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BEHAVIOUR OF HYBRID FIBRE ENGINEERED CEMENTITIOUS COMPOSITES

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Abstract: ECC is a family of High performance, fibre reinforced composite that have the benefits of concrete such as compressive strength but eliminate a key failure mode for concrete i.e its brittleness. Unlike conventional concrete, ECC has fibre, mineral admixture and chemical admixtures along with the basic constituents (i.e) cement, fine aggregate and water. No coarse aggregate is used in ECC, to avoid brittle failure. PVA fibres are known for their low modulus of elasticity, ductility, tensile strength and bonding strength, whereas, Steel fibre increases the flexural, impact and fatigue strength of composite. Hence a combination of these two fibres is used in this work. Flyash is a material that was proved to be a good replacement for cement, from the previous studies. It occupies the void space in the matrix which would otherwise be occupied by water. GGBS consists of silicates and aluminates of calcium and it can be used as a good substitute material for cement. These two mineral admixtures (Flyash, GGBS) are used for the experimental studies. In this research, series of investigations were carried out to employ hybrid ductile fibres (PVA and steel fibres) in ECC with high volume of mineral admixture (flyash) which replaces cement. The amount of mineral admixtures is again replaced by 10%, 20%, 30% and 40% of GGBS and the performance of the resulting composite is studied.
Keywords: ECC, PVA fibre, Steel fibre.

INTRODUCTION

Concrete is made up of coarse and fine aggregate with a binding material. Cement mixed with water creates a fine paste which has hydration process so it acts as binding material and finally rigid structure is made. Concrete is one of the manmade materials which have highest usage in the world due to its durable building material property. To overcome the disadvantages of concrete, fibres are introduced to the concrete namely Fibre reinforced concrete. A fibre is a small discrete reinforcing material produced from various materials like steel, plastic, glass, carbon and natural materials in various shapes and size. Depending upon the type of fibres used in the concrete, the property of concrete is also varied. To increase the tensile strength of concrete higher tensile strength reinforcement is used. Reinforcements are generally designed in the place where the tensile stress in concrete creates cracking.

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Reinforced concrete is capable to carry the compressive strength as well as bending to some extend. Further development of concrete leads to composite materials. Composite material is made up of two or more different materials with their specific properties. For example concrete has brittle nature and steel reinforcement has ductile nature by combining these materials to form single structure that has both properties. Thus a composite meets requirements what we design for it. Engineered cementitious composite usually called as ECC is a ductile fibre reinforced cementitious mortar composite. The material constituents are similar to fibre reinforced concrete. Cement, water, fine aggregate, fibre, mineral admixtures and chemical admixtures are used. Fracture mechanics and micromechanics principle are used to design the ECC to attain it's unique property of strain hardening. But the materials, mixing procedure and placing are similar to conventional concrete. Fibre used must be less than 2% by its volume.

MATERIALS AND EXPERIMENTAL PROGRAM

I Materials

To develop ECC it is essential to select suitable materials and their properties, proportion, mixing and curing. The materials used in ECC are cement, fine aggregate, short discontinuous fibers, water, mineral admixture and chemical admixture. Material used in this investigation were cement, fine aggregate, fly ash, Ground granulated blast furnace slag (GGBS), water, super plasticizer, steel fiber, polyvinyl alcohol fiber (PVA).

II Mix design

The mix design for ECC Concrete is basically based on Micromechanics design. Micromechanics are a branch of mechanics applied at the material constituent level that captures the mechanical interactions among the fiber, mortar matrix, and fiber–matrix interface. Matrix heterogeneities in ECC, including defects, sand particles, cement grains, and mineral admixture particles. To design a new class of ECCs we use a matrix incorporating suitable aggregates that will result in higher elastic modulus while maintaining the desirable feature of strain hardening. First the effect of matrix mechanical properties on composite properties is reviewed from the micromechanical viewpoint with regard to conditions of composite pseudo-strain-hardening.

III Mix proportions

The micromechanics based mix design requires pull test to be carried on the PVA fibers, which is not possible in the laboratory. The mix proportion shown in table 2.1 is taken as reference proportion

Table 2.1. Reference Mix Proportions

Cement	**Mineral admixture**	**Fine aggregate**	**Water – cement ratio**	**Super plasticizer**	**Fiber (by volume)**
1	1.2	0.8	0.56	0.013	1.5

For experimental investigation the following trial mix proportion is used as shown in table 2.2.

Table 2.2. Trial mix proportions

NAME	***CEMENT (kg/m³)***	***MINERAL ADMIXTURE***		***FA (kg/m³)***	***WATER (lit/m³)***	***SP (lit/m³)***	***FIBER (kg/m³)***	
		FLY ASH	***GGBS***				***PVA***	***SE***
R0	381.6	890.4	-	462	319	7.51	13	39
R10	381.6	763.2	127.2	462	319	7.51	13	39
R20	381.6	636	254.4	462	319	7.51	13	39
R30	381.6	508.8	381.6	462	319	7.51	13	39
R40	381.6	381.6	508.8	462	3199	7.51	13	39

Note:

R0 = 70% replacement of flyash + 0% replacement of GGBS
R10 = 60% replacement of fly ash + 10% replacement of GGBS
R20 = 50% replacement of fly ash + 20% replacement of GGBS
R30 = 40% replacement of fly ash + 30% replacement of GGBS
R40 = 50% replacement of fly ash + 40% replacement of GGBS

IV Mixing , Casting of Beam and companion specimens

Hand mixing was adopted. Initially sand, cement, half percentage of fly ash, half quantity of water and super plasticizer were mixed. Then slowly remaining quantity of fly ash, water and super plasticizer were added. Once the homogenous mixture is formed, fibers added slowly. To study the flexural behaviour of the hybrid fibre ECC, beam specimens were cast. The beam cross section and reinforcement details are shown in figure 2.1.

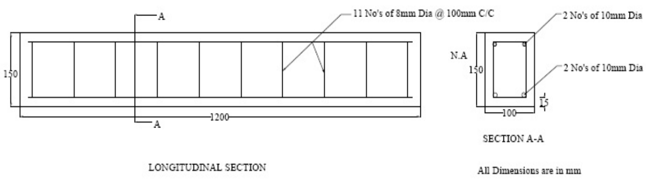

Figure 2.1 Beam Specifications

Figure 2.2 Beam specimen

VI .Tests on hardened ECC

1. Compressive Strength Test

For cube compression testing of concrete, cubes of size (75 x 75 x 75 mm)were used. All the cubes were tested in saturated condition, after wiping out the surface moisture. For each mix combination, three cubes were tested at the age of 7 days and 28 days of curing. The procedure for test, apparatus required and loading condition was followed as per IS 516: 1959.Figure 2.5 shows the specimen tested in compression testing machine.

Figure 2.3 Compressive strength test

2. Split Tensile Strength Test

Split tensile strength test is an indirect test to determine the tensile strength of cylindrical specimens. Splitting tensile strength tests were carried out on cylindrical specimens of size 150 mm diameter and 300 mm length at the age of 28 days curing. The load was applied gradually till the specimens split and readings were noted. The procedure for test, apparatus required and loading condition was followed as per IS 516: 1959.Figure 2.6 shows specimen tested for split tensile strength.

Figure 2.4 Split tensile strength test

3. Flexural Strength Test

The steel moulds of size 100 mm x 100 mm x 500 mm were used for casting the beam specimens. The procedure for test, apparatus required and loading condition was followed as per IS 516: 1959.

Results and discussion

I. Compressive strength test

The tests were conducted on the cube specimens after 7 and 28 days curing. Figure 3.1 shows the comparison of average compressive strength of various trial mix proportions. From the graph it was clear that R30 replacement mix as optimum point regarding compressive strength. R0, R10, R20, R30 test results shows gradual increase in strength.

II Split Tensile Strength Test

The tests were conducted for the cylinder specimens after 7 and 28 days curing. Figure 3.2 shows the comparison of average split tensile strength of various trial mix proportions. Both 7 days and 28 days test results explains that the variation increased in steady state manner.

III Flexural Strength Test

The flexural strength test was conducted on the prism specimens after 7 and 28 days curing. Figure 3.3 shows the comparison of average flexural strength of various trial mix proportions.

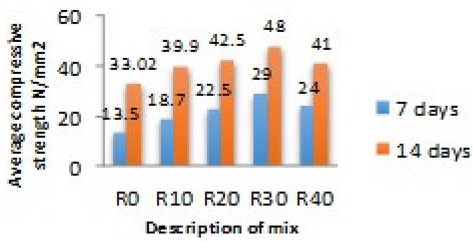

Figure 3.1 Compressive strength at different replacement levels

Figure 3.2 Split tensile strength at different replacement levels

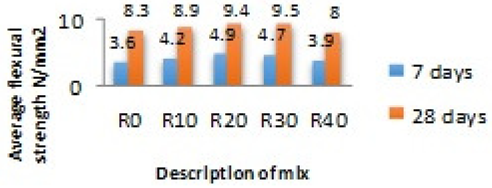

Figure 3.3 Flexural strength at different replacement levels

CONCLUSION

An experimental investigation was carried out on the replacement of cement by admixture of flyash and GGBS to check the properties of ECC. 70% of the total cementitious content is replaced by mineral admixture (flyash) and further flyash is replaced by GGBS. Further to analyse the composite behaviour 0.5% of steel fibre and 1% of PVA fibre were additionally added to the matrix. The following conclusions were drawn from the experimental work.

- The mixture used here achieved the requirements to be satisfied for ECC. Usage of steel fibres increased the strength properties whereas PVA fibre increased the micro cracking mechanism and also increased the flexural strength.
- Anyways, the quantity of total fibre used here is only 1.5% of total volume of the matrix and hence the cost incurred for fibre is comparatively low than HPFRCC.
- Increasing the percentage of GGBS results in an increase of mechanical properties (i.e) compressive strength, flexural strength and split tensile strength.
- Compressive strength increases by 45.4%, split tensile strength increases by 50% and flexural strength increases by 14.5%.
- GGBS when added separately has no impact on the strength properties but when combined with PVA, it shows good improvement in the strength. This is due to the formation of a chemical bond between them which enhances the strength of ECC.

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