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AN EXPERIMENTAL STUDY ON MAKING BRITTLE CONCRETE TO BENDABLE CONCRETE BY ADDITION OF FIBRES IN OPTIMUM

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Abstract

Bendable concrete also known as Engineered Cementitious Composites abbreviated as ECC is class of ultra-ductile fiber reinforced cementitious composites,characterized by high ductility and tight crack width control. This material is capable to exhibit considerably enhanced flexibility. An ECC has a strain capacity of more than 3% and thus acts more like a ductile metal rather than like a brittle glass. A bendable concrete is reinforced with micromechanically designed polymer fibers. In this paper literature survey of fresh and mechanical properties of different ECC mixtures are evaluated by incorporating supplementary cementitious material

Keywords: ECC mixtures, bendable Concrete.

1. Introduction

Traditional concrete has a lot of issues. For instance, it cracks readily. These are very brittle and inflexible, practically unbendable, and only have a 0.1 percent strain capacity. Modern methods must be used in order to prevent such issues. Engineered Cementitious Composites is one such method. The term "engineered cementitious composites" (ECC) also refers to concrete that is flexible. Engineered cementitious composites are made to provide a robust and adaptable material that may be utilized in a variety of situations where fiber reinforced concrete would not be appropriate. An ECC behaves more like a ductile metal since it has a strain capacity more than 3 percent. Comparing this material to traditional concrete, it may demonstrate much more flexibility.

In order to impart superior workability, High-Range Water Reducing Agent (HRWRA) is added to traditional concrete's basic materials for making ECC. However, ECCs don't employ coarse aggregates, hence mortar is used instead of concrete in these structures. The amount of powder in ECC is comparatively considerable. To improve the paste content, cementitious materials such as fly ash, silica fume, blast furnace slag, silica fume, etc. may be added to cement. Additionally, ECC employs short, discontinuous fibers in small quantities, generally 2% by volume. ECC contains very fine Polyvinyl fibers and silica sand that is coated with a thin (nanometer-thick) slippery layer. The surface layer prevents the fibers from breaking by allowing them to start sliding when they are overloaded. It stops the fiber from rupturing, which would cause significant cracking. As a result, an ECC deforms much more than regular concrete without cracking.

The many components of ECC cooperate to share applied load. ECC has shown to be 40 times lighter and 50 times more flexible than conventional concrete, which may have an impact on skyscraper design decisions. Additionally, ECC is particularly ideal for crucial components in seismic zones due to its superior energy absorption qualities.

Contrary to conventional fiber reinforced concrete, ECC is a class of materials with micromechanical design. A cementitious material may be referred to be an ECC as long as it was created using the principles of fracture mechanics and micromechanics. As a result, ECC is not a set material design but rather a wide spectrum of subjects in various levels of development, study, and implementation. The family of ECC materials is growing.

The same basic components as conventional concrete are used to make bendable concrete (ECC), but a high-range water reduction (HRWR) agent is added to improve workability. Fine aggregates, cement, and fiber make up the majority of the constituents in ECC. To boost the paste content, cementitious substances such fly ash, silica fumes, blast furnace slag, etc. may be used. The amount of powder in ECC is comparatively considerable. Additionally, ECC employs short discontinuous fibers in small quantities, generally 2% by volume. ECC has nanometrically thin (nanometrically thick) coatings of polyvinyl alcohol and ultrafine silica sand. This surface layer prevents the fibers from breaking by allowing them to start sliding when they are overloaded. ECC combines many components to shear the given stress. ECC has shown to be 40 times lighter and 50 times more flexible than conventional concrete, which may have an impact on skyscraper design decisions. Additionally, ECC is particularly ideal for crucial components in seismic zones due to its high energy absorption capabilities.

1.1 Problem Statement:
Conventional concretes are very inflexible and brittle with a strain capacity of just 0.1 percent, making them practically impossible to bend. This material's inability to bend is a crucial factor in failure when under stress.

1.2 Objectives of the study

1) Design of bendable concrete.
2) Analyze various strength parameters of bendable concrete such as flexural strength and compressive strength.
3) Compare normal and bendable concrete on the basis of strength parameter

1.3 Materials

1. Cement
2. Fine aggregate
3. Polypropylene fiber
4. PCE admixture (Poly Carboxylate Ether)
5. Water

1.3.1 CEMENT

In the present study Ordinary Portland Cement (OPC) 53 grade was used.

Table-1 Physical Properties of Cement

S.N0	Physical Property	Test Result
1	Standard Consistency	30.00%
2	Fineness	5.00%

3	Special Gravity	3.08
4	Initial Setting time	28 min

1.3.2 FINE AGGREGATE:

Sand from a nearby river that met IS: 383-1970 standards was utilized. At the location, the sand was screened to eliminate harmful substances.

Table-2 Physical Properties of Fine aggregate

Physical Properties	Value
Fineness Modulus	2.5
Water Absorption	0.8%
Specific Gravity	2.61
Bulk Density	1610 kg/m^3

1.3.3 Polypropylene fiber

85% propylene is converted into 100% synthetic polypropylene, a fabric. Propylene serves as the monomer in polypropylene. Petroleum produces polypropylene as a byproduct. It has crystalline and non-crystalline areas and is a thermoplastic. Although it is a little stronger and more heat resistant than polyethylene, it has qualities that are comparable. It is a white, strong mechanical substance with a high level of chemical resistance. The second-most-produced plastic, polypropylene is often used in packaging and labeling.

Table 3 Physical Properties of Polypropylene fiber

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Tensile strength (MPa)	50-600
Elongation (%)	40-100
Abrasion resistance	Good
Moisture absorption (%)	0-0.05
Softening point(^{o} C)	140
Melting point (^{o} C)	165
Chemical resistance	Generally excellent
Relative density	0.91
Thermal conductivity	6.0(with air as 1.0)
Electric insulation	Excellent

Fig. 1 Polypropylene fiber

1.3.4 PCE admixture (Poly Carboxylate Ether)

Modern concrete needs this high range water lowering additive to improve flowability at relatively low w/c ratios. It has been a crucial element in a variety of concrete types, including fiber-reinforced, self-consolidating, and high performance. It contains comb copolymers with a non-adsorbing side chain and an adsorbing backbone. This is done to enhance the rheological qualities of newly-poured concrete. Super plasticizers are additives that are added to new concrete to assist disperse the mix's components evenly and improve workability. Superplasticizer reduces the water required by 15 to 30 percent while increasing slump characteristics from 5 cm to 30 cm without the use of water. This leads to an increase in crucial characteristics including density, water tightness, and workability, which are necessary for and eliminate the need for compaction.

2. Review of Literature

Albert et al. (2014) carried conducted an experimental investigation on polyolefin fiber-reinforced concrete that had a small amount of steel-hooked fibers added. On the basis of the same self-compacting concrete that was built as a reference, four varieties of conventional fiber reinforced concrete using steel and polyolefin fibers were created. These concrete combinations were created individually, and two further hybrid mixtures were created using the same fiber ingredients. In addition to fresh and mechanical characteristics, fracture properties were evaluated. With a mix of hooked steel fibers and macro polyolefin fibers, the results showed that it is feasible to create a hybrid fiber reinforced self-compacting concrete while maintaining the high-performance fresh qualities while meeting the most common self-compacting criteria. Adding fibers did not significantly alter the reference SCC's compressive strength, indirect tensile strength, or modulus of elasticity for any of the quantities, varieties, or combinations of fibers utilized.

Jun Zhang et al. (2013) conducted an experimental study on the potential applications of the fiber-reinforced engineered cementitious composite (LSECC) with low drying shrinkage characteristics in concrete pavements with the goal of removing joints that are typically used to account for temperature and shrinkage deformation. It was discovered that a composite slab made of plain concrete and LSECC may have tensile fractures localized inside the LSECC strip rather than the surrounding concrete slab by using steel bars at the LSECC/concrete interface and tailored building techniques. Using reinforcing bars across the interfaces solved the important issue of interfacial failure in composite slabs. The total strain capacity and integrity of the composite slab may be greatly increased because to the strain-hardening and high strain capacity of the LSECC. The length ratio of the LSECC strip and concrete slab may be properly chosen to account for temperature and shrinkage deformations.

Soutsos et al. (2012) conducted an experimental investigation using synthetic fibers and steel that are readily accessible in commerce. Flexural strength, toughness, equivalent flexural strength, and equivalent flexural strength ratio have all been calculated using correlations between flexural stress and deflection. Steel and synthetic fibers were shown to significantly boost the flexural toughness of concrete. Equal amounts of various fibers did not, however, produce specimens with the same flexural toughness. The flexural behavior of self-compacting concrete reinforced with straight and hooked end steel fibers at values of 0.5%, 1.0%, and 1.5% was examined experimentally by Pajak and Ponikiewski (2013) and compared to normally vibrated concrete (NVC). The results of the lab tests were established in accordance with the advice of RILEM TC 162-TDF. The flexural behavior of SCC seemed similar to that of NCV, where a rise in the pre peak and post peak parameters of SCC was caused by an increase in the fiber volume ratio. However, the kind of steel fibers greatly affects this dependence. However, the SCC outperforms the NVC for lesser deflections, achieving the largest crack mouth displacement.

Qian et al. (2010) conducted an experimental investigation to look into the self-healing behavior of ECC with an emphasis on how curing conditions and pre cracking time affected the results. ECC beams were pre-cracked using four-point bending tests at various ages, and then underwent several curing processes, including air curing, curing at 3% CO_2, cyclic wet/dry curing (dry at 3% CO_2 concentration), and water curing. Deflection capability after self-healing may match or even surpass that of virgin samples with almost all pre cracking ages for all curing circumstances. Even if the amount of retention reduces with an increase in pre cracking time, flexural stiffness was also

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considerably kept after self-healing compared to that from virgin samples. For samples that were pre-cracked at ages of 14 and 28, the flexural strength improves, most likely as a result of the cementitious materials' ongoing hydration. Additionally, using nano clay as dispersed internal water reservoirs to encourage self-healing behavior inside ECC without depending on an external water source appeared promising.

3. Research Methodology

Creation of ECC using the right ratio of the elements. Micromechanics design principles serve as the foundation for the mix design for ECC Concrete. The mechanical interactions between the fiber, mortar matrix, and fiber-matrix interface are captured by the branch of mechanics known as micromechanics, which is used at the material component level. A nanometer-scale surface coating may be present on fibers, which are typically millimeters in length and tens of microns in diameter. Defects, sand particles, cement grains, and mineral admixture particles are examples of matrix heterogeneities in ECC, and their sizes vary from micro to millimeter scale. The pull test on the PP fibers is necessary for the micromechanics-based mix design, however this cannot be done in a lab. Therefore, the appropriate mix ratio specified in the ECC literature. Below is a list of the optimal Mix percentage that was used as a guide. The concrete mix design for ECC is based on M25 with no coarse aggregate. On the basis of various fiber percentages, various concrete mixtures are created. 350 kg of cement, 2015 kg of fine aggregate, 2.8 kilogram of additives, and 0.4 w/c ratio for one cubic meter of concrete make up the design mix for our concrete. Based on the amount of cement used, the fiber is collected. To the cement used for mixing, we added fiber in increments of 0%, 1%, 2%, and 3% to complete the job. Several tests were conducted in order to achieve workability. Three cubes and three beams were cast for each experimental mix, cured in the curing tank, and tested to meet the appropriate strength requirements.

Table-4-Mix proportion

CEMENT (kg/m3)	SAND (kg/m3)	ADMIXTURE (kg/m3)	WATER/CEMENT RATIO
350	2015	2.8	0.4

Table-5-Fiber used in samples

FIBER Used				
In percentage	0%	1%	2%	3%

4. Results and Discussion

4.1 Compressive Strength:

The compressive strength of the concrete cubes of fiber 0%, 1%, 2%, 3% for 7, 14, 28days were tested and listed below:

Table-6-Compressive strength of the cubes

PERCENTAGE OF FIBER	**COMPRESSIVE STRENGTH OF CUBES**		
	FOR 7 DAYS	FOR 14 DAYS	FOR 28 DAYS
0%	13.32	19.14	25.22
1%	12.97	18.54	25.87
2%	14.44	19.88	27.49
3%	14.53	20.22	27.84

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4.2-Flexural Strength Of Beams:

The flexural strength of the concrete beams of fiber 0%, 1%, 2%, 3% for 7, 14, 28 days were tested and listed below:

Table-7-Flexural strength of beams

PERCENTA GEOF FIBER	FLEXURAL STRENGTH OF BEAMS		
	FOR 7 DAYS	FOR 14 DAYS	FOR 28 DAYS
0%	2.05	2.30	2.90
1%	2.24	2.96	3.85
2%	3.67	4.40	5.06
3%	4.01	5.20	5.90

4.3- Comparative Study:

Table-8-Comparative study of normal and bendable concrete

S. No	PARTICULAR	NORMAL CONCRETE	BENDABLE CONCRETE
1	Self-Weight	High	40% lighter
2	Cracking Resistance	Less	High
3	Cement Usage	Less	High
4	Coarse Aggregate	Present	Absent
5	Nature	Brittle	Ductile
6	Compressive Strength	Moderate	High
7	Flexural Strength	Moderate	High

4.4 Field Applications

Numerous extensive applications in Japan, Korea, Switzerland, Australia, and the US employ ECC. These consist of:

1. In 2003, the Mitaka Dam in the vicinity of Hiroshima was renovated utilizing ECC. The 60-year-old dam's surface was significantly harmed; there were signs of fissures, spalling, and minor water leaking. ECC was sprayed over the 600 m2 surface in a 20 mm thick layer.

2. Using ECC, a retaining wall made of earth was restored in Gifu, Japan, in 2003. Because of how badly the previous building had cracked, conventional concrete could not have been utilized to prevent reflected cracking. ECC was designed to reduce this risk, and after a year, only little fractures of bearable width were found.

3. To reduce earthquake damage, the 95 m (312 ft) Glorio Roppongi high-rise residential building in Tokyo has a total of 54 ECC connection beams (two per floor). When compared to traditional concrete, ECC has better earthquake resistant capabilities because of its high damage tolerance, high energy absorption, and capacity to flex under shear. The Nabeaure Yokohama Tower, which has 41 stories and four connecting beams each level, has similar structures.

4. In a similar vein, a 225-mm thick ECC bridge deck on Michigan's Interstate 94 was finished in 2005. Material delivery on-site in common mixing trucks totaled 30 m3. This deck also required less material than a suggested deck built of standard concrete because of the special mechanical qualities of ECC. University of Michigan as well as the Michigan Department of Transportation has been keeping an eye on the bridge for the last four years in an effort to confirm the ECC's purportedly enhanced endurance.

5. CONCLUSION

This work has investigated experimentally how newly built fiber reinforced engineered cementitious concrete (ECC) differs from traditional or conventional concrete in terms of its mechanical qualities. In this project, bendable concrete and conventional concrete were prepared and analyzed. It has been discovered that the ECC has much better compressive strength and flexural strength than conventional concrete. The sole ingredients of flexible concrete are cement, sand, fiber, water, and additive. By forming a strong link with the components, the fibers added to the concrete will raise its strength characteristics. Then, in order to demonstrate the differences in the strength characteristics, a comparison study was conducted between conventional concrete and bendable concrete.

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