2 is (cement + 20% of Palm oil fuel ash + fine aggregate + PVA fiber + super plasticizer).
Materials used in trial 3 is (cement + 20% of silica fume + fine aggregate + PVA fiber + super plasticizer).

3.9 Placing, Compaction & Casting of Concrete Specimens:

Before placing of concrete, the concrete mould must be oiled for the ease of concrete specimens stripping. Once the workability test of ECC Concrete was done, the fresh concrete must be placed into the concrete moulds for hardened properties tests.

3.10 Curing of Concrete Specimen:

After leaving the fresh concrete in the moulds to set overnight, the concrete specimens in the moulds were stripping. The identification of concrete specimens was done. After 24 hours, all the concrete specimens were placed into the curing tank with a controlled temperature of 25 C in further for 28 days for the hardened properties test of concrete.

3.11 Testing Of Specimen:

3.11.1 Compression Test- (Test on Cubes)

The cubes of size 70 x 70 x 70 mm are placed in the machine such that load is applied on the opposite side of the cubes as casted. Align carefully and load is applied, till the specimen breaks.

Compressive Strength = Total Failure Load/Area of the Cube

3.11.2 Flexural Strenght- (Test on Prism)

The test is carried out to find the flexural strength of the prism of dimension 280 x 80 x 75 mm. The prism is then placed in the machine in such manner that the load is applied to the uppermost surface as cast in the mould. Two points loading adopted on an effective span of 400 mm while testing the prism. The load is applied until the failure of the prism.

$f_b = P \times l / bd^2$ (or) $fb = 3 \times P \times a / bd^2$

3.11.3 Split Tensile Strenght- (Test on Cylinder)

The specimens were tested in accordance with IS 5816:1999. Specimens when received dry shall be kept in water for 24 h before they are taken for testing. Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal from the water whilst they are still wet. Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips. The load shall be applied without shock and increased continuously at a nominal rate within the range 1.2 N/ (mm²/min) to 2.4 N/ (mm²/min).The size of specimen is 100 x 200 mm.

$$ft = 2 P/(\pi \times l \times d)$$

IV. Results And Discussion

4.1 Compressive Strength:

The test results of compressive strength at 7th, 14th and 28th day with various percentages of fibers. Compressive strength increases strength of concrete by addition of 2% fiber addition of fibers into the concrete shows maximum benefits in compressive strength.

Compressive strength (N/mm^2)

Filler Materials	% of Fiber Used	7th day test	14th day test	28th day test
Conventional Concrete	**2%**	**9.83**	**11.6**	**12.2**
Rice husk ash	**2%**	**10.31**	**12.92**	**13.6**
Palm oil fuel ash	**2%**	**10.20**	**11.22**	**13.26**
Silica fume	**2%**	**9.91**	**11.04**	**12.5**

Table 4.1 Compressive strength result

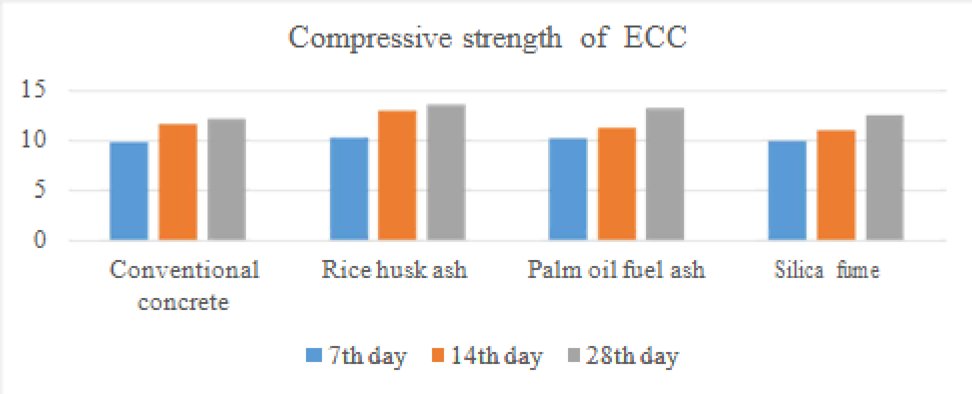

Fig 4.1 Compressive strength

4.2 Split Tensile Strength

The test results of Split tensile strength at 7, 14 and 28 days. Tensile strength increases with increasing percentage of fibers. 0.15% addition of fibers into the concrete shows maximum benefits in tensile strength.

Split tensile strength (N/mm^2)				
Filler Materials	**% of Fiber Used**	**7^{th} day test**	**14^{th} day test**	**28^{th} day test**
Conventional Concrete	**2%**	**1.59**	**1.86**	**1.9**
Rice husk ash	**2%**	**1.01**	**1.19**	**1.27**
Palm oil fuel ash	**2%**	**1.43**	**1.59**	**2.06**
Silica fume	**2%**	**1.24**	**1.43**	**1.68**

Table 4.2 Split tensile strength result

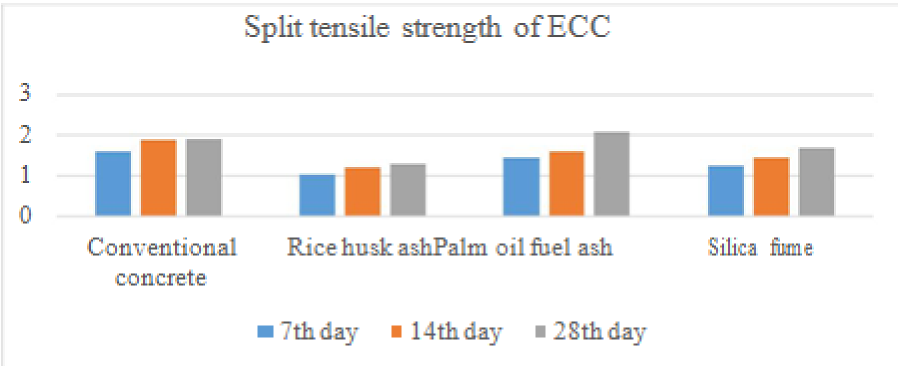

Fig 4.2 Split tensile strength

4.3 Flexural Strength

The test results of flexural strength at 28 days. Flexural strength increases with increasing percentage of fibers. 0.15% addition of fibers into the concrete shows maximum benefits in flexural strength.

Flexure strength (N/mm^2)				
Filler Materials	**% of Fiber Used**	**7th day test**	**14th day test**	**28th day test**
Conventional Concrete	**2%**	**8.23**	**8.91**	**9.2**
Rice husk ash	**2%**	**8.62**	**9.43**	**9.97**
Palm oil fuel ash	**2%**	**9.84**	**10.42**	**10.87**
Silica fume	**2%**	**9.63**	**10.24**	**10.39**

Table 4.3 Flexural strength result

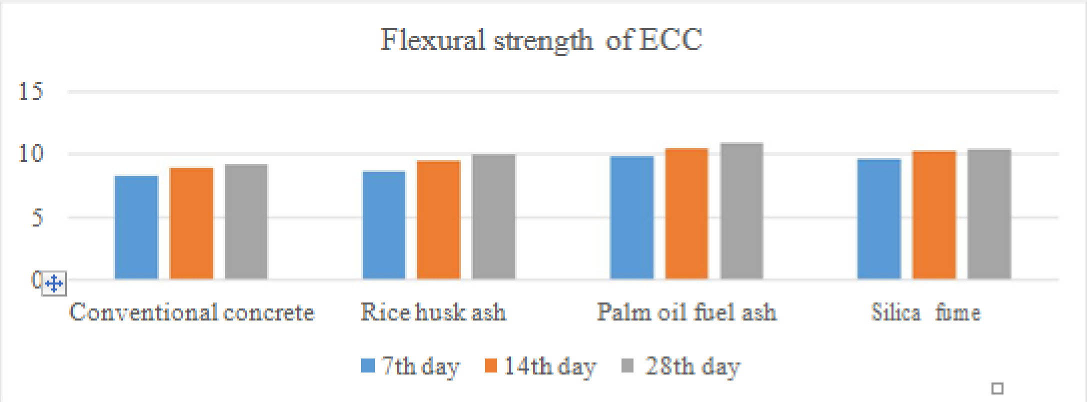

Fig 4.3 Flexural strength

Conclusion

- From the investigations, it is concluded that the Bendable Concrete with the mixes are having best results and stated as best mixes when compared with Conventional concrete.
- Fracture controlled failure is exhibited by the ECC under flexural loading, and a bend a bend is obtained because of crack controlling nature.
- In the Bendable Concrete for the mixes having 20% replacement of cement with palm oil fuel the best mix which is obtained at Cement/Sand ratio 1:3 and having 2% volume of fibers.
- It was noticed that Fibers reduces the w/c ratio which leads to the low workability but the workability can be maintained by super plasticizers.
- The maximum Compressive strength in Bendable Concrete having 20% replacement of cement with Rice Husk ash and having 2% volume of fibers is occurred at the mix.
- The maximum Flexural strength in Bendable Concrete having 20% replacement of cement with palm oil fuel ash and having 2% volume of fibers.
- The maximum Splitting Tensile strength in Bendable Concrete having 20% replacement of cement with palm oil fuel ash and having 2% volume of fibers is occurred at the mix.

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