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A STUDY ON MECHANICAL PROPERTIES OF ENGINEERED CEMENTITIOUS COMPOSITE CONCRETE

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ABSTRACT: Bendable concrete is also known as ECC (Engineered Cementitious Composites) is a class of ultra-ductile fibre reinforced cementitious composite charaterised by high ductility and tight crack with control. The demand for tensile strength is high for concrete because higher loading requires more than 10% of compressive strength which make a critical issue for engineers. Another major issue faced by normal concrete is lack in ductility and strain capacity. Engineered Cementitious Composites (ECC), also known as Bendable Concrete, has been designed to overcome the brittleness of concrete. It has tensile ductility of 3–5% and its self-controlled tight crack width is less than 100μm.It is a unique type of cement mixture with composition of low volume fibers (~ 2%) so as to impart ductility, ability to repair and high tensile strength besides. It also has low maintenance and is environment friendly in nature. The ECC composition does not contain coarse aggregate because they develop larger crack width which tend to have a negative effect on ductile behavior of ECC. This paper demonstrated a detailed review on properties of ECC and experimentally identified the best ECC mix by analysing the compressive the flexural strength at different ratios: 0.5%, 1%, 1.5% and 2% of PVA fibre. Twelve cubes (150mm x 150mm x 150mm) were casted for compressive strength test and Four beams (500mm x 100mm x 100mm) were casted for flexural strength and tested at the age of 28 days.

KEYWORDS: ECC- Engineered Cementitious Composites, (PVA) Polyvinyl Alcohole Fibre, Flexural Strength, Compressive strength

1. INTRODUCTION

Engineered Cementitious Composite (ECC) is a highly ductile composite having crack control property. It has excellent mechanical properties. It is said to have higher durability than normal conventional concrete. It is composed of cement, fine aggregate, fiber and chemical admixture. Here coarse aggregate is not used to reduce the crack propagation. ECC exhibits strain hardening property when compared to other fiber reinforced concrete.

The development of ECC is said to have high impact in construction industry since it imparts more useful properties compared to other reinforced concrete. ECC uses only two percentage by volume of fiber. The major component of ECC is cement and hence it results in more cost of production. To overcome this some supplements like fly ash, silica fume ash, blast furnace slag, etc. are used as replacement of cement up to a limit.

In this work, an experimental investigation is carried out to find the best ECC mix. 24 ECC mixes are developed by adopting some guidelines and the best among them is chosen by conducting tests. The best ECC mix is compared with M25 mix. The test procedure includes preliminary test on all materials, slump test on M25 mix, flow table test on ECC mixes, split tensile strength test on all mixes, compressive test on cubes and flexural test on beams.

2. MATERIALS

The material used in this work includes cement, M-sand, Coarse aggregate, PVA fiber, super plasticizer, flyash and water.

2.1. Cement

The cement used in this study is OPC 53 grade. The properties of cement found by conducting preliminary test are as shown below:

Table -1: Properties of cement

Properties	Result
Fineness of cement	1.66%
Normal Consistency	32%
Specific gravity	3.15
Initial setting time	More than 1 hour

Fig -1: OPC Cement

Fig- 2: Specific gravity test on cement

2.2. M-sand

M-sand is used as fine aggregate. The physical properties of M-sand obtained by conducting test are tabulated below:

Fig – 3: M-Sand

Table - 2: Properties of M-sand

Properties	Result
Zone	Zone 2
Bulk density	1.65
Void ratio	0.44
Porosity	0.30
Specific gravity	2.42

2.3. Coarse Aggregate

Crushed granite rock is used as coarse aggregate. The properties of coarse aggregate are as shown below:

Table – 3: Properties of Coarse Aggregate

Properties	**Result**
Maximum size of aggregate	20 mm
Bulk density	1.69
Void ratio	0.81
porosity	0.56
Specific gravity	2.89

Fig -4: Coarse Aggregate

2.4. PVA fiber

The fiber used for making ECC in this work is Poly-vinyl alcohol. PVA Fibers (polyvinyl alcohol) are high-performance reinforcement fibres for concrete and mortar. PVA fibres are well-suited for a wide variety of applications because of their superior crack-fighting properties, high modulus of elasticity, excellent tensile and molecular bond strength, and high resistance to alkali, UV, chemicals, fatigue and abrasion. PVA fibres are unique in their ability to create a molecular

bond with mortar and concrete that is 300% greater than other fibres. The main purpose of PVA fiber is cement mortar insulating mortar putty powder. PVA fiber improves the cracking resistance of mortar, proof permeability of mortar, shock resistance seismic capacity.

The properties of PVA fiber is given below:

Table – 4: Properties of PVA fiber (The Yarn Guru India)

Technical Parameter	
Material	100% PVA
Fibre Type	Bunchy Monofilaments
Density	1.29
Formula	（CH2CHOH)n
Titer	1.80-2.40 Dtex
Dry breaking tenacity	≥11.50 cN/dtex≥
Dry breaking elongation	4.0-9.0 %（L/L）
Initial modulus	280 cN/dtex ≥
Specification	6MM, 12MM
Hot water resistance	2.0 % ≤
Olil agent content	0.2 % ≤

Fig-5: PVA fiber

3. MIX DESIGN

M25 mix design was done using IS 10262:2009 and IS 456:2000.The mix ratio was found to be 1:1.7:3.2:0.5 (cement: fine aggregate: coarse aggregate: water-cement ratio). For ECC, 24 mixes were proportioned. Superplasticizer dosage adopted was 0.2 L/100 Kg of binder (cement+flyash). Absolute volume method was used to calculate quantity of each material in ECC.

The mixes are designed using certain limits. The volume of fiber in ECC mixes is limited to 2% of total volume of mix. Many researches work shows that best result is achieved when flyash constitute 30-70 % volume of binder (cement+flyash).

Table – 5: Mix proportioning of ECC

ECC Mix Design for 1m3(35.3147 ft3)							
Mix proportion	Cement (kg)	Fly Ash (kg)	Sand (kg)	Water (kg)	HRWR (kg)	PVA (kg)	PVA (%)
M1	393	865	457	311	5	6.5	0.5
M2	393	865	457	311	5	13	1
M3	393	865	457	311	5	19.5	1.5
M4	393	865	457	311	5	26	2

4. TEST RESULT

4.1 Compressive strength Test

Compressive strength is measured using compression testing machine and the maximum compressive load a material can bear before fracture was measured. In this study, cube of size 150 mm×150mm×150mm were used. The specimen is placed in the machine and load was applied. The maximum load at which specimen fails is noted. The maximum load divided by the original area of the specimen gives the compressive strength. Compressive strength of the cube was evaluated after 7days and 28 days and the obtained compressive strength value of ECC mix is shown in Table 6.3.
Compressive strength is calculated by the following formula:

$$F=\frac{P}{A} \tag{1}$$

P = Maximum load in N applied to the specimen
A = Area of a cross section in mm2

Fig-6: Compression testing on cube

Table 6: Compressive Strength

S.No	Reference code	Specimen	Compressive strength 7 days N/mm2	Compressive strength 28 days N/mm2
1	M1	Mix 1	13.8	23.4
2	M2		14.2	23.6
3	M3		13.6	23.4
4	M4	Mix 2	15.4	26.4
5	M5		15.8	26.2
6	M6		15.6	26.2
7	M7	Mix 3	20.6	34.6
8	M8		21.2	34.6
9	M9		20.8	34.4
10	M10	Mix 4	21.6	36.2
11	M11		21.8	36.4
12	M12		21.6	36.6

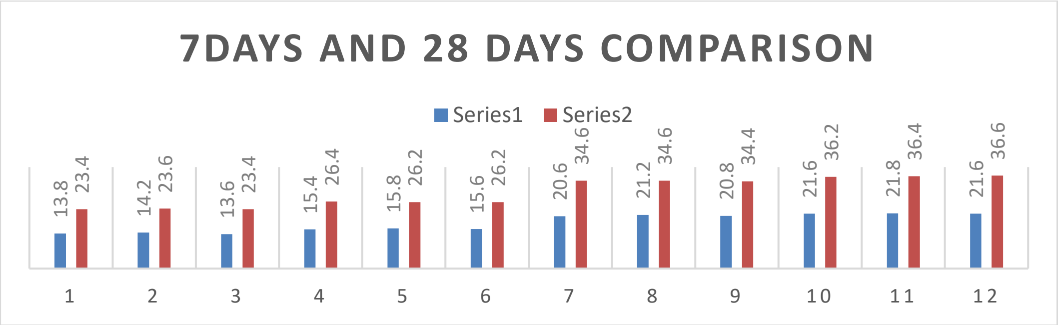

Fig-7: Comparison of 7&28 Days Strength

4.2. Split tensile strength Test

Three cylinders of each mix are casted and cured. After 28-day curing, split tensile test is conducted on them using Compression testing machine.

Fig-8: Casted cylinder

Fig-9: Split tensile test on cylinder

Table – 7: Average split tensile strength value

Mix Designation	Average Split Tensile Strength N/mm2
M1	4.25
M2	4.32
M3	4.76
M4	5.23

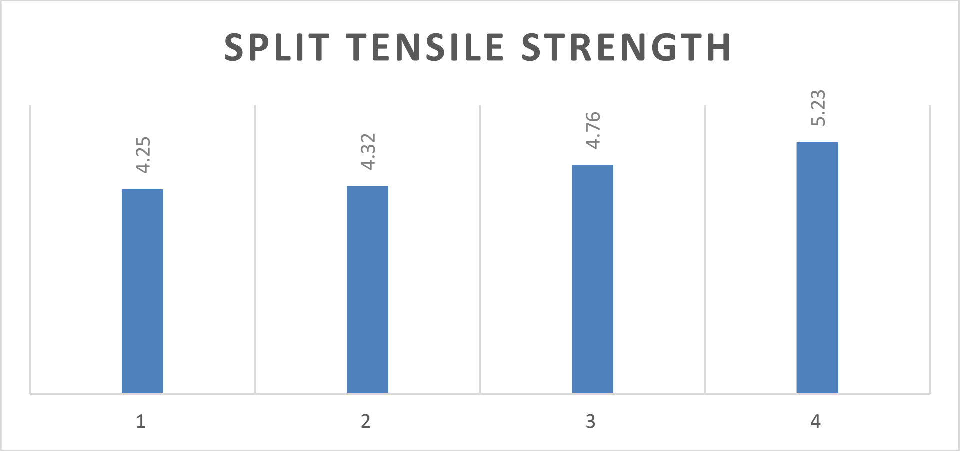

Fig-10: 28 Days Split tensile Strength

4.3. Flexural strength Test

Flexural strength is measured using a flexural testing machine and it is shown in Fig. 6.8. Beam specimen of 500mm×100mm×100mm was used for the study. The bed of testing machine must be provided with two rollers, and all rollers shall be mounted in such a way that the load is applied axially without any torsional stresses or restraints. Flexural strength of the beam was evaluated after 28 days and the obtained values are shown in Table 6.5. Flexural strength of beams can be calculated by:

$$f = \frac{PL}{bd^2} \quad (2)$$

where,

P = Maximum load in N applied to the specimen L = Length of the specimen in mm
d = Depth measured in mm of the specimen at the point of failure. b = Breadth of specimen in mm

Fig-11: Flexural strength test

Table – 8: Flexural Strength

S.No	Mix	Flexural Strength (Mpa)
1	M1	5.4
2	M2	6.2
3	M3	7.4
4	M4	8.2

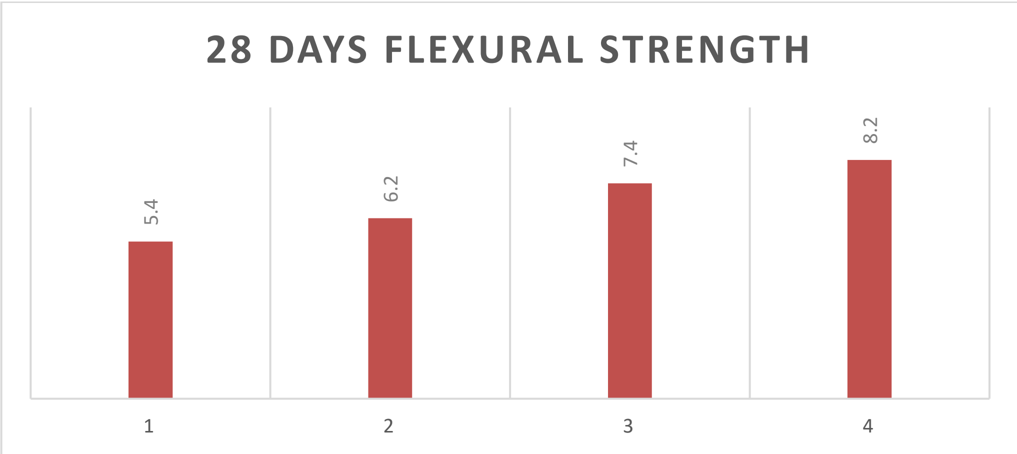

Fig-12: 28 Days Flexural Strength

5. CONCLUSIONS

This paper experimentally analysed the compressive and flexural strength of ECC with 0.5%, 1%, 1.5% and 2% of PVA at 28 days of curing. Conclusion can be drawn as follows:

1. The compressive strength and flexural strength of ECC was found to be high with ECC mix of 1.5% of PVA content and hence chosen to be the best ECC mix.
2. ECC have good workability and lies between the standard values of concrete. The value slump was increased without changing water/cement ratio because of superplasticizer (High Reducing Water Reducing agent)
3. The ECC specimen beams produced greater flexural strength than what would be normally produced by conventional concrete beams.
4. The ECC specimen cubes produced slightly lesser compressive strength than that which would have been produced by conventional concrete.
5. ECC technology focuses more on increasing the flexural strength of the concrete and does not significantly increase the compressive strength of the concrete.

The contrivance of ECC emphasis civil engineers to provide a safer, lighter, more durable, economic and sustainable construction environment for society. ECC also have self-healing and self-consolidating properties. The results from life cycle assessment modelling confirmed that the use of ECC technology leads to a reduction of carbon and energy footprints of constructed facilities. The various investigations are done by several engineers for further development of Engineered Cementitious Composite (ECC) and its applications in the real field proves to be one of the best alternative and sustainable concrete materials of the future decades.

REFERENCES

1. Adeyemi Adesina, and Sreekanta Das (2020) Evaluation of the Durability Properties of Engineered Cementitious Composites Incorporating Recycled Concrete as Aggregate. DOI: 10.1061/(ASCE) MT.1943-5533.0003563.
2. Fathumathul Anasi K, Sankaranarayanan. K. M (2020) Experimental Investigation on Engineered Cementitious Composite (ECC). International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 05
3. Jiangtao Yu, Jianhui Lin, Zhigang Zhang, Victor C. Li (2015) Mechanical performance of ECC with high-volume fly ash after sub-elevated temperatures. Construction and Building Materials: volume 99(2015)82-89.
4. Michael D. Lepech, Victor C. Li, Richard E. Robertson, and Gregory A. Keoleian(2008) Design of Green Engineered Cementitious Composites for Improved Sustainability. ACI Materials Journal Title no. 105-M64
5. Munshi GalibMuktadir, M I Fahim Alam, Asifur Rahman, Mohammad Robiul Haque (2020) Comparison of Compressive Strength and Flexural Capacity between Engineered Cementitious Composites (Bendable Concrete) and Conventional Concrete used in Bangladesh. Journal of materials and engineering structures 7 (2020) 73–82)
6. Sagar Gadhiya(2015) Parametric Study on Flexural Strength of ECC. International Journal for Scientific Research & Development Vol. 3, Issue 04, 2015
7. Sallal R. Abid, Mohammed S. Shamkhi, Noor S. Mahdi, Yasir H. Daek (2018) Hydro abrasive resistance of engineered cementitious composites with PP and PVA fibers. Construction and Building Materials 187 (2018) 168–177
8. Victor Li, Hezhi Liu, Qian Zhang, Huaizhi Su, Chongshi Gu (2017) Durability study on engineered cementitious composites (ECC) under sulfate and chloride environment. Construction and Building Materials 133 (2017) 171–181
9. Wu C, Li VC (2016) THERMAL-MECHANICAL behaviors of CFRP-ECC hybrid under elevated temperatures. doi:10.1016/j.compositesb.2016.11.037.
10. Zhigang Zhang, Yuanzhao Ding, Shunzhi Qian (2018) Influence of bacterial incorporation on mechanical properties of engineered cementitious composites (ECC). Construction and Building Materials 196 (2019) 195–203