Determination of Relationship between Mechanical Properties of Engineered Cementitious Composites

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Abstract

This paper investigates the relationship between compressive strength and mechanical properties of M35 and M40 grade engineered cementitious composite (ECC) with recron and multifilament polypropylene fiber. It also investigates the durability property of M40 grade conventional concrete and ECC. Different grades of ECC with recron fiber give higher compressive strength, tensile strength, flexural strength and modulus of elasticity compared to conventional concrete and ECC with polypropelene fiber. The replacement of recron fiber by polypropylene fiber reduced the strength of ECC.
Keywords: *Recron fibre, polypropylene fibre, strength test, Durability test.*

1. Introduction

Concrete is one of the most widely used construction materials in the world. Due to its high compressive strength, cracks originate and evolve in concrete structures subjected to in-service loading situations because of its low tensile resistance.
Engineered Cementitious Composite is a type of ductile fibre reinforced cementitious composites. ECC is also known as bendable concrete, is an easily molded mortar-based composite reinforced with specially selected short random fibres, usually polymer fibres. ECC has higher tensile strain capacity as compared to other fibre reinforced concrete. Under loading conventional concrete subjected to brittle failure. But in the case of ECC, it shows ductile behaviour. It is developed for the applications in the large material volume usage, cost sensitive construction industry [1]. In this paper two types of fibres are used in ECC such as recron and multifilament polypropylene fibre to check the effect of replacement of rercon fibre by multifilament polypropylene fibre.

2. Objectives

1. To compare the properties of M40 grade ECC with same grade of conventional concrete.
2. To determine the effect of replacement of recron fibre in ECC with polypropylene fibre.
3. To obtain the relationship between the compressive strength and other mechanical properties of ECC.
4. To check the durability property of ECC

3. Materials Used

3.1. Cement

The cement used for the experiment is Ordinary Portland cement (OPC - 53 grade). Specific gravity of cement used is found to be 3.12 and Standard consistency of cement used is found to be 33%.

3.2. Fine Aggregate

Natural river sand is used as the fine aggregate. Fineness modulus of sand used is found to be 1.53 and Specific gravity of fine aggregate used is found to be 2.63.

3.3. Coarse Aggregate

Coarse aggregate used for this study was collected from a local quarry. Fineness modulus of coarse aggregate used is found to be 3.43and Specific gravity of coarse aggregate used is found to be 2.73.

3.4. Superplasticizer

Superplasticizer used in this study was BASF-Master Glenium Sky 8233. It helps to produce high

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performance concrete with longer workability retention, and high early strength.

3.5. Fly Ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash [2]. The glassy silica and alumina of class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds.

3.6. Recron Fibre

Table 1: Properties of Recron fibre

Properties	Value
Chemical composition	Modified polyester
Cross section	Triangular
Diameter	30-40 micron
Cut Length	12 mm
Elongation	>100%
Melting point	240 – 260 ^{0}C
Specific gravity	1.34-1.40 cc/g

3.7. Multifilament Polypropylene Fibre

Polypropylene is a synthetic hydrocarbon polymer. It will helps in significant reduction of plastic shrinkage cracking and minimizing of thermal cracking.

3.8. Water

Water needed for the study was for the production of concrete and for curing. Potable water is used for the study.

4. Mix Design

The mix design for M40 grade conventional concrete is carried out as per IS 10262:2009. Mix proportions for M40 grade conventional concrete is tabulated in Table 2. Mix proportions for M35 and M40 grade ECC is tabulated in Table 3. The nomenclatures used in this study are given in Table 4.

Table 2: Mix Proportions for M40 Conventional Concrete

Materials	Cement	Fine Aggregate	Coarse Aggregate	water
Weight (kg/m^3)	350	858.09	1133.64	140

The mix for M35 and M40 grade ECC was selected after referring previous journal paper [2] [3]

Table 3: Mix Proportion of ECC

Mix	Cement	Fly ash	Sand	Water	Super plasticizer	Fibre
M35	1	1.2	0.8	0.56	0.012	0.02
M40	1	1	0.44	1	0.019	0.04

Table 4: Nomenclatures used for different mixes

Mix ID	Description
CC40	M40 Mix Conventional Concrete
ECC40/R	M40 ECC with Recron fibre
ECC40/PP	M40 ECC with Multifilament Polypropylene fibre
ECC35/R	M35 ECC with Recron fibre
ECC35/PP	M35 ECC with Multifilament Polypropylene fibre

5. Results and Discussions

5.1 Compressive Strength

Table 5: Compressive Strength

Specimen	Compressive Strength at 7 day (N/mm^2)	Compressive Strength at 28 day (N/mm^2)
CC40	32.19	41.9
ECC40/R	23.28	42.6
ECC40/PP	21.8	39.6
ECC35/R	14.89	39.29
ECC35/PP	12.73	33.9

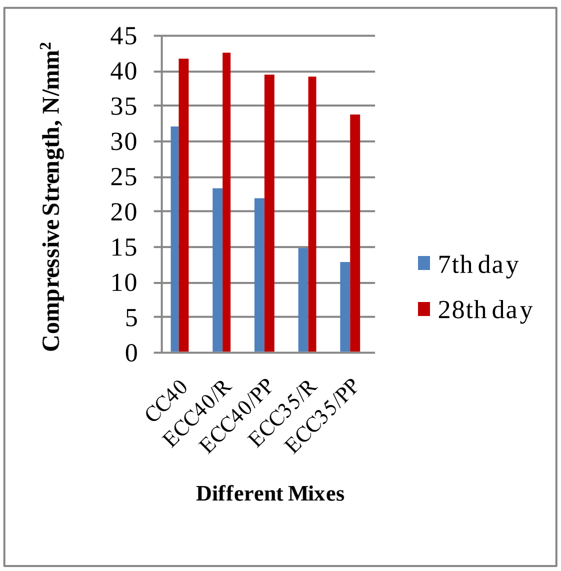

Fig .1 Compressive strength Vs Age of the specimen

It is observed that the percentage increase in compressive strength with age is more for ECC as compared to conventional concrete. The compressive strength of ECC40/R is higher as compared with CC40.The achievement of strength after 7 days of curing is higher for conventional concrete than ECC. The replacement of recron fibre in ECC with polypropylene fibre decreases the compressive strength.

5.2 Split Tensile Strength

Table 6: Split Tensile Strength

Mix	Split tensile strength (N/mm^2)
CC40	4.52
ECC40/R	4.62
ECC40/PP	4.48
ECC35/R	4.38
ECC35/PP	4.26

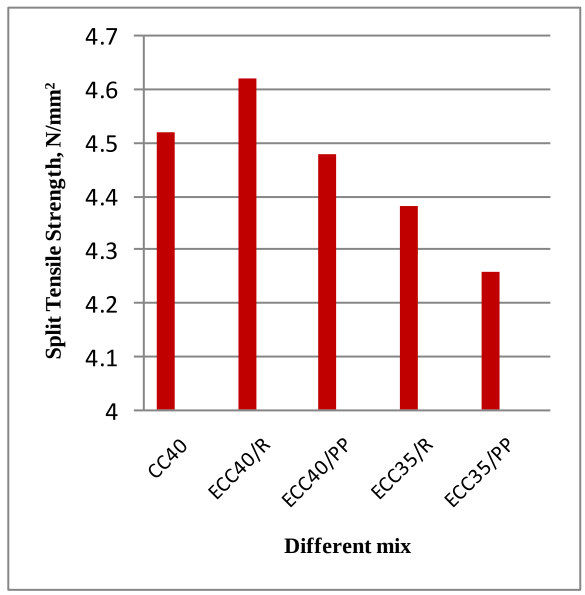

Fig .2 split tensile strength Vs Age of the specimen

As the compressive strength, split tensile strength also increases and the split tensile strength of ECC is found to be comparable with conventional concrete. But the value is slightly lower for ECC with polypropylene fibres. The split tensile strength of ECC40/R is higher as compared with CC40.

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5.3 Relation between split tensile strength and compressive strength

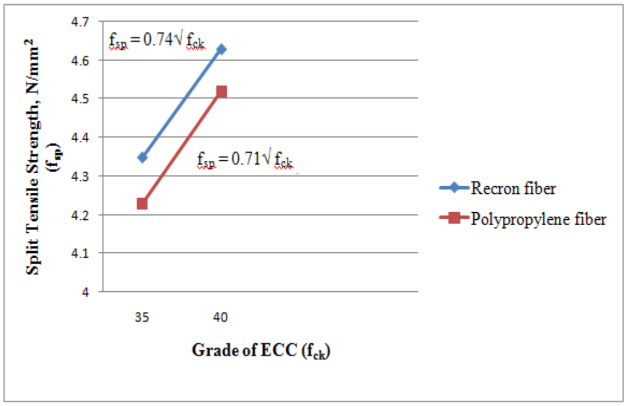

Fig. 3 Relation between split tensile strength and compressive strength

From the figure 3 the relation between characteristic compressive strength and splitting tensile strength of concrete is obtained as

For ECC/R $f_{sp} = 0.74\sqrt{f_{ck}}$
For ECC/PP $f_{sp} = 0.71\sqrt{f_{ck}}$

So it can be concluded that the equation for split tensile strength proposed by IS 456; 2000 can also be used for calculating the split tensile strength of ECC.

5.4 Flexural Strength

Table 7: Flexural Strength

Mix	Flexural strength (N/mm^2)
CC40	4.6
ECC40/R	8
ECC40/PP	7
ECC35/R	5.6
ECC35/PP	4.9

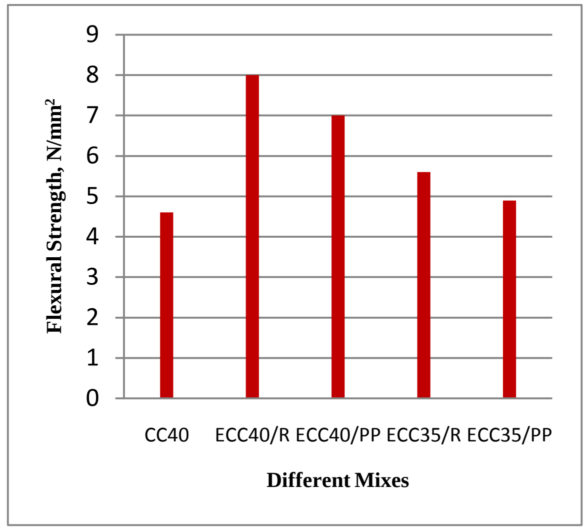

Fig 4. flexural strength Vs Age of the specimen

Flexural strength of ECC with recron fibre is found to be 1.7 times higher than that of normal concrete for M40 mix. But the value is slightly lesser for ECC with polypropylene compared to ECC with recron fibre. It is also found that the flexural strength of M35 ECC with recron and polypropylene fibres are higher than that of M40 grade conventional concrete.

5.5 Relation between flexural strength and compressive strength

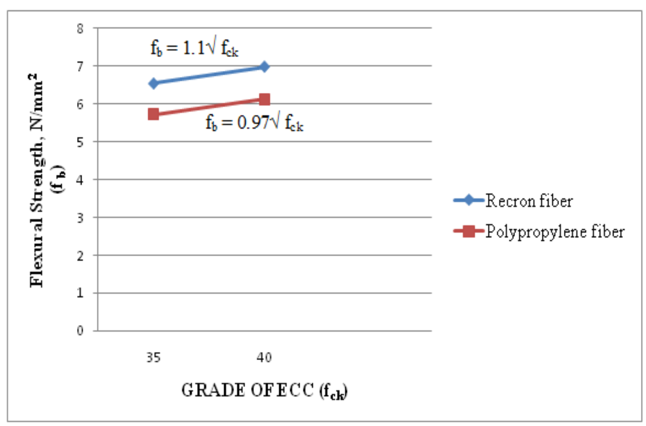

Fig. 5 Relation between flexural strength and compressive strength

From the figure 5 the relation between flexural strength and characteristic compressive strength of concrete is obtained as

For ECC/R $f_b = 1.1\sqrt{f_{ck}}$
For ECC/PP $f_b = 0.97\sqrt{f_{ck}}$

So it can be concluded that the equation for flexural strength proposed by IS 456; 2000 is not applicable in the case of ECC. Due to the presence of fibre as an ingredient, ECC shows higher flexural strength, but the value is relatively lower for ECC/PP compared to ECC/R.

5.6 Modulus of Elasticity

Table 8: Modulus of elasticity of different mixes

Mix	Modulus of Elasticity (N/mm^2)
CC40	37000
ECC40/R	39486.28
ECC40/PP	36950.64
ECC35/R	34288.54
ECC35/PP	32148.45

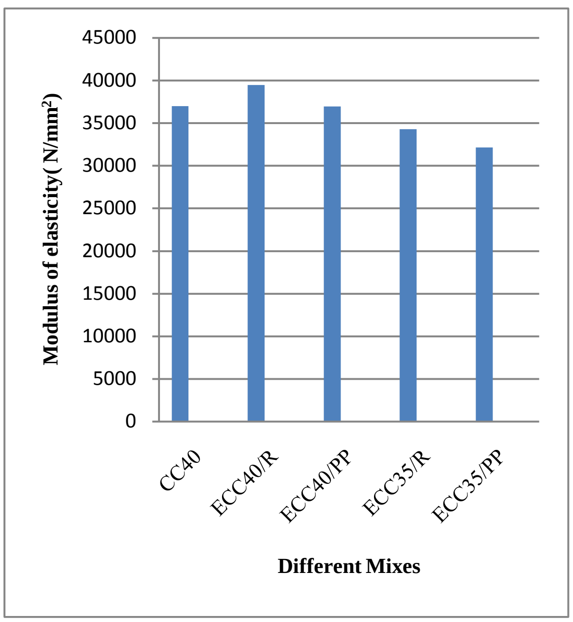

Fig 6 Modulus of Elasticity Vs Age of the specimen

The modulus of elasticity of ECC is also comparable with conventional concrete of same grade.

5.7 Relation between Modulus of elasticity and compressive strength

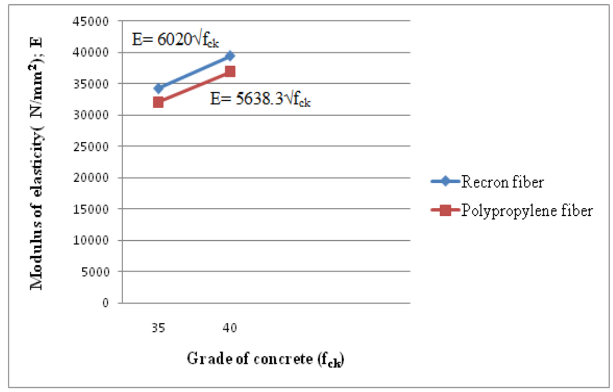

Fig. 7 Relation between modulus of elasticity and compressive strength

So it can be concluded that the equation for Modulus of Elasticity proposed by IS 456; 2000 cannot be used for calculating the Modulus of Elasticity of ECC.

5.8 Durability Property of Concrete - Water Absorption Test

The water absorption test results of CC, M40 Recron ECC and M40 Polypropylene ECC are presented in Table.

Table 9: Water absorption of different mixes

Mix	Water Absorption (%)
CC40	2.65
M40ECC/R	2.5
M40ECC/PP	2.53

Water absorption of ECC is lower than that of conventional concrete of same grade .This may be due to the presence of flyash as constituent in ECC which reduces the pore size in the concrete.

6. Conclusions

1. M40 grade ECC has higher compressive strength, tensile strength, flexural strength as compared with M40 grade conventional concrete.
2. Compressive strength, tensile strength, flexural strength of ECC reduced when recron fibre is replaced with polypropylene fibre.

3. Some equations are proposed for the mechanical properties of ECC in terms of compressive strength.

4. Water absorption of ECC is lower than that of conventional concrete of same grade. This may be due to the presence of flyash as constituent in ECC which reduces the pore size in the concrete.

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