EXPERIMENTAL STUDY ON BENDABLE CONCRETE

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ABSTRACT- **Engineered cementitious composites (ECC) also called as Bendable concrete is an easily moulded mortar based composite reinforced with specially selected short random fibres. Traditional concrete suffers catastrophic failure when strained in an earthquake or by routine overuse. ECC remains intact and safe to use at tensile strains up to 5%. Traditional concrete fractures and may not carry a load at 0.01 % tensile strain. In this paper, to overcome the demand for concrete in future and to develop the fibre materials, the Poly Vinyl Alcohol Fibre is used so as to reduce the cement content and to enhance flexibility. It has high aspect ratio, high ultimate tensile strength, relatively high modulus of elasticity, good chemical compatibility with Portland cement, good affinity with water and no health risks. To increase the workability of concrete super plasticizer is used. The compressive strength and flexural strength of cubes and slabs (two different thicknesses) is determined and also the bendability characteristics of the concrete are checked during flexural strength test.**

Keywords: *ECC (Engineered Cementitious Composites) or Bendable concrete, Poly Vinyl Alcohol, fibre, Super plasticizer.*

I. INTRODUCTION

POLY VINYL ALCOHOL FIBER (PVA)

While selecting fibres for ECC, it was found that polyvinyl alcohol (PVA) fibre was of low cost and high performance. The hydrophilic nature of PVA fibre imposed great challenge in the composite design, as the fibres are susceptible to rupture instead of being pulled out because of the tendency for the fibre to bond strongly to cementitious matrix. The objective of this paper is to provide a performance summary of an exemplary PVA-ECC. 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, which possesses alkali and weather resistance due to its unique molecular structure, taking on good affinity to cement, effectively prevent and suppress the crack formation and development, improve bending strength, impact strength and crack strength, improve permeability, impact and seismic resistance of concrete. This product can be widely used in civil and industrial buildings, walls, roofing, flooring and roads, bridges, tunnels, reinforcement for embankment slopes.

BENDABLE CONRETE

Bendable concrete also known as Engineered Cementitious Composites abbreviated as ECC is class of ultra-ductile fibre reinforced cementitious composites, characterized by high ductility and tight crack width control.

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. This material is capable to exhibit considerably enhanced flexibility. A bendable concrete is reinforced with micromechanically designed polymer fibres. ECC is made from the same basic ingredients as conventional concrete but with the addition of High-Range Water Reducing (HRWR) agent is required to impart good workability.

However, coarse aggregates are not used in ECCs, the powder content of ECC is relatively high. Cementitious materials, such as fly ash, silica fume, etc., may be used in addition to cement to increase the paste content. Additionally, ECC uses low amounts, typically 2% by volume, of short, discontinuous fibres. ECC incorporates super fine silica sand and tiny Polyvinyl Alcohol-fibres covered with a very thin (manometer thick), silk coating. This surface coating allows the fibre to begin slipping when they are over loaded so they are not fracturing. It prevents the fibre from rupturing which would lead to large cracking. Thus an ECC deforms much more than a normal concrete but without fracturing. The behaviour of ECC under flexural loading and it can be seen that the beam can deform sufficiently without direct failure. ECC has proved to be 50 % more flexible than traditional concrete, and 40% 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.

The challenge in making a lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost. Introducing new aggregates into the mix design is a common way to lower density of concrete. Normal concrete contains four components, cement, crushed stone, river sand and water. The crushed stone and sand are the components that are usually replaced with lightweight aggregates.

II. INGREDIENTS OF ECC CONCRETE

Engineered cementitious composite is composed of

- Cement (53 grade of OPC)
- Sand
- Water
- Super plasticizer
- PVA fibre (length is 12mm and diameter is 40µm).

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 contradicts the property of ECC Concrete.

III. PROCEDURE FOR MAKING ECC CONCRETE

MIX RATIO

The initial mix proportion was PVA fibre at 2% and super plasticizer dose was 30ml per slab mould (700x150x60 mm),(700x150x30 mm) and 10ml per cube mould(70.6x70.6x70.6 mm), then water to cement ratio of 0.5. By using this proportion workability was achieved. The ratio of concrete mix is 1:2(cement : sand) and w/c=0.5.

Figure 1, 1.1, 1.2 shows the mixing of ECC concrete.

Fig.1. Mixing of ECC concrete.

Fig.1.1 Mixing of PVA Fibre in Concrete.

Fig.1.2. Mixture of ECC concrete.

CASTING PROCEDURE OF ECC-CONCRETE.

The performance of the ECC Concrete was influenced by the mixing. This means that a proper & good practice of mixing can lead to better performance & quality of the ECC Concrete. The quality of the concrete is also influenced by the homogeneity of the mix material. Flexural Test was carried out on the slab during the mixing & after the placement of fresh concrete. A proper mixing of concrete is encouraged to obtain the strength of concrete & better bonding of cement with the PVA fibres. Once the concrete mix design was finalized, the mixing was carried out. The mixing of ECC Concrete was carried out by using hand mixing. The procedure of hand mixing was as follows:- Add sand, cement, add the PVA fibres slowly then add 50% of water & super plasticizer. Add slowly remaining quantity of water & super plasticizer and mix till the homogenous mixture is formed. Figure 2 and 2.1 represents the casting of cubes and slabs.

Fig.2. Casting of ECC concrete in cube.

Fig.2.1. Casting of ECC concrete in slab.

PLACING, COMPACTING & CASTING OF CONCRETE SPECIMEN.

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 property tests. During the placing of fresh concrete into the moulds, tamping was done using Tamping rod in order to reduce the honeycombing. It allows full compaction of the fresh concrete to release any entrained air voids contained in the concrete. If the concrete was not compacted in a proper manner, the maximum strength of the concrete cannot be achieved. After this operation, the levelling of concrete was done on the surface of the concrete. Levelling is the initial operation carried out after the concrete has been placed & compacted. After the levelling of the fresh concrete was done, the concrete in the mould was left over night to allow the fresh concrete to set. Figure 3 and 3.1 shows the demoulding of slabs with different thickness.

Fig.3. ECC concrete slab with 60mm thickness after demoulding.

Fig.3.1. ECC concrete slab with 30mm thickness after demoulding.

CURING OF CONCRETE SPECIMEN

After 24 hours, the concrete specimens are demoulded from the moulds. All the concrete specimens were placed into the curing tank with a controlled temperature of 25 ^{o}C for a period of 28 days to attain the hardening property of concrete shown in figure 4 and 4.1 . Curing is an important process to prevent the concrete specimens from losing of moisture while it is gaining its required strength. Lack of curing will lead to improper gain in the strength. After 7, 14 and 28 days of curing, the concrete specimens were removed from the curing tank to conduct hardened properties test of ECC Concrete.

Fig.4. Curing of slabs.

Fig.4.1. Curing of cubes.

IV. TESTING ON CONCRETE

After curing process, the specimen has to be tested. Investigations are carried out by testing cubes, slabs for 7, 14, 28 days. Cubes were tested on Compression testing equipment and slabs of (two different thickness) were tested on flexural testing machine and during this flexural testing the bendable characteristics of slab also been determined. The results are given below:

Table.1. Mechanical Properties of Bendable concrete and Conventional cubes and slabs.

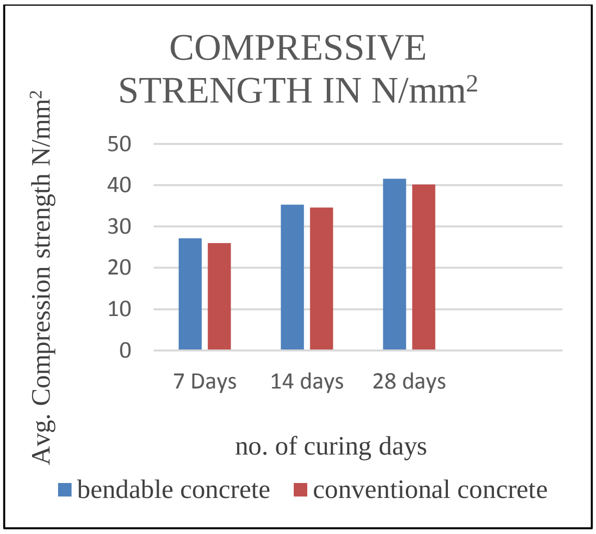
Mechanical	**Bendble concrete**	**Conventional concrete**
Compressive strength in N/mm² at 7 days	27.2	26
14 days	35.3	34.6
28 days	41.6	40.2
Flexural strength in N/mm² at 7 days	3.76	3.03
14 days	4.83	3.89
28 days	5.56	4.24
Flexural strength in N/mm² at 7 days	3.81	3.23
14 days	5.11	4.58
28 days	5.92	5.15

Discussion

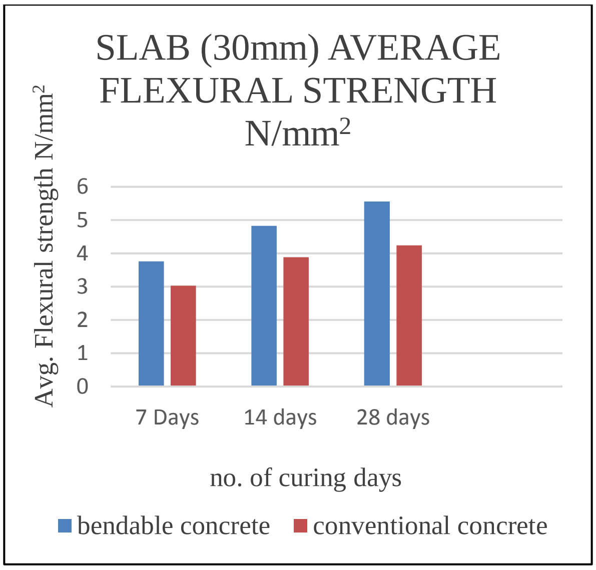
The strength of the bendable concrete is comparatively higher than the conventional cubes and slabs. This higher strength shows that the presence of PVA fiber in bendable concrete has increased its efficiency.

V. COMPARISION

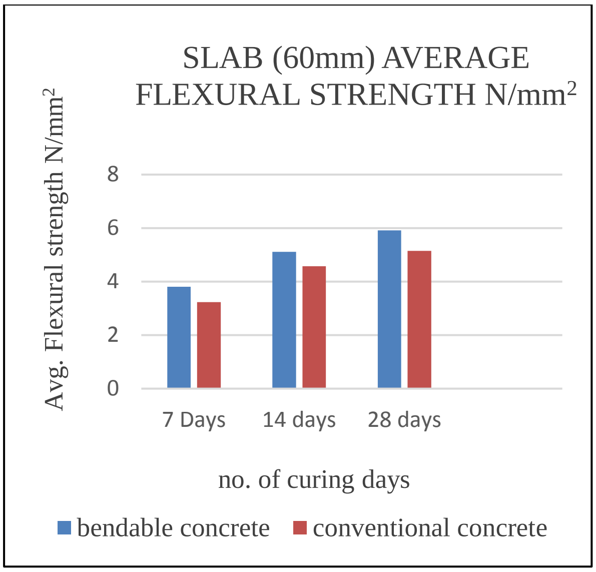
The comparison of results of mechanical property test between the bendable concrete and conventional concrete.



Graph 1.Comparison of bendable and conventional cubes.



Graph 2.Comparison of bendable and conventional slabs (30 mm).



graph 3. Comparison of bendable and conventional slabs (60 mm).

Discussion

In the above comparisons the compression strength and flexural strength of the bendable concrete is comparatively higher than the conventional cubes and slabs. The reason behind the higher strengths of bendable concrete is due to the presence of fiber as reinforcement. The strength of conventional cubes and slabs is comparatively low since it is not reinforced.

V. CONCLUSION

In this paper the compression and flexural strength of bendable concrete is done the values are compared with conventional cubes and slabs. Therefore it is proved that the bendable concrete is more strength than the conventional concrete and it is more flexible so that it resists cracks and acts as more efficiency in seismic regions.

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