



Performance And Strength Characteristics Of Engineered Cementitious Composites

¹Mr.V.Arivu Thiravida Selvan, ²A.Naveen, ³M.Rakshana

¹Assistant Professor, ²UG Student, ³UG Student

¹Department of Civil Engineering,

¹Jai Shriram Engineering College (Autonomous), Tirupur, India.

Abstract: Today's construction industry views Engineered Cementitious Composites (ECC) as a novel and significant material. Because of their exceptional mechanical qualities (compressive strength between 35 and 100 MPa and typical tensile strength between 2 and 7 MPa), ECC materials are employed in structural design, repairs, and retrofitting. The current work examines the impact strength, direct tensile testing, and compressive strength of engineered cementitious composites (ECCs) that contain fibers. To this end, three more schemes the 2%, 2.5%, and 3% Polypropylene fiber, the 5%, 6.5%, 8%, and 10% Metakaolin, and the 12% Silica grid are employed in this ECC study. Cube and cylindrical specimen testing The test subjects, who are 14 and 28 days old, are evaluated for their respective split tensile strength and compressive strength. To assess the ultimate tension test, a dog-bone-shaped specimen is also put through 28 days of testing. The impact resistance of the first fracture is further increased by the presence of silica grid, metakaolin, and polypropylene fiber. In addition, the failure strength of mixtures containing fiber is improved by 35 to 90% when compared to mixtures without fiber.

Index Terms – ECC, Polypropylene fiber, Metakaolin, Silica grid, compressive strength, split tensile strength.

I. INTRODUCTION

ECC lies in its exceptional tensile ductility, meaning it can deform significantly before failure without sudden, catastrophic cracking. This special quality is made possible by the fibers' bridging action, which more evenly distributes stresses and stops cracks in the concrete from spreading. With its exceptional inherent tensile ductility and moderate fiber content, Engineered Cementitious Composites (ECC) stand out among other HPRCC materials. The hardening tendency of ECC under tensile strain is similar to that of ductile metals. ECC has a fracture toughness comparable to that of aluminum alloys and a tensile strain capacity several hundred times greater than that of regular concrete. Because traditional reinforced concrete (R/C) structures typically experience brittle failure and a loss of structural integrity under extreme loads, the high tensile ductility and toughness of ECC material significantly improve the mechanical performance of reinforced ECC (R/ECC) structures.

Engineered Cementitious, or ECC, is a term used in civil engineering. It is a particular kind of concrete material with improved tensile strength, durability, and ductility. To increase the performance and resistance to cracking of the concrete mixture, ECC adds fine fibers, usually based on polymers. A cutting-edge class of concrete materials called Engineered Cementitious Composites (ECC) was created to solve some of the drawbacks of conventional concrete. ECC incorporates a network of very fine, evenly distributed fibres, often made of materials like, polypropylene, or other polymers, into the concrete matrix.

II. MATERIALS

2.1 Metakaolin

Metakaolin fibres are produced by subjecting metakaolin, a form of processed kaolin clay, to specific treatments to create fibrous structures. The addition of metakaolin fibres to concrete or cement-based materials can improve their performance by reducing shrinkage, increasing strength, and enhancing overall durability.

2.2 Silica Grid

A byproduct of the production of silicon metal or ferrosilicon alloys is silica grid, often referred to as micro silica. This amorphous, ultra-fine silica powder is added to concrete as an additional cementitious ingredient. By lowering the porosity of the material, strengthening the link between cement particles, and filling gaps, Silica Grid improves the strength, durability, and impermeability of concrete.

2.3 Polypropylene fibre

When concrete is required, polypropylene (PP) fibers, a type of synthetic fiber, are an excellent addition to building supplies because of their unique properties. Olefin, another name for polypropylene, is a synthetic thermoplastic polymer made from natural gas and oil extraction.

2.4 Superplasticizer

A kind of chemical additive called a superplasticizer is added to concrete mixtures to lower the water content and increase workability and strength without changing the characteristics of the concrete. Concrete is ultimately more durable and performs better as a result of its capacity to become more fluid and easier to pour.

2.5 Cement

One essential component that holds concrete together is cement. Although they are categorized as adhesives, many organic compounds used for fastening or adhering materials are referred to as cement. Portland slag cement is a type of cement that is made using slag from blast furnaces. For this experiment, regular Portland cement will be utilized.

2.6 M Sand

Natural sand, also known as fine aggregate, is a collection of mineral particles that are left over after rocks break down. The size of the grains or particles is the only difference between it and gravel; organic elements are present in clay. The fineness modulus is measured by inducing fine aggregate. It is undertaken by the sieve size of 600microns is used. The stream sand with sieve is used as fine aggregate. The IS 2386(PART 1):1963 is confirmed to fine aggregate.

III. MIX PROPORTION

The foundation of the ECC concrete mix design is essentially micromechanics design. Applying mechanics at the level of material constituents, micromechanics is a discipline of study that describes the mechanical interactions between the fiber, mortar matrix, and fiber matrix interface. Fibers are typically tens of microns in diameter and millimeters in length, with the potential for nanoscale surface coatings. The size range of the matrix heterogeneities in ECC, which include flaws, sand, cement, and mineral admixture particles, is from nano to millimeter. Nevertheless, pull tests on PVA fibers are necessary for the micromechanics-based mix design, and they cannot be performed in a laboratory. Therefore, the optimal mix proportion provided in the ECC-ECC Concrete literature served as a guide for figuring out the relative amounts of the different components in the concrete. Based on earlier literature research, it was determined to replace cement with metakaolin at a rate of 5 to 10%. In addition, silica grid and polypropylene will boost the strength by roughly 3% and 12%, respectively. In order to lower the water content and improve the workability of ECC concrete, a 0.5% superplasticizer is additionally added. As tested by ASTM E617, ASTM 670, and ASTM C778 for the ECC mix percentage.

MIX	PROPORTION
M1	C+M.S+W
M2	C+M.S+W+S.P (0.5%)
M3	C+M.S+W+M (5%)
M4	C+M.S+W+M (6.5%)
M5	C+M.S+W+M (8%)
M6	C+M.S+W+M (10%)
M7	C+M.S+W+M (5%) + S.P(0.5%)
M8	C+M.S+W+M (6.5%) + S.P(0.5%)
M9	C+M.S+W+M (8%) + S.P(0.5%)
M10	C+M.S+W+M (10%) + S.P(0.5%)
M11	C+M.S+W+ Poly (2.5%) + S (12%) + S.P(0.5%)
M12	C+M.S+W+ Poly (2%) + S (12%) + S.P(0.5%)
M13	C+M.S+W+Poly (3%) + S (12%) + S.P(0.5%)

IV. DOG BONE DESK MOULD

Tension testing will be conducted using the dog bone desk specimen. Dog bone specimens were interlocked with fixtures while being held in place by hydraulic wedge clamps (see to Junhong Ye et al., 2023) for further details. This could prevent the specimen from breaking too soon. The specimen's dimensions were 330 x 60 x 13 mm for length, width, and thickness, respectively. The dog bone desk mold Autocad pictures.

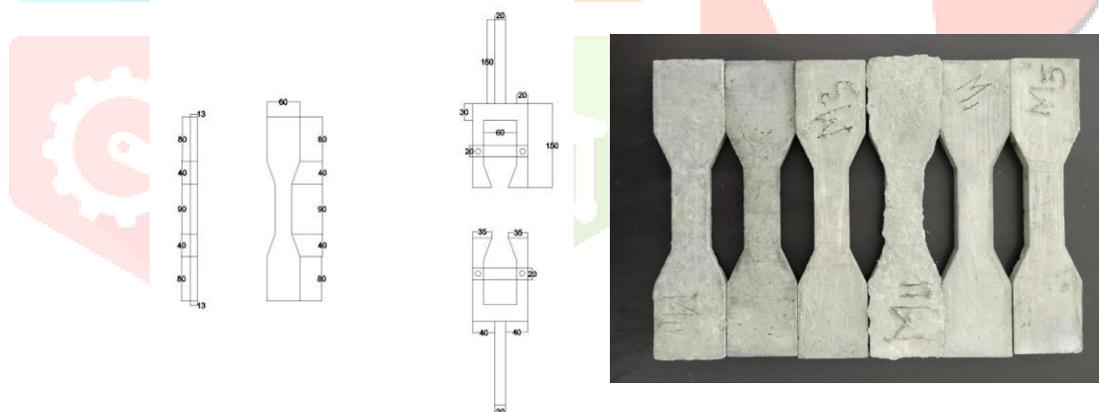


Fig. 1 Dog bone desk mould design

V. RESULTS AND DISCUSSION

4.1 Compressive strength of specimen

Concrete cubes with dimensions of 150 mm and 100 mm were used for the cube compression testing. The test was carried out in accordance with IS 516 -1959. After the specimen's surface moisture was removed, all of the cubes were evaluated in their saturated states. Once the specimen was centered within the testing apparatus, the tests were conducted at a constant stress. The ultimate cube compressive strength was equal to the ultimate load divided by the specimen's cross-sectional area.

Table 4.1: Average compressive strength 100 mm cubes

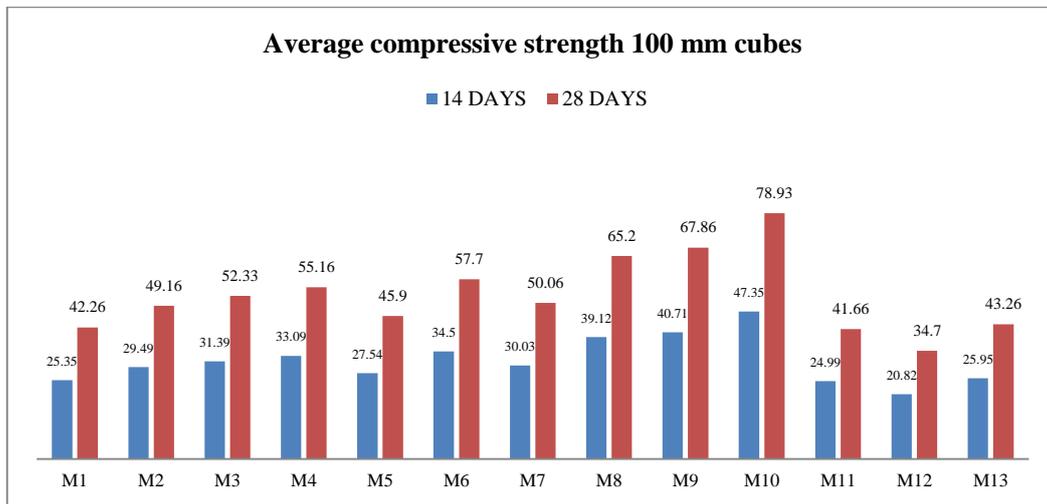
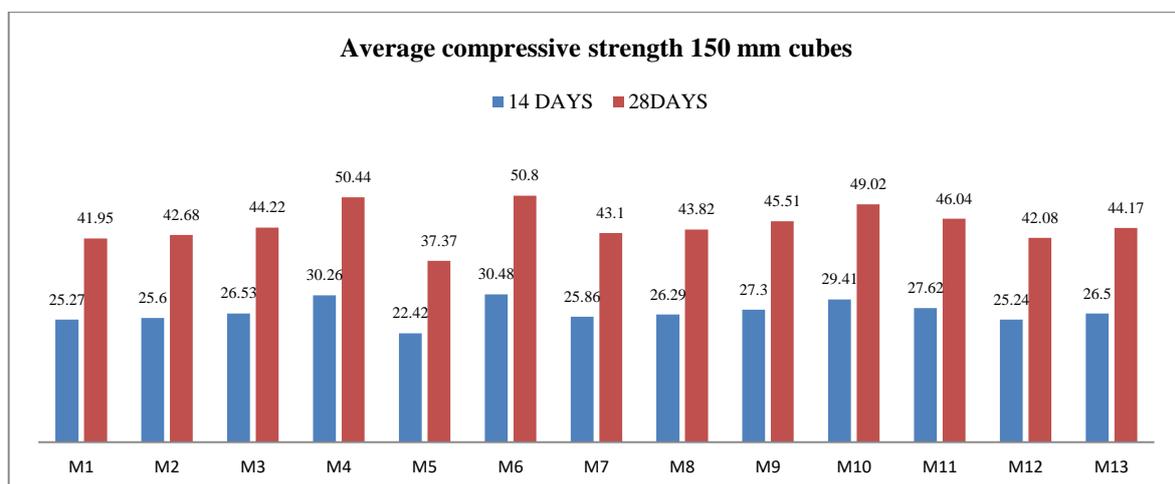


Table 4.2: Average compressive strength 150 mm cubes

Specimen ID	Average compressive strength 150mm (N/mm ²) 14 Days	Average compressive strength 150mm (N/mm ²) 28 Days
M1	25.17	41.95
M2	25.60	47.68
M3	26.53	44.22
M4	30.26	50.44
M5	22.42	37.37
M6	30.48	50.80
M7	25.86	43.10
Specimen ID	Average compressive strength 100mm (N/mm ²) 14 Days	Average compressive strength 100mm (N/mm ²) 28 Days
M8	26.29	43.82
M9	40.71	67.86
M10	47.35	78.93
M11	24.99	41.66
M12	20.82	34.70
M13	25.95	43.26
M5	27.54	45.90
M6	34.50	57.70
M7	30.03	50.06
M8	39.12	65.20
M9	40.71	67.86
M10	47.35	78.93
M11	24.99	41.66
M12	20.82	34.70
M13	25.95	43.26

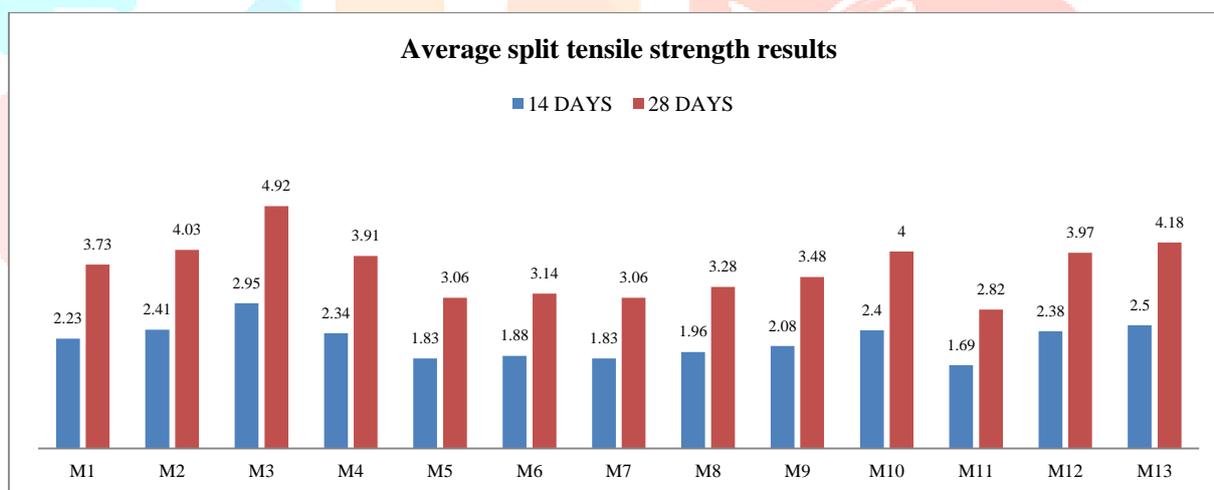


4.2 Split tensile strength test

Split tensile strength is a fundamental and significant characteristic of concrete. According to the codal clause of IS 516 -1959, the test was conducted. The 150 mm diameter and 300 mm height cylinder was used to measure split tensile strength. With the cast forces in contact with the testing machine's plates, the specimen was positioned horizontally inside the compression testing apparatus. Up until the sample fails, a constant load was applied.

Table 4.3: Average split tensile strength results

Specimen ID	Average split tensile strength (N/mm ²) 14 Days	Average split tensile strength (N/mm ²) 28 Days
M1	2.23	3.73
M2	2.41	4.04
M3	2.95	4.92
M4	2.34	3.91
M5	1.83	3.06
M6	1.88	3.14
M7	1.83	3.06
M8	1.96	3.28
M9	2.08	3.48
M10	2.40	4.00
M11	1.69	2.82
M12	2.38	3.97
M13	2.50	4.18

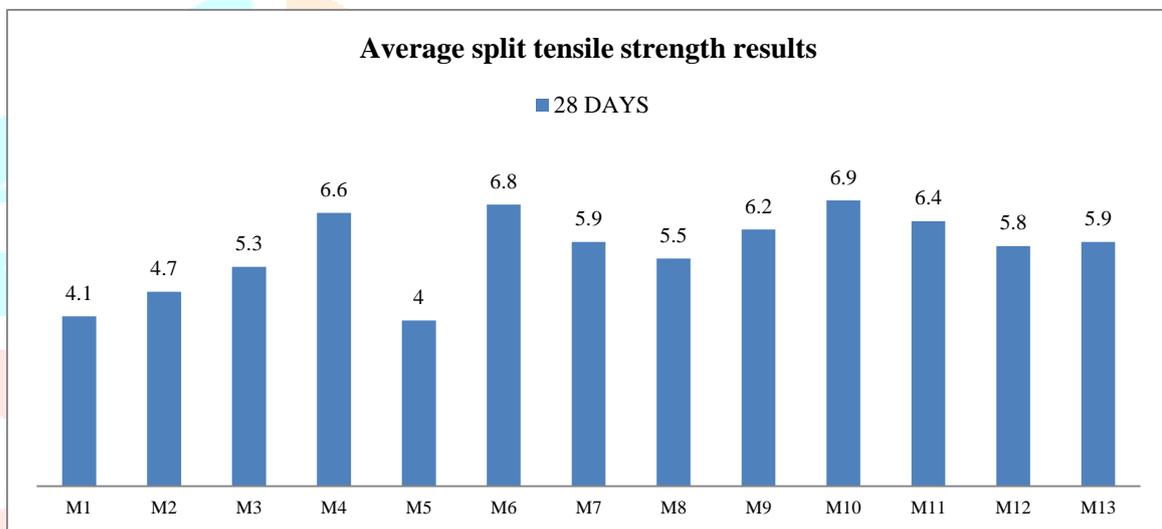


4.3 Ultimate tensile strength test

Ultimate testing is a test in which a sample is subjected to a ultimate force until failure. The ultimate force can be applied as either a tension or a compression. The force applied to the specimen during these tests is measured as a function of the distance between the testing machine's grips. One popular technique for figuring out the highest stress a material can sustain under tension is the ultimate tensile strength test. A specimen is subjected to a progressively higher load until it cracks. In order to create safe and dependable structures and components, engineers and researchers need to have a thorough understanding of the mechanical characteristics and behavior of materials under tension. This test helps with this understanding.

Table 4.4: Average split tensile strength results

Specimen ID	Average ultimate tensile strength(N/mm ²) 28 Days
M1	4.1
M2	4.7
M3	5.3
M4	6.6
M5	4.0
M6	6.8
M7	5.9
M8	5.5
M9	6.2
M10	6.9
M11	6.4
M12	5.8
M13	5.9



4.4 Water absorption test

The specimens were removed from the curing tank after 28 days of curing. For a full day, the specimens were dried. The specimens that had dried were precisely weighed and recorded as dry weight. The desiccated samples were submerged in water. After cleaning the specimen's surface with a dry cloth, the specimen's weight was recorded at pre-determined intervals. This technique was carried out for at least 48 hours, or two consecutive observations yield a constant weight. The variation in static modulus of elasticity with respect to type of concrete cubes created by using different combinations of silica grid, polypropylene, and metakaolin replacement by weight of cement is obtained and reported in Table 4.5.

Table 4.5: water absorption test results

Specimen ID	Water absorption
M1	2.35
M4	0.38
M6	0.18
M10	0.10

VI. CONCLUSION

We have performed a planned experiment and the result shows that the variation in the compressive, split tensile and ultimate tensile strength with respect to changes in the ECC. The goal of replacing cement in concrete with metakaoline and supplementing it with silica grid and polypropylene fiber is to make the concrete stronger overall. Mechanical behaviour of ECC concrete we prepared 13 mix proportions of concrete and we do the compressive, split tensile and ultimate tensile test then compared to the nominal ECC test results. When compared to regular concrete, the ECC is essentially more expensive, but it provides higher mechanical strength. In comparison to regular ECC, the proportions M4, M6, M10, and M11 provide effective strength. All 13 proportions were evaluated for compressive strength, split tensile strength, and ultimate tensile strength over 14 and 28 days. The results are presented. The ECC method is the most efficient way to build strong, low-maintenance buildings. It is utilized to build high rise buildings, military facilities, etc. In 14 days, our ECC achieves 60% strength, and in 28 days, it reaches 100% predicted strength.

REFERENCES

- [1] Adeyemi Adesina et, al. (2020). mechanical performance of engineered cementitious composites incorporating glass aggregate. *journal of cleaner production*, 0959-6526.
- [2] Adeyemi Adesina et, al. (2020). performance of engineered cementitious composites incorporating crumb rubber as aggregate. *construction and building materials* , 0950-0618.
- [3] Komeil Rahmati et, al. (2022). evaluation of engineered cementitious composites containing polyvinyl alcohol fibre under compressive direct tensile and drop-weight test. *multiscale and multidisciplinary modelling, experiments and design*, 41939-022-00135-8.
- [4] Junxia Li, et, al. (2023). Micromechanics of engineered cementitious composites (ECC): A critical review and new insights. *construction and building materials*, 129765.
- [5] Amin Al-Fakih, et, al. (2021). On rubberized engineered cementitious composites (R-ECC): A review of the constituent material. *case study in construction materials*, e00536.
- [6] IS:516-1959, 'Indian Standard Methods of Test for Strength of Concrete', 13 reprint, June 1989, Bureau of Indian Standards, New Delhi – 110 002.
- [7] IS: 2386 (Part III) – 1963 'Indian Standard Methods of Test for Aggregate for Concrete; Specific Gravity, Density, Voids, Absorption and Bulking' 8th reprint March 1997, Bureau of Indian Standards, New Delhi – 110 002.
- [8] IS: 383-1970, 'Indian Standard Specification for Coarse and Fine Aggregate from Natural Sources for Concrete' 11th reprint, September 1993, Bureau of Indian Standards, New Delhi – 110 002.
- [9] IS: 12269-1987, 'Specifications for 53-Grade Portland Cement', Bureau of Indian Standards, New Delhi, India.
- [10] IS: 456-2000, 'Indian Standard Code of Practice for Plain and Reinforced Concrete', 4th revision, Bureau of Indian Standards, New Delhi – 110 002.
- [11] Mustafa Sahmaran, Ozbay, Yucel, Lachemic and Victor C.(2012) 'Frost resistance and microstructure of Engineered Cementitious Composites: Influence of fly ash and micro poly-vinyl-alcohol fiber', *Cement & Concrete Composites of Vol. 34*, pp. 156-165.
- [12] Scott Muzenski, Flores-Vivian and Konstantin Sobolev (2015) 'Durability of super hydrophobic engineered cementitious composites', *construction and building materials of Vol.81*, pp. 291–297.