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Study on mechanical properties of Engineered Cementitious Composites

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Abstract-- In this paper, the effect of mechanical properties of engineered cementitious composites (ECC) is investigated. Emphasis of this study is to evaluate the use of PVA in its powder form. Concrete is the utmost essential construction material used worldwide. Historically, structural designers have mostly depended on concrete to carry compressive loads. Though, in actual field conditions, concrete is also exposed to tensile stresses due to loading and environmental effects including thermal effects. The tensile strength of concrete is only 10% of its compressive strength. The main shortcoming of the concrete is its brittle nature and as a result of its brittle nature cracking, damage and deterioration occurs and it requires repeated maintenance of the structural members. Mostly experiments are done using PVA fibers and it shows enhancement of strength and durability parameters. Experimental studies using PVA in powder form is comparatively less. Mechanical properties are found out by using strength parameters such as compressive, flexural and modulus of elasticity test. It was found that the test results show an increment in strength and ductile behavior.

Index Terms-PVA (Poly vinyl alcohol), compressive strength, split tensile strength, flexural strength, modulus of elasticity

1. INTRODUCTION

Concrete is the most important construction material unlike other construction material and as such can vary to a great extent in its quality, properties and performance. One of the short coming of the concrete is its brittle nature as a result of its causes cracking, damage and deterioration and it requires repeated maintenance of the structural member [2]. In concrete structures lack of bendability is a major cause for failure under strain. ECC (Engineered cementitious composites) is a special concrete and is also known as bendable concrete [2][4]. ECC belongs to the class of HPFRCC (High performance fiber reinforced cementitious composites). Its most unique features is ductile behavior [5]. Mostly the experiments done using PVA fibers showing enhancement in its strength and durability properties. In this paper the experimental studies mainly aims to evaluate the use of PVA in its powder form. PVA (poly vinyl alcohol).Hydroxyl groups that present in PVA has the potential to modify the surface bond between the aggregate, matrix and fiber reinforcement and also to reduce the formation of flocculated structures by cement particles and the bleeding effect of cement paste. The PVA narrows the thickness of ITZ (interfacial transition zone) and also its presence can able to increase the CSH (calcium silicate hydrate).

The scope of the present study is to experimentally analyze the advantage of bendable concrete over traditional concrete.

1.1. *PVA (poly vinyl alcohol).*

Polyvinyl alcohol is manufactured commercially from polyvinyl acetate, frequently by a continuous process. It is an odorless and tasteless, translucent, white or cream colored powder. PVA is unique among polymers i.e. it is a chemical compounds made up of large and multiple-unit molecules, in that it is not built up in polymerization reactions from single-unit precursor molecules known as monomers. Poly vinyl alcohol which is made by dissolving another polymer, polyvinyl acetate in an alcohol such as methanol and treating it with an alkaline catalyst such as sodium hydroxide. PVA which is added to the cement matrix can reduce the formation of flocculated structures by cement particles and the bleeding effect that occur cement paste. It contains two OH groups, that helps to retain water from concrete and hydroxyl group present in the poly vinyl alcohol have the potential to improve the surface bond between the aggregate, matrix and fiber reinforcement[1][3]. In concrete interfacial transition zone is the weakest zones and the region which mainly has high porosity and large bulk amount of calcium hydroxide [$Ca(OH)_2$].With the presence of PVA , the thickness in the ITZ (interfacial transition zone) between the aggregate and paste and also the amount of $Ca(OH)_2$ formation were found to be reduced which provide better adhesion between cement paste aggregates and also its presence may be able to increase the calcium silicate hydrate (C-S-H).

2. EXPERIMENTAL INVESTIGATION

2.1. *Mix Design*

A total of three mixes were used for casting the concrete specimens such as cubes, beams, cylinders. Mix design was done as per IS 10262 2009 and IS 456:2000. Conventional concrete mix M30 and a replacement of 2% and 4% PVA. Mix proportion obtained for M30 was 1:1.54:2.79 at w/c of 0.38 and addition of super plasticizer at 0.35%. The proportioning for various mixes is given in the following table (1) and table (2)

Table 1. Mix proportion

Mix	M30	CCP2%	CCP4%
Cement	1	1	1
Fine aggregate	1.54	1.56	1.58
Coarse aggregate	2.79	2.82	2.88
W/C ratio	0.38	0.38	0.38
Super-plasticizer	0.35%	0.5%	0.52%

Table 2. Mix proportion per m3

Mix	M30	CCP2%	CCP4%
Cement (Kg)	415.07	406.76	398.46
Fine aggregate (Kg)	640.30	636.25	632.77
Coarse aggregate (Kg)	1156	1148.79	1142.50
Water	157.72	157.72	157.72
PVA	-	8.3014	16.602

2.2. *Preparation of test specimen*

Specimens were casted on the basis of mix proportion. Better mix proportions were obtained until the workability attained and slump is checked for particular mix. The mould is then filled with freshly mixed concrete by giving proper compaction and tamping, after casting the specimens was demoulded after 24 hrs and were kept in water tank for curing. Standard moulds for the specimens were used 150mmx150mmx150mm cubes, 150mmx300mm and 100mmx500mm beams.

Table 3. Test specimens

SL NO	Specimen	Size (mm)
1	Cubes	150mmx150mmx150mm
2	Cylinders	150mmx300mm
3	Beams	100mmx500mm

2.3. *Strength test*

2.3.1 *Compressive strength test*

Compression test were carried out as per IS 516-1959. Specimens were casted on 150mmx150mmx150mm size both control and partially replaced cement concrete cubes. The concrete cube specimens were placed on the compression testing machine then apply the load without shock and gradually increase the rate of loading, approximately 140 kg/cm² per minute. Due to compression load, the concrete cube specimens undergo lateral expansion. Loading at the crushing of the specimen were recorded. Compressive strength of the concrete cube specimen was calculated by using the formula.

Compressive strength = (P/A) x1000

Where,

P=load in Kn

A= Area of the cube surface

2.3.2Split tensile strength test

Split tensile strength were carried out as per IS 516-1959.Specimens were casted were casted on 150mm x150mmx150mm size, both control and partially replaced cement concrete cylinders. Cylindrical specimen is placed horizontally between the loading surface on compression testing machine and the load is applied until failure of the specimen along its vertical diameter. The splitting tensile strength *f*ct, of the specimen shall be calculated using the formula:

Eq. (1) $f\text{ct} = 2P/\pi\text{dl}$

Where P= maximum load in newton applied to the specimen

l = length of the specimen (in mm)

d= cross sectional dimension of the specimen (in mm)

2.3.3*Flexural strength test*

Flexural test were carried out as per IS 516-1959. Beam specimens were casted on 150mmx100mmx100 mmAfter proper mixing, casting and curing the specimens should remove from water. Then align the axis of the specimen with the axis of loading device. From extreme edges of the specimen 2,5mm were marked. Load was applied without shock and increased at a rate until the specimen fails and the max load applied during test is recorded.
Flexural strength of the specimen is expressed as the modulus of rupture:

Eq. (2) $fb = pl/bd^2$

when 'a' is the distance between the line of fracture and the nearest support, measured on the central line of the tensile side of the specimen, in cm, is greater than 13.3cm where,fb =3pa/bd2, when 'a' is less than 13.3 cm

2.3.4*Modulus of elasticity test*

Modulus of elasticity test were carried out as per IS 516-1959.Specimens of 150mmx300mm size concrete cylinders for both control partially replaced concrete cylinders. All specimens were loaded in axial compression using a compression testing machine. Two lines were marked by 5cm from top and bottom in concrete cylinders. The specimens placed in the top and bottom frames of the compressometer and measuring the deformations by means of dial gauges. A series of readings are taken and stress strain relationship is obtained.

3. RESULTS AND DISCUSSIONS

3.1. *Compressive strength*

From the journals referred so far it was seen that zero percentage of coarse aggregate is used in ECC (engineered cementitious composites).To make it as an efficient construction material 10mm an 20mm coarse aggregate were casted and 20mm aggregates gives better results are shown in table (4). Hence 20mm coarse aggregate was used for further studies. Results obtained shows when cement is replaced with PVA there was an increment in compressive strength when compared to M30 conventional concrete specimens. From the results it is evident that 20mm coarse aggregate give better results and used for further studies.Optimum is obtained at 2% and beyond the optimum 2% compressive strength decreasing. There is an increase of 50.54% compressive strength at 7th day and 2.717% at 28th day when compared with M30 OPC are shown in table (5).

Table 4. Compressive strength test results

Mix Id	Binder composition	Fine aggregate	Coarse aggregate	Compressive strength	
				7th day	28th day
CCP2%	98%OPC+2% PVA	100% M-sand	10mm	23.92 N/mm²	31.85 N/mm²
CCP2%	96%OPC+2% PVA	100% M-sand	20mm	28.77 N/mm²	36.29 N/mm²

Table 5. Compressive strength for different mix

Mix Id	Binder composition	Fine aggregate	Compressive strength	
			7th day	28th day
M30	OPC	100% M-sand	19.11 N/mm²	35.33 N/mm²
CCP2%	98%OPC+2% PVA	100% M-sand	28.77 N/mm²	36.29 N/mm²
CCP4%	96%OPC+2% PVA	100% M-sand	18.08 N/mm²	26.44 N/mm²

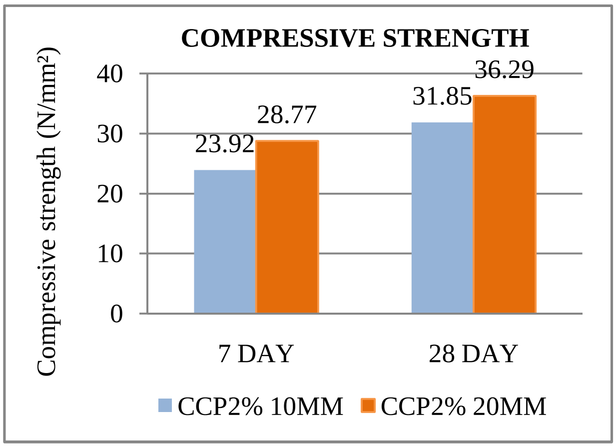

Fig. 1. Compressive strength test results

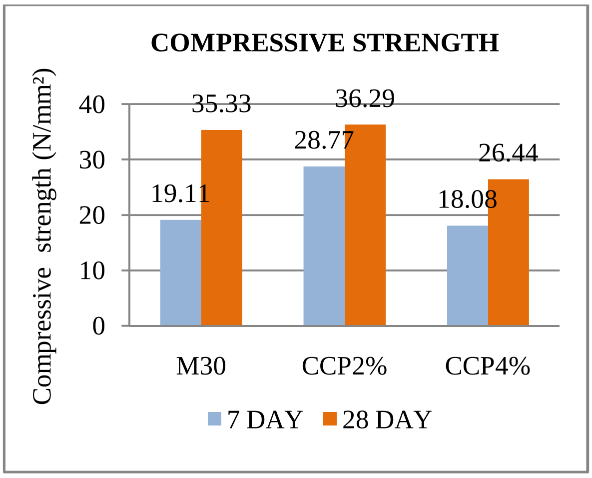

Fig. 2. Compressive strength for different mix

3.2. *Split tensile strength*

From the test results of split tensile strength shown in table (6), there is an increase of 3.14% at 7th day and an increase of 5.61% split tensile strength at 28th day when compared with M30 OPC concrete.

Table 6. Compressive strength for different mix

Mix Id	Binder composition	Fine aggregate	Compressive strength	
			7th day	28th day
M30	OPC	100% M-sand	1.91 N/mm²	2.67 N/mm²
CCP2%	98%OPC+2% PVA	100% M-sand	1.97 N/mm²	2.82 N/mm²

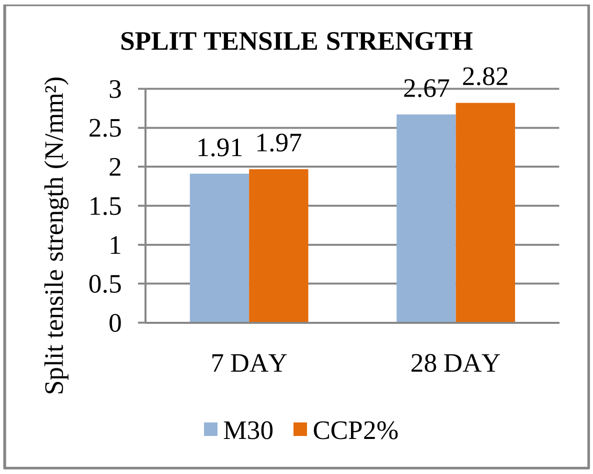

Fig. 3. Split tensile strength test results

3.3. *Flexural strength*

From the test results of flexural strength shown in table (7) it can be seen that there is an increase of 22.10% at 7th and an increase of 4.118% at 28th day. Since concrete is weak in tension any improvement in the mix can which increase the flexural strength is a benefit.

Table 7. Flexural strength test results

Mix Id	Binder composition	Fine aggregate	Compressive strength	
			7th day	28th day
M30	OPC	100% M-sand	4.75 N/mm²	6.08 N/mm²
CBP2%	98%OPC+2% PVA	100% M-sand	5.80 N/mm²	6.33 N/mm²

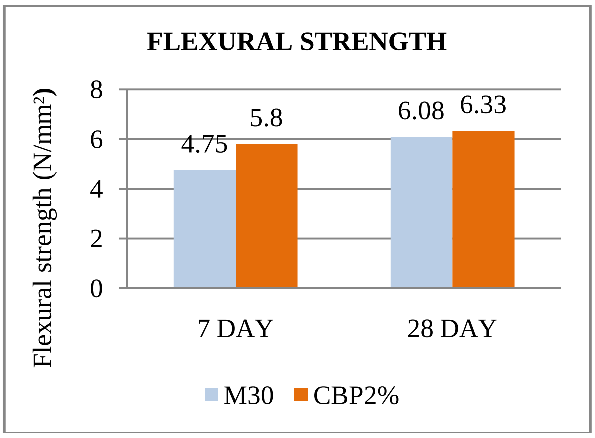

Fig. 4. Flexural strength test results

3.4. *Modulus of elasticity test*

Modulus of elasticity results obtained shows there is an increase of 12.5% when compared with M30 OPC concrete are shown in table (8).From the stress strain graph shows there is an improvement in ductile behavior when the optimum replacement of PVA with cement compared to M30 are shown in fig. (5). This implies that the structure remains serviceable even if it undergoes strain.

Table 8. Compressive strength for different mix

Mix Id	Binder composition	Fine aggregate	Modulus of elasticity
M30	OPC	100% M-sand	25163.16 N/mm^2
CCP2%	98%OPC+2% PVA	100% M-sand	28308.56 N/mm^2

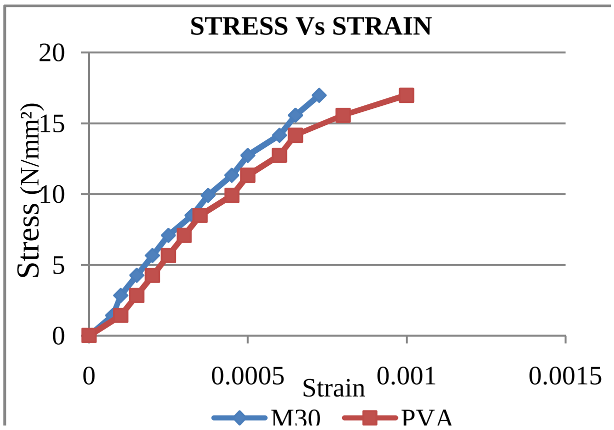

Fig. 5. Stress vs. Strain graph

4. CONCLUSIONS

Following are the conclusion that drawn out from the test results.

- Workability was found to be decreasing with the presence of PVA and hence super plasticizer was added to improve workability
- The optimum value is obtained at 2% and beyond 2% the strength value is found to be decreasing.
- When optimum replacement of PVA with cement shows in compressive strength there is an increase of 50.54% at 7th and 2.717% at 28th day.
- Split tensile strength shows an increment of 3.14% at 7th day and 5.61% at 28th day when optimum replacement of PVA with cement compared with conventional concrete
- Flexural strength results obtained shows an increment of 22.10% at 7th day and 4.118% at 28th day when optimum replacement of PVA with cement compared with M30.
- The stress strain graph of optimum replaced by PVA with cement shows an improvement in ductile behavior of concrete when compared with conventional concrete.

REFERENCES

[1] A. Allahverdi; K. Kianpur (2010): Effect of polyvinyl alcohol on flexural strength and some important physical properties of Portland cement paste; Iranian Journal of Materials Science & Engineering Vol. 7.

[2] Dr. A. W. Dhawale; Mrs. Josh (2013): Engineered cementitious Composites for structural application. Volume 2, Issue 4, ISSN 2319 – 4847

[3] Kamatham Radhakrishna; K.Rajasekha (2015): An Experimental investigation on self-cured concrete. IJATES, Vol No.3, Issue 09.

[4] Sagar Gadhiya; Prof. T. N. Patel (2015); Dr. Dinesh Shah: Parametric Study on Flexural Strength of ECC. IJSRD Vol. 3, Issue 04

[5] Jun Zhang; Christopher K.Y. Leung; Yin Nee Cheung. (2005): Flexural performance of layered ECC-concrete composite beam. 2005 Elsevier Ltd