# A REVIEW ON BENDABLE CONCRETE

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***ABSTRACT: The correct decision of building materials assumes a pivotal part once arranging a structure to fall among the meanings of sustainable development. One in everything about premier normally utilized development materials is concrete. [1] Concrete is the most utilized material inside world with solid applications and expanding requests. Regardless of critical progression in concrete and cementitious materials in the course of the most recent hundreds of years, framework inbuilt the current world with these materials, similar to dams, roads, bridges, tunnels, and buildings need intensive repair and maintenance throughout its life because the brittleness of concrete rises with the increase in strength. The strain capability of typical concrete is 0.1% creating it unbendable and brittle. [23] The brittle nature of concrete may be a major explanation for failure beneath strain. Cement primarily based strain hardening ductile building material composite is termed designed cementitious composite (ECC) or flexible concrete. The strain capability of ECC varies from 3 to 8% and acts as a ductile material.[2] This paper is an attempt to outline bendable concrete, advantages, and downsides of bendable concrete and applications by literature review.***

***Key words: ECC, Bacteria, Strength, Polyvinyl alcohol (PVA), Polypropylene (PP)***

## I. INTRODUCTION

Engineered cementitious composites (ECC) have been in the beginning evolved by Li on the University of Michigan in 1993.A bendable concrete is strong with micro mechanically designed polymer fibers [3]. It's a widely familiar incontrovertible fact that the addition of very little, separate, and uniformly distributed fibers in concrete acts as a barrier to crack propagation and improves its mechanical properties. Such a range of concrete consisting of the concrete mix (cement, sand, coarse aggregates, water, and typically admixtures) containing uniformly distributed separate fibers is assumed as Fiber concrete abbreviated as FRC.

The conventional fiber-reinforced concrete is prepared by exploiting totally different material fibers, the important ones being steel, plastic, asbestos, glass, and carbon fibers. ECC is created from primary substances as concrete but, with the addition of a high-range water-reducing (HRWR) agent is needed to impart workability. However, coarse aggregates are not used in ECCs.

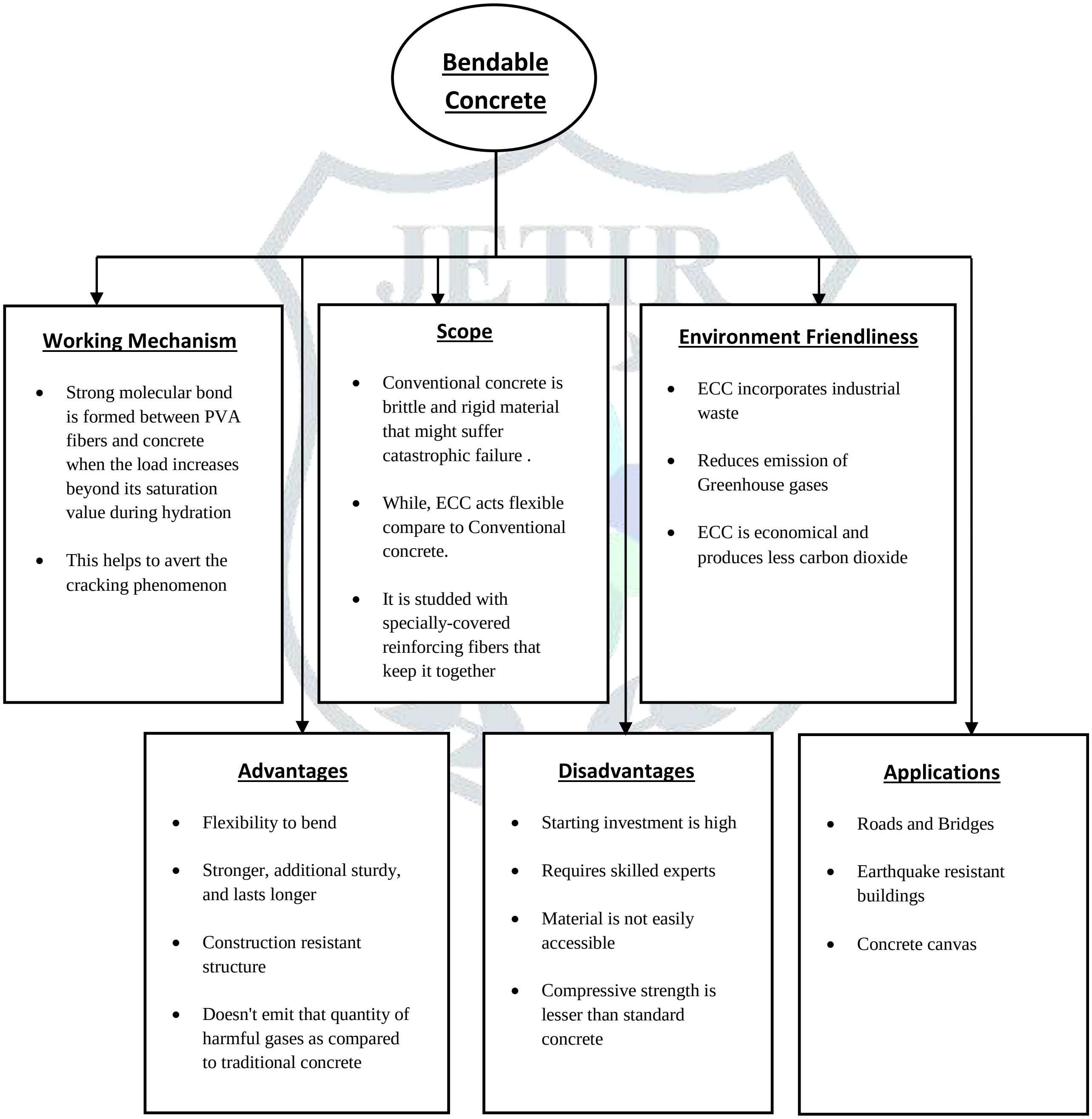
Cementitious substances, like Silica fume, blast Furnace, fly ash, etc. can be applied similarly to cement to increase the paste content. ECC makes use of low quantities of round 2% by volume, short, discontinuous fibers.[3] ECC contains little Polyvinyl Alcohol-fibers coated with a thin (nanometer thick), slick coating and fine silica sand . This surface coating allows the fiber to start slithering as soon as it may be complete so they are not fracturing. It prevents the fiber from rupturing that can cause big cracking. Therefore, an ECC deforms as an alternative greater than a popular concrete[24] The energy captivating properties of ECC make it in particular appropriate for critical additives in Earthquake zones.[25]

## II. Constituents in ECC

Bendable concrete includes all of the substances of conventional concrete besides coarse aggregates and is strengthened with polymer fibers. It consists of cement, sand, water, fibers, and admixtures The use of fiber in ECC significantly improves the tensile plasticity properties of ECC with an exact volume fraction. Fibers like steel fiber (SE), plastic fiber (PP), normal fiber (PE), and polyvinyl alcohol (PVA) fiber are normally ECC mixes. Adding fibers will improve strength and strain capabilities as energy absorption of

ECC [4]. This additionally reduces the injury of the ECC structure throughout an effect loading. High-modulus fibers like SE, glass fiber, and carbon fiber increase the majority strength and toughness of the fabric, however, their intrinsic brittle behavior doesn't allow plasticity or strain hardening in ECC [5]. Additionally, the slick coating (anti-friction coating) is provided so that the fibers particles will slide over each other and don't have friction which might result in cracks in concrete. This tendency of slithery fibers over each other helps the concrete to reduce the crack and supply flexibility to the concrete.

## III. Bendable Concrete Overview



## IV. Comparison between conventional and ECC concrete

| Point of difference | Normal Concrete | Engineered Cementitious Composite (ECC) |
|---|---|---|
| **Durability** | The normal concrete structures are less durable. | The flexible concrete structures are more durable. |
| **Earthquake Resistance** | The structures made with the original concrete are prone to earthquakes. They generally form cracks or may collapse during earthquakes. | As the flexible concrete does not break easily by the earthquake motion. So the structures made with flexible concrete are more earthquake resistant. |
| **Self-healing property** | The normal concrete has very low self-healing property as it has very low free cement concrete. | The flexible concrete has a very good self-healing property as it can heal the micro-cracks itself by the reaction of carbon dioxide and water. |
| **Repair and Maintenance** | The repair and maintenance cost of concrete structures is high as they developed cracks and other defects. | The repair and maintenance cost of flexible concrete is low as it does not develop that many cracks. |
| **Self-weight** | The self-weight of conventional concrete is more. | The flexible concrete is 30-40% lighter than conventional concrete. |
| **Reinforcement** | The steel bar reinforcement is required for taking a tensile load. | The fiber reinforcement can provide the required tensile strength in the concrete so less or may be steel reinforcement is required. |
| **Curing time** | The concrete structure generally requires more curing time (around 28 days). | The flexible concrete generally requires less curing time (around 7 days). |
| **Labour** | It requires less skilled labor. | It requires more skilled labor. |
| **Cost** | The cost of construction is less as it consists of common material. | The initial cost of construction is more. |

# V. RECENT RESEARCHES ON BENDABLE CONCRETE

***Zhang Z. et al (2019)*** **[14]** presented the impact of directly adding vegetative Bacillush alodurans and its mutant cells into ECC material was investigated. The mechanical performance of ECC together with compressive strength and tensile properties were extremely influenced once the incorporation of microorganism. At the macroscale level, the compressive strength and strength of bacteria-ECC magnified as compared with Control-ECC thanks to microorganism ECC. metabolism on the opposite hand, the tensile strain capability shows a reverse trend in bacteria-ECCs, however, continues to be maintained at a high level. At the microscale level, kind of like the strength improvement, the matrix fracture toughness was additionally magnified in bacteria-ECCs. For the matrix/fiber interface properties related to fiber bridging performance, lower chemical bond and slip-hardening constant were determined bacteria-ECCs, nonetheless the magnified resistance bond strength prevailed over the shriveled chemical bond that successively results in the reduction of complementary energy. it's noted that a form of biofilm and microorganism aggregation was connected to the fiber surface, thereby ever-changing the interface properties.

***Pan Z. et al (2015)*** **[15]** Assessed un-oiled polyvinyl alcohol fibers and hybrid PVA fibers in ECC had been taken into consideration and additionally the combined proportion changed into redesigned via quantity analysis. In maintaining with the cost and overall performance of PVA-ECC, three normal mixes have been proposed: for M7 has low tensile strength and M17, M21 have excessive tensile strength.

***Yu Zhu et al. (2014)*** **[17]** The water–binder substances ratio (W/B) is kept at 0.25 for various combinations for binary and ternary systems. It was observed that ductility of ECC was progressive by adding fly ash and slag.

***Ramin Andalib et al, (2016)*** **[19]** discussed portrays five distinctive cell groupings of Bacillus megaterium ($10x10^5$ to $50x10^5$cfu/ml) were acquainted in underlying cement to accomplish the ideal convergence of microbes. A significant increase in the strength was obtained in the case of $30x10^5$ cfu/ml at different ages. The strength of the highest grade of bacterial concrete had improved (24%) as compared to the lowest grade (12.8%) due to the calcification mechanism. Microbial calcite precipitation was measured utilizing X-beam diffraction examination, envisioned by filtering Electron microscopy and investigated by energy dispersive spectrometer It was found that the Optimum concentration of B. megaterium had a helpful result on high strength structural concrete.

**Agarwal *et al* 2020[20]** research work are to assess the strength parameters of the concrete specimens made by inducing bacteria along with a suitable cement replacing substance. Therefore, the use of sustainable strategies like inducing bacterial culture into the concrete mix can act as active support for both natural as well as the economy of construction industries. Many substitutes are used for replacing cement. In this paper, control concrete, concrete made by replacing cement with 8% of Micronized Biomass Silica (MBS), and bacteria-induced concrete are compared. The bacteria used is Bacillus Sphaericus and is mixed in the concrete specimens at different levels of 10ml, 20ml, 30ml. $M_{60}$ grade high strength concrete is cast in the form of cubes and cylinders and their compressive strength and split tensile strength at the age of 7and 28 days are compared with that of conventional concrete. From the test results, it was concluded that specimens with 20ml bacteria and 8% MBS showed optimum results. Hence, this combination of bacteria and MBS would not only increase strength but also help the concrete against moisture and other harmful particles.

***Bhaskar s et al(2020)*[21]*,*** Sporosarcina pasteurii and Bacillus subtilis were selected as two different bacterial strains, with zeolite as a protective carrier. Four-point bending and ultrasonic pulse velocity tests were performed on ECC specimens to evaluate their mechanical properties during damage and healing processes. Micro structural observations to quantify self-healing compounds were performed using X-ray diffraction analyses and SEM. The bacteria-incorporated ECC specimens were found to be promising in the healing of cracks recovery of flexural strength and stiffness.

***A. Richard and P. Krithika(2019)*[22]** Carried out on growing the self-healing property of ECC with PP and PVA fibers with different percentage of microorganism in water content. It indicated that PVA fibers provide higher overall performance as compared to PP fibers and self-healing takes place beneath distinct exposures of the ECC specimens.

# VI. Literature summary

- At the macro scale level, the compressive strength and tensile strength of bacteria-ECC increased as compared with Control-ECC due to bacterial metabolism in ECC. Tensile strain capacity shows a reverse trend in bacteria-ECCs but is still maintained at a high level.[14]
- Outcome of bending and compressive tests confirmed that the growth of water-cement ratio and fly ash substitution is in the desire of strain-hardening and a couple of cracking.[15]
- In the ternary system, for ECC with a 70% combination of fly ash and slag, the defection becomes smaller when the ratio between slag and fly ash increases. However, introducing a 70% combination of fly ash and silica fume weakens the deflection.[17]
- In the binary system, the compressive strength of ECC becomes weak as the content of a single mineral admixture increases, especially for ECC with a high volume of fly ash. In the ternary system, the combination of different mineral admixtures can enhance the compressive strength of ECC, especially at an early age.[17]
- Replacing 30% of bacteria with water content increases compressive, flexural and split tensile strength. **[22]**
- Bacterial ECC specimen is induced via way of means of calcium lactate on reacting with water precipitates calcium carbonate which acts as a healing agent. [22]
- Self-healing-induced mechanical property recovery was observed for specimens treated with zeolite-immobilized bacteria compared with the control and unprotected bacteria counterparts.[21]
- ECC specimens dosed with both types of zeolite immobilized bacteria showed an increase in flexural strength (23% for S. pasteurii and 17% for B. subtilis) and higher UPV values compared with their virgin (before loading) counterparts due to self-healing.[21]
- A combination of bacteria and Micronized Biomass Silica (MBS) would not only increase strength but also help the concrete against moisture and other harmful particles. a maximum of 12% increase in compressive strength was observed with the addition of 0.5% of calcium lactate in concrete.[20]
- Microbial calcite precipitation was quantified by X-ray diffraction (XRD) analysis and visualized by SEM. [20]

# VII. CONCLUSION

Embedded bacteria enhance strength properties and lowers strength capacity of ECC. The mechanical performance of ECC including compressive strength and tensile properties were highly influenced after the incorporation of bacteria. SEM and EDS studies of healed specimens with and without bacteria proved visually that the addition of bacteria produced large amounts of crystals that have the potential to seal freshly formed cracks.

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