Bio concrete: A Sustainable Future Alternative

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Abstract:
Bio concrete is a type of concrete which fills the voids developed in a civil structure. The cracks are formed due to various activities like evaporation, shrinkage, land slip, vibration etc. In this project, M25 is the grade of the cement and *Escherichia coli* as the bacteria. The culture was prepared by taking LB media and distilled water which was autoclaved and further the bacteria was added. Growth was observed post 13-14 hours. After determining the specific gravity of cement using kerosene, coarse aggregates, fine aggregates and cement was weighed and added in a mixing chamber. After sufficient mixing, 10 concrete cubes of 10×10 cms were moulded and allowed to harden. These cubes are called control concrete cubes. For 10 more cubes, *Escherichia coli* culture along with Calcium lactate was added along with the previous added mixture. These cubes are bacterial concrete cubes. Bacteria helps in formation of limestone. When calcium lactate reacts with water, limestone is formed which helps to fill the voids present. After all the 20 cubes were hardened, it was subjected to curing by placing them in a curing tank. The cubes were taken out of the curing tank on 7, 14, and 28 days for X Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) analysis. XRD helped in determining the cement hydration levels on 7^{th}, 14^{th}, and 28^{th} day. SEM helped in analysing the microstructure of the concrete mixes.

Keywords: Bio concrete, Calcium Lactate, Curing, XRD, SEM

1)Introduction:

Because of its superior characteristics, concrete is a widely utilised building material (about 6 million million/year are produced). It is, however, a delicate material that breaks readily owing to a variety of factors such as autogenous shrinkage, freeze-thaw reactions, mechanical compressive and tensile stresses. Due to the strength, durability and permeability of concrete, its demand is increasing year by year (15). The presence of cracks reduces not only the mechanical strength and durability of the material, but also the structural safety. Shrinkage, settlement, and fast loss of water are all causes of cracks, as are weather impacts, temperature effects, and a lack of water content (dryness) among many others (14).

To overcome, these obstacles bio concrete/self-healing concrete incorporated many different species of bacteria into concrete formulations for fracture repair and durability enhancement. Self-healing Concrete refers to the capacity of concrete to mend itself by automatically treating fractures or filling voids [7]. Cracks may mend over time as a result of clinker mineral hydration or calcium hydroxide carbonation.[2] Many admixtures, including as mineral additions, crystalline admixtures, and superabsorbent polymers, can be used to improve autogenous healing.[3] Concrete can also be changed to include self-healing processes. The most prevalent forms of autonomous self-healing strategies include capsule-based self-healing, vascular self-healing, and microbiological self-healing.[8] Late researches focuses on biotechnology and civil engineering aspect of developing self-healing concrete technology [1, 17, 16, 12, 13].

The current study focussed if the bacteria had the capacity to change organic soluble nutrients into inorganic insoluble calcium crystals which can be used to fill the void in the cracks.

2)Materials and Methods:

The specific gravity of cement and the fineness of the aggregates were determined. *Escherichia coli* was prepared using LB media and distilled water. This mixture was autoclaved after which *Escherichia coli* was added and it was further subjected to incubation. The cement, sand, and aggregates were combined with the water, *Escherichia coli*, and calcium lactate. Once the mixing process is complete, the resulting mixture is introduced into concrete cube moulds, each with dimensions of 10x10x10 centimetres. A total of 20 concrete cube moulds are prepared. Among these 20 moulds, 10 are filled before the addition of *Escherichia coli* culture, and they serve as the Control samples. The remaining 10 moulds are filled after adding both the *Escherichia coli* culture and Calcium Lactate, and these are referred to as the Bacterial samples. After filling the moulds with the mixture, the cubes should be placed in a cool location and left undisturbed. Over the next 12 hours, the cubes will undergo a hardening process and become solid. After the 12-hour hardening period, the cubes are taken out of the moulds. Subsequently, all 20 cubes, including both the Control samples and the Bacterial samples, undergo a curing process. This curing process involves placing the concrete cubes in a water tank. After 7 days of curing in the water tank, one Control sample and one Bacterial sample are taken out for testing. These samples are subjected to loading to assess their compression strength. This test will help in evaluating the ability of the concrete to withstand compressive forces and determine if the introduction of the *Escherichia coli* culture and Calcium Lactate had any impact on the concrete's strength. After the compression strength testing is completed, the concrete cubes are converted into a powdered form. Following the same procedure, on the 14th and 28th day after curing, additional concrete cubes are taken from the curing tank and subjected to loading for compression strength testing. Once the loading is completed, the cubes are again converted into a powdered form and taken in Eppendorf tubes for Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) analysis.

3) Results:

The synthesis of calcite precipitation in most bacterial mortars is studied using scanning electron microscopy (SEM). A couple of voids are sighted in 1A-1C due to the absence of bacteria. The filling of the voids can be determined in pictures 2A-2C because of the presence of *Eschericia coli*.

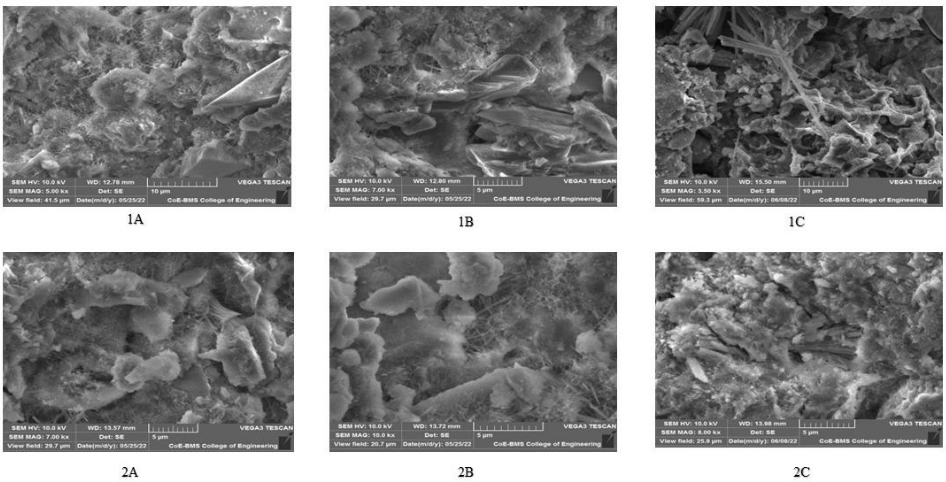

Figure 1: SEM Analysis (1A-1C) Control Concrete Cubes (2A-2C) Bacterial Concrete Cubes

The XRD examination verified that the white crystal developed in the concrete crack was calcium carbonate, and the higher the calcium carbonate concentration, the closer the specimen was to the surface.

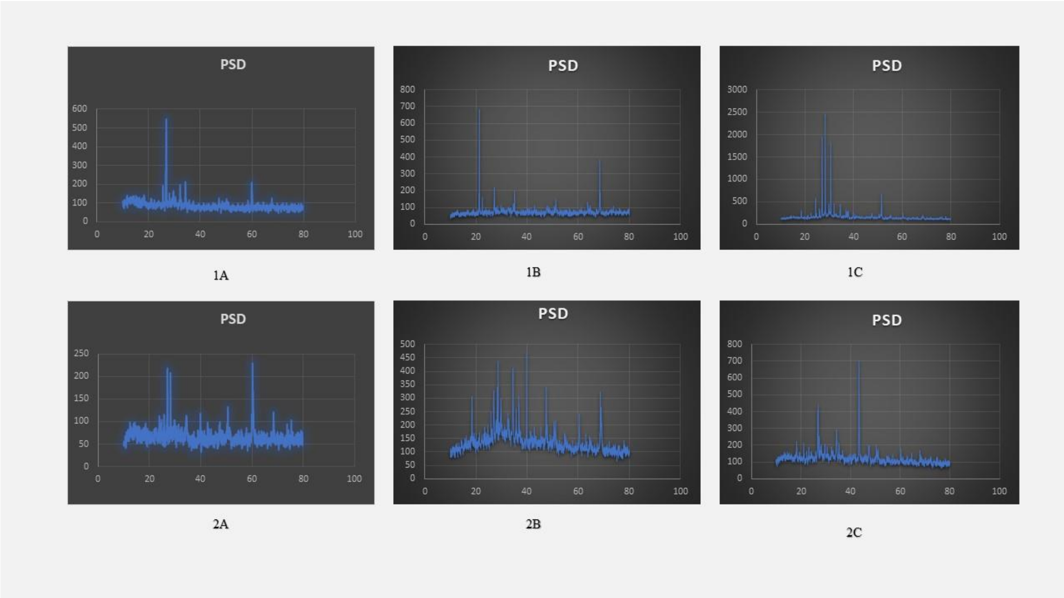

Figure 2: XRD Analysis (1A-1C) Control Concrete Cubes (2A-2C) Bacterial Concrete Cubes

4) Discussions:

Healing products formed in a fracture may result in strength recovery via the development of C-S-H or Ettringite (8). The cuboid crystals created at the surface seal the fracture, resulting in a larger ion concentration inside the fissure. This, in turn, allows the development of various self-healing products such as C-S-H, Ca (OH)2, and ettringite inside the crack (10). The causes of autogenous self-healing may be divided into three categories: physical, chemical, and mechanical [4]. Later studies focused on the determination of the physicochemical background of this process (5, 10, 5). XRD peaks showed that lactate content was actively involved in faster healing process resulting in the formation of calcium carbonate. Whenever these concrete walls are subjected to some hydration or curing, bacteria is activated and the self-healing process starts. On the 7th day of SEM analysis, not much difference was seen between the control sample and the bacterial sample. On the 14th day concrete being dense in the bacterial sample than the control sample can be seen. On the 28th day of SEM analysis, the voids being completely filled in the bacterial sample and open voids in the control sample is visualized.

5) Conclusions:

Bio concrete is the ideal response to the demand for sustainable concrete because of its resilience and potential for self-healing. This will play the most important role in concrete technology in the future. The capacity of concrete to self-heal cracks would boost its durability and sustainability while also prolonging the lifespan of concrete structures. The compressive strength and self-healing capability of the concrete were both increased when bacteria were introduced into it.

6) Future Scope:

From 2020 to 2027, the worldwide self-healing concrete market is predicted to develop at a compound yearly growth rate of 37.0%, reaching USD 305.38 billion. The desire for eco-friendly and durable buildings is likely to drive the development of self-healing concrete. Currently, bio concrete is used for tunnel lining, highway bridges, marine structures, walls of the building, concrete floors, and structural basement. As self-healing concrete technology advances, it has the potential to significantly alter the construction sector by providing longer-lasting and more sustainable infrastructure solutions. Its usage might result in less maintenance and repair work, which benefits both building businesses and the environment.

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