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Experimental Investigation on Engineered Cementitious Composite (ECC)

Fathumathul Anasi K[1], Sankaranarayanan. K. M[2]

[1]*M.Tech. Student, Structural Engineering, SIMAT, Kerala Technological University, Kerala, India*
[2]*Assistant Professor, Dept. Of Civil Engineering, SIMAT, Kerala Technological University, Kerala, India*

Abstract – *Engineered Cementitious Composite (ECC) is newly developed composite which shows high durability, tensile strength, strain hardening and crack control properties. This paper is an experimental investigation on finding out the best ECC mix among twenty four developed mixes and comparing its properties in terms of tensile strength, compressive strength and flexural strength with M25 concrete mix. The test result shows that the best ECC mix chosen from twenty four mixes shows high tensile strength and flexural strength than M25 concrete mix and compressive strength of about 25 N/mm^2.*

Key Words: **Engineered cementitious composites (ECC), Ductility, Crack control, Durability, Tensile strength, Compressive strength, Flexural strength, Flow table test, slump test**.

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:

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

Fig – 3: M-Sand

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 % ≤
Oli agent content	0.2 % ≤

Fig-5: PVA fiber

2.5 Super plasticizer

The super plasticizer used for water reduction is poly carboxylate ether. It is High Strength, High Water Reducing; High Retention PCE for making Polycarboxylate based Admixture. HI- PCE HR50 is a Polycarboxylate ether for making polycarboxylate based superplasticizers has excellent water reduction, good flow-ability and High retardation. It shows high efficiency at low dosage rates. It is designed as 50% solid contents for the economical transportation cost saving. Uses of this admixture include high fluidity at low water levels, retain the slump longer time, excellent water reducing by dispersing effect, low stickiness concrete. Advantages of this admixture include high compressive strength by low w/c ratio, Cost effective, Self compacting (SCC) concrete ,Applicable for Pre-cast concrete, Higher durability, Silica Fume concrete and Cohesive and Monolithic concrete. HI-PCE HR 50 has a recommended dosage range of 0.25 ~ 0.9 litres/100 kgs of binders on a basis of undiluted solution. It is well soluble in water. The optimum dosage of HI-PCE HR 50 may depend on specific requirements of concrete properties and materials.

So, it is determined by trials using the materials and conditions.

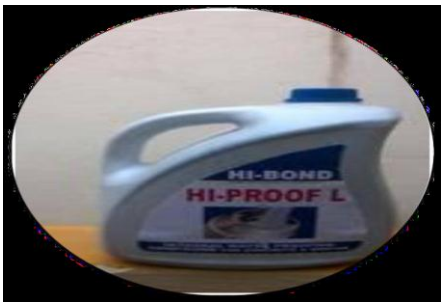

Fig -6: HI- PCE HR50

Table – 5: Properties of HI- PCE HR50

Color	Pale Color
Form	Liquid
Odor	Characteristic
Total Solid Contents	50%
Specific gravity	1.10-1.12@25°C
pH Value	5.0 - 7.5
Chloride	Nil

2.6 Flyash

Class C flyash is used for making ECC. The specific gravity of flyash was found out to be 2.33.

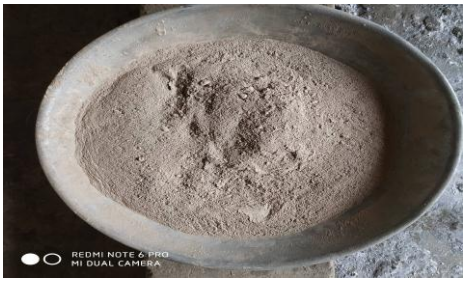

Fig – 7: Class C Flyash

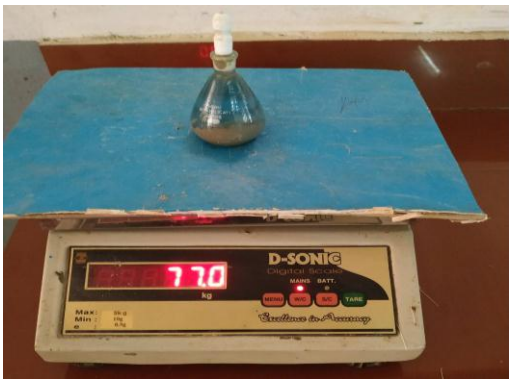

Fig – 8: Specific gravity test on flyash

2.7 Water

Water is one of the most important elements in construction and is required for preparation of mortar, mixing of cement concrete and for curing work etc. The quality of water used has a direct impact on the strength of the mortar and cement concrete in the construction work. The water used for curing and mixing must be free from high quantities of alkali, acid, oils, salt, sugar, organic materials.

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 – 6: ECC mixes

Designation	Cement	Sand	flyash	Fiber (% volume of mix)
E1	1	1	0	0.5
E2	1	1	0	1
E3	1	1	0	1.5
E4	1	1	0	2
E5	1	1	0.5	0.5
E6	1	1	0.5	1
E7	1	1	0.5	1.5
E8	1	1	0.5	2
E9	1	1	1	0.5
E10	1	1	1	1
E11	1	1	1	1.5
E12	1	1	1	2
E13	1	1	1.5	0.5
E14	1	1	1.5	1
E15	1	1	1.5	1.5
E16	1	1	1.5	2

E17	1	1	2	0.5
E18	1	1	2	1
E19	1	1	2	1.5
E20	1	1	2	2
E21	1	1	2.5	0.5
E22	1	1	2.5	1
E23	1	1	2.5	1.5
E24	1	1	2.5	2

4. EXPERIMENTAL WORK

Slump test was conducted to find the water-cement ratio for M25 concrete mix. Flow table test was conducted for ECC mixes.

3 cubes and 3 cylinders were casted for M25 mix, cured and tested. And also 3 beams of M25 mix singly reinforced with 2 reinforcing bars of 4mm diameter was casted, cured and tested.

3 cylinders for each ECC mix was casted, cured for 28 days and tested. Among the mixes, 3 mixes which shows high split tensile strength was chosen and 3 cubes of each mix was casted to find out the compressive strength.

The best ECC mix having the high tensile strength and compressive strength was chosen and 3 ECC beam of that mix singly reinforced with 2 reinforcing bars of 4mm diameter was casted.

5. RESULTS AND DISCUSSION

5.1 Fresh mix test

Slump test was conducted for M25 mix and 100 mm slump was observed for 0.5 water-cement ratio.

Fig-9: Slump of concrete

Flow table test was done for ECC mixes using flow table.

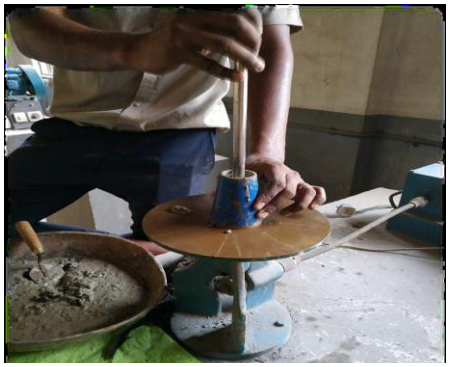

Fig-10: Compacting the mould

Fig -11: Flow table test conducted on ECC mix

The result obtained in conducting flow table test is tabulated below:

Table -7: Flow percentage of various ECC mixes

Mix Designation	Flow Percentage (%)
E1	143
E2	121.5
E3	117
E4	115.3
E5	109.2
E6	123.07
E7	110.76
E8	98.46
E9	130.76
E10	115.3
E11	130.76
E12	112.3
E13	146.15
E14	123.07
E15	130.76
E16	145
E17	132
E18	146.15
E19	149.2
E20	131.6
E21	142
E22	112.30
E23	104.6
E24	126

All the ECC mixes showed flow percentage in between standard value 0- 150 %. Here the flow percentage ranges from 98 % to 149 %.

5.2 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-12: Casted cylinders

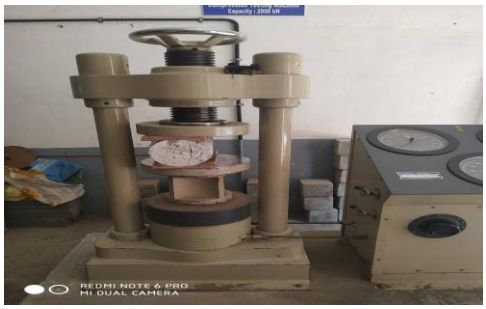

Fig-13: Split Tensile Test on cylinders

The average split tensile strength of M25 and ECC mixes are tabulated below:

Table – 8: Average Split tensile strength value of all mixes

Mix Designation	Average Split Tensile Strength N/mm^2
M25	3.68
E1	5.44
E2	5.58
E3	5.52
E4	5.38
E5	5.38
E6	5.51
E7	5.23
E8	5.16
E9	5.80
E10	5.94
E11	5.09
E12	4.95
E13	5.37
E14	5.65
E15	4.81
E16	4.67
E17	4.10
E18	3.96
E19	3.82
E20	3.68
E21	3.60
E22	3.53
E23	3.39
E24	3.25

The best mixes chosen among the 24 ECC mixes are E9, E10 and E14.

5.3 Compressive strength test

3 cubes of each mix namely M25, E9, E10 and E14 for 7 day and 28 day compressive test is casted. Compressive test is conducted in Compression testing machine.

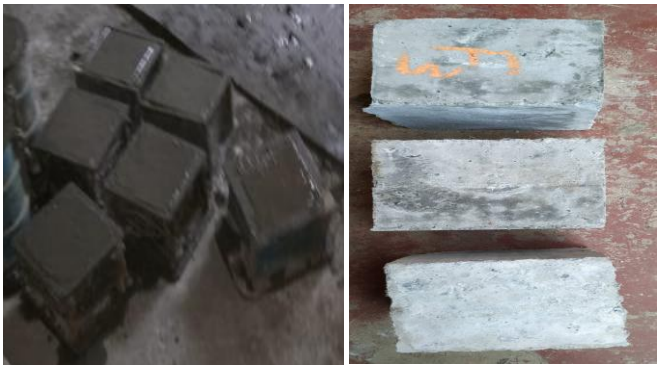

Fig- 14: Casted cubes

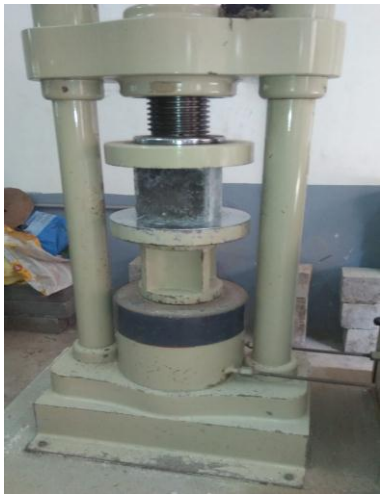

Fig -15: Compression testing on cube

Table-9: Average compressive strength of cubes

Mix Designation	Average Compressive Strength N/mm^2	
	7 Day	28 Day
M25	20	32.88
E9	15.33	25.11
E10	16.88	25.55
E14	16	25.33

From the result, it is seen that ECC mixes achieved compressive strength above 25 N/mm^2 after 28 days curing. The best mix of ECC chosen is E10.

5.4 Flexural Strength

3 beams of each M25 mix and E10 mix is casted and cured for 28 days. Flexural strength of beams was tested under two-point loading method using Universal Testing Machine (UTM).

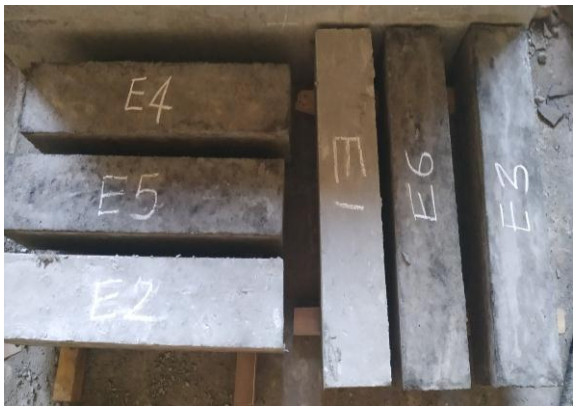

Fig-16: Casted beams

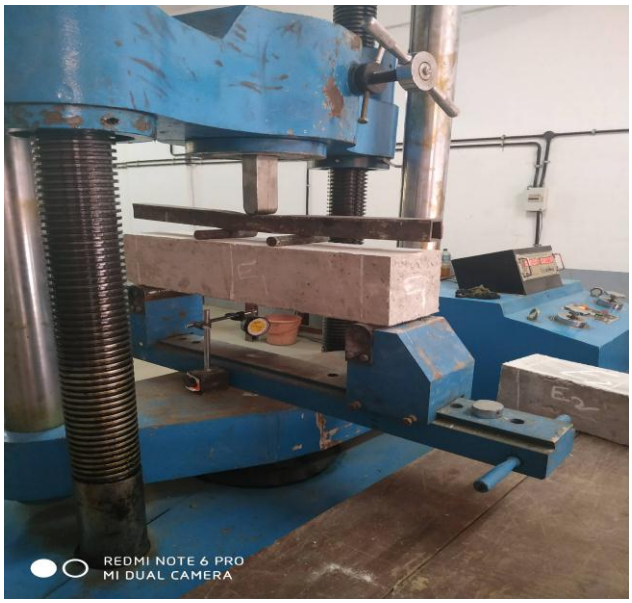

Fig-17: Two point load flexural strength testing method

Table-10: Average Flexural strength value of beams

Mix Designation	Average Flexural Strength N/mm^2
M25	9.505
E10	10.057

From the test result it is found that flexural strength of E10 is more than M25.

6. CONCLUSION

The experimental investigation is mainly conducted to find the best ECC mix. The following conclusions are drawn from this:

- Most of the ECC mixes showed high tensile strength than M25 mix.
- All the ECC mixes showed good workability and flow percentage lied in between standard value.
- E9, E10 and E14 cubes showed compressive strength more than 25 N/mm^2.
- From split tensile strength value and compressive strength value E10 (1:1:1 PVA fiber 1%) is chosen as the best mix
- Flexural strength of E10 is greater than M25.

The best mix E10 can be used as a replacement for M25 in places where tensile strength and flexural strength are more important. ECC can also be provided as a bottom reinforcement cover in M25 beams due to its high tensile property. It can also be used in retrofit and repair works of concrete.

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REFERENCES

[1] Ammapalayam Ramasamy Krishnaraja and Shanmughasundaram Kandasamy, "Flexural Performance of Hybrid Engineered Cementitious Composite Layered Reinforced Concrete Beams", Periodica Polytechnica, Civil Engineering, 62(4), pp. 921–929, 2018.

[2] Parul Khaped, Prof. Jignesh Solanki and Prof. M A Jamnu, "Experimental Study on Strength of Engineered Cementitious Composite Prepared By Using Alccofine and Fly Ash", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 6 ,Issue X, Oct 2018.

[3] S.Ooviya, S.Vaishalani, D.Nethra and S.Karuppasamy, "Experimental Study on Flexible Concrete", International Journal for Research in Applied Science & Engineering Technology (IJRASET**),** Volume 6, Issue IV, April 2018.

[4] Yanhua Guan, Huaqiang Yuan, Zhi Ge , Yongjie Huang, Shuai Li, and Renjuan Sun, "Flexural Properties of ECC-Concrete Composite Beam", Hindawi, Advances in Civil Engineering, Volume 2018, Article ID 3138759, 7 pages.