EMERGING WAY TO ENHANCE THE STRENGTH ASPECTS & DURABILITY OF CONCRETE STRUCTURE BY ADDING BACILLUS SUBTILLIS

[1] Shaik Bifathima & [2] Dr. T.V.S Varalakshmi
[1] Research Scholar, ANU University, Andhra Pradesh
[2]Assistant Professor, ANU University, Andhra Pradesh
Email: - fathimaline@gmail.com

ABSTRACT

Concrete is one of the mainly used construction material, with over 2.5 billion tons produced internationally in each year. When concrete is exposed to temperature fluctuation, corrosive chemicals and excessive stress, crack are arise in concrete. Bacterial concrete is a latest technology in recent days on use of different bacteria as self-healing agent. A variety of materials are available in market for repair like polymers, epoxies etc…But these are harmful to the environment; therefore this technique being environmental friendly can be used as their substitution [3]. Cracking of concrete is a common phenomenon with out immediate and proper treatment, cracks in concrete structures tend to expand further and eventually require costly repairs. Even though it is possible to reduce the extent of cracking by available modern technology, remediation of cracks in concrete has been the subject of research for many years. There are a large number of products available commercially for repairing cracks in concrete: structures epoxy, resins, epoxy mortar and other synthetic mixtures. Cracks and fissures are a common problem in building structures, pavements, and historic monuments. We have introduced a novel technique in fixing cracks with environmentally friendly biological processes that is a continuous self-remediating process. In the study, Bacillus Subtilis that is abundant in soil has been used to induce CaCO3 precipitation. It is therefore vital to understand the fundamentals of microbial participation in crack remediation.

Keywords-Bacteria, Coarse aggregates, Fine aggregates, Cement.

INTODUCTION

Concrete however being utilized and received as a perfect development material in view of its simple accessibility, ease good compressive strength and so forth has some downside additionally , the significant disadvantage of concrete is its low tensile strength because of which smaller scale cracks happen. The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that are able to constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation. It has been shown that under favorable conditions for instance Bacillus Subtilis. The process can occur inside or outside the microbial cell or even some distance away within the concrete. Often bacterial activities simply trigger a change in solution chemistry that leads to over saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads to potential invention of new material called Bacterial Concrete". The long term goal is to understand the significance of micro-organisms in concrete structures. Therefore, bacterially induced calcium carbonate precipitation has been proposed as an alternative. Durability problems such as crack formation are typically tackled by manual inspection and repair, i.e. by impregnation of cracks with cement or epoxy-based or other synthetic fillers. An integrated healing agent will save manual inspection and repair and moreover increases the structure's durability. Addition of such an agent to the concrete mixture would save money and environment.

CLASSIFICATION OF BACTERIA

Classification of bacteria on the basis of shape

In the year 1872 scientist Cohn classified bacteria to 4 major types depending on their shapes are as follow: –

1) **Cocci:** These types of bacteria are unicellular, spherical or elliptical shape. Either they may remain as a single cell or may aggregate together for various configurations.
2) **Bacilli:** - this is rod shaped or cylindrical bacteria which either remain singly or in pairs.
3) **Vibro:** -the vibro are the curved, comma shaped bacteria and represented by a single genus.
4) **Spirilla:** - this type of bacteria are spiral or spring like with multiple curvature and terminal flagella.

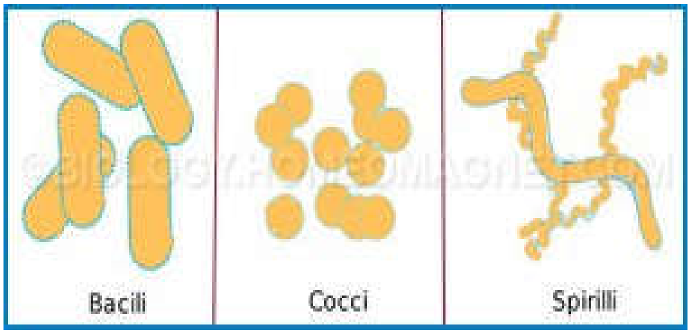

Fig (1) Classification of bacteria based on shape

Classification of bacteria on the basis of nutrition: –

1) **Autotropic bacteria:** - these bacteria are nonpathogenic, free living, self sustaining in nature, which prepare their own food by utilization of solar energy and inorganic components like carbon dioxide, nitrogen etc.
2) **Heterotrophic bacteria:** – this type of bacteria cannot fix inorganic Carbone but rather depend on external organic Carbone for their nourishment. They also can be classified on the basis of presence and absence of flight and on the basis of the media on which the bacteria are growing.

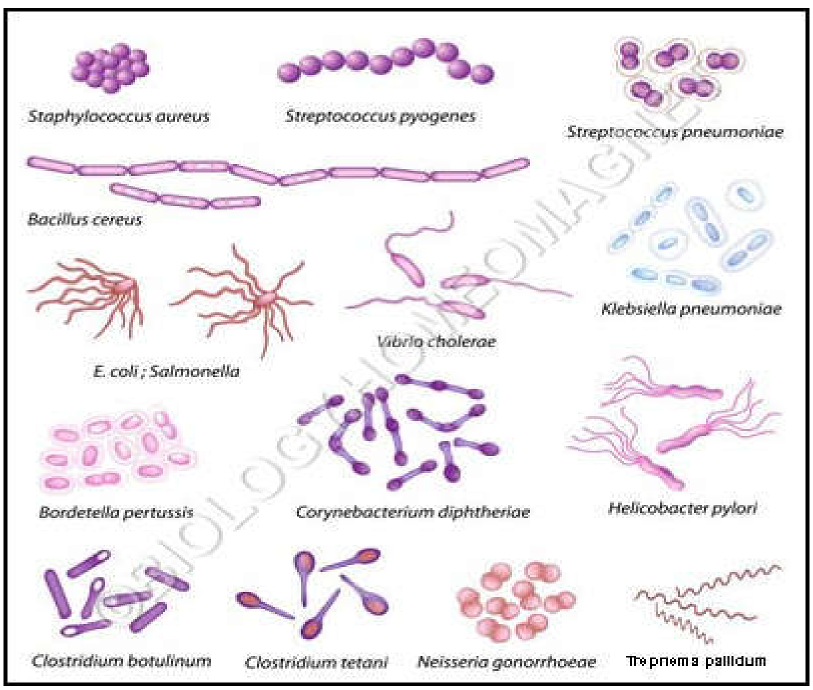

Fig (2) Classification of bacteria based on nutrition.

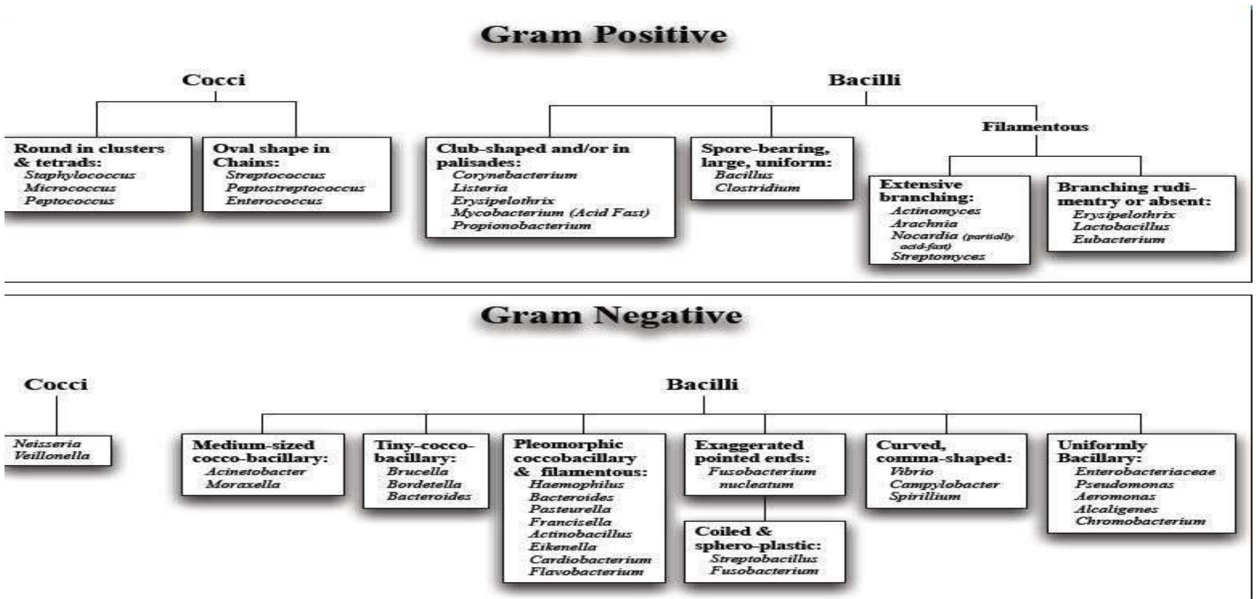

Fig (3) Classification of Bacteria based on Gram size.

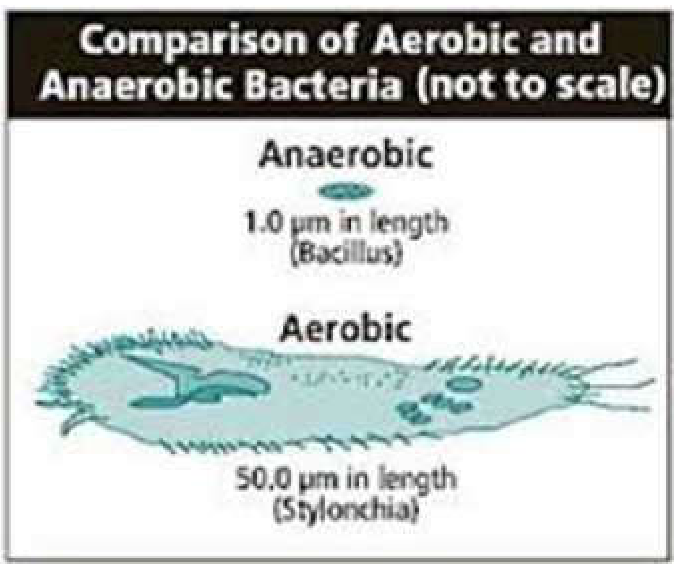

Fig (4) Classification Based on Oxygen Demand

Various Types of Bacteria Used in Concrete From literature review:

- Bacillus pasteurii
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cohnii
- Bacillus halodurans
- Bacillus pseudofirmus etc.,

Advantages and Disadvantages of Bacterial Concrete Advantages:

Advantages:-

- Bacterial concrete in crack remediation.

- Compressive strength is increased in concrete.
- Enhanced resistance to freeze-thaw cycle.
- Reduction in permeability of concrete.
- Reduction in corrosion of reinforced concrete.

Disadvantages:

- Bacterial concrete Cost is double than that of conventional concrete.
- Development of bacteria is not good quality in any atmosphere and media.
- Design of concrete mix with bacteria is not available in IS codes or any other codes.

Mechanisms:-

Some possible mechanisms for Self-healing are:

1. Formation of material like calcite.
2. Blocking of the path by sedimentation of particles.
3. Continued hydration of cement particles.
4. Swelling of the surrounding cement matrix.

SELF BACTERIAL HEALING CONCRETE

Autogenously crack-healing capacity of concrete has been recognized in several recent studies. Mainly micro cracks with widths typically in the range of 0.05 to 0.1 mm have been observed to become completely sealed particularly under repetitive dry/wet cycles. The mechanism of this autogenously healing is chiefly due to secondary hydration of non- or partially reacted cementing particles present in the concrete matrix. Due to capillary forces water is repeatedly drawn into micro cracks under changing wet and dry cycles, resulting in expansion of hydrated cement particles due to the formation of calcium silicate hydrates and calcium hydroxide. These reaction products are able to completely seal cracks provided that crack widths are small. Larger sized cracks can only be partially filled due to the limited amount of non-reacted cement particles present, thus resulting in only a thin layer of hydration products on the crack surface.

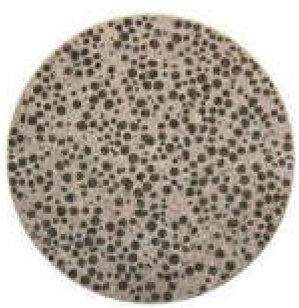

Fig (5) Self healing bacterial concrete

Species from Bacillus group appear promising intrinsic agents as their spores, specialized thick-walled dormant cells, have been shown to be viable for over 200 years under dry conditions. Such bacteria would comprise one of the two components needed for an autogenously healing system. For crack repair filler material is needed, and bacteria can act as catalyst for the metabolic conversion of a suitable organic or inorganic component, the second component, to produce this. The nature of metabolically produced filler materials could be bio minerals such as calcite or apatite. These minerals are relatively dense and can block cracks, and thus hamper ingress of water efficiently. The development of a self-healing mechanism in concrete that is based on a potentially cheaper and more sustainable material then cement could thus be beneficial for both economy and environment.

MICRO-ORGANISM

Microbes are the most various and copious gathering of living beings on Earth. They are found in ocean water, soil, air, creatures' gastrointestinal tracts, hot springs and even far below the Earth's outside in rocks. Microbes are frequently expelled as germs, however enable us to do a scope of helpful things like generation of anti-toxins, nitrogen obsession, live in the guts of creatures (counting people) or somewhere else in their bodies, or on the foundations of specific plants. Microscopic organisms are of extraordinary significance in view of their outrageous adaptability, limit with regards to fast development and generation. A smaller scale life form is a living being that is minute (too little to be seen by the stripped human eye). Small scale living beings are unimaginably various and incorporate microbes, parasites, archaea, and protists, and in addition some minute plants and creatures, for example, microscopic fish, and prominently referred to creatures, for example, the planarian and the one-celled critter.

Bacterial concrete and its applications:

Microbial or bacterial concrete is set up by blending a cement paste containing microbial cells alongside a calcium-based supplement known as calcium lactate, and nitrogen and phosphorus are added to the elements of the concrete specifically proportion. Aside from its other awesome properties, because of its significant property of crack remediation or self-healing, it is otherwise called self-heaing concrete.

This special kind of concrete has multiple usages. According to its different usage it can be classified as following

Bacterial concrete as concrete crack remediation/healing.

- Bacterial concrete as an unusual surface treatment for concrete.
- Bacterial concrete as antifungal cement mortar.
- Bacterial concrete as water purifier.
- Bacterial concrete as restoration material for stone building.

Bacterial concrete for concrete crack remediation

Regular procedures, for example, weathering, deficiencies, land subsidence, earthquakes and human exercises make splits and cracks in concrete structures. Weathering incites expanded porosity, auxiliary debilitating of surface layers, ugly appearance and eventually lessens the service life of the structures [6]. Worry about the degradation of concrete and the monetary effect of the support and repair of concrete structures have attracted the consideration regarding procedures of concrete weakening, and to the techniques to back off or even to take out solid debasement. Without prompt and appropriate medications, cracks in concrete structures have a tendency to extend further and in the long run require exorbitant repair. Despite the fact that it is conceivable to diminish the degree of splitting by accessible present day innovation, remediation of crack in concrete has been the subject of research for a long time.

Concrete Crack Remediation with Conventional Solutions:

There are such a large number of manufactured agents which are utilized to keep away from any sort of cracks and fissures in the concrete structures. These are additionally utilized as a part of repair applications, for example, the bonding of concrete, sprayed concrete or cement/sand repair mortar to solidified concrete. bonding agents are regular, aggravated or manufactured materials used to expand the joining of individual individuals from a structure without utilizing mechanical fasteners. The primary sorts of bonding agents utilized as a part of the development business to remediate cracks and to solidified structure are:

- Latex emulsions
- Epoxy bonding agents
- Surface treatments with silanes.

These conventional means of protection show a number of disadvantageous aspects such as:

- Weak bonding with surface

- different thermal expansion coefficient of treated layers
- degradation over time
- Need for constant maintenance and costly too.
- Some solvents contributes to pollution
- Styrene butadiene latex coagulates if subjected to high or freezing temperatures.

Cracking in concrete structures proceeds over a drawn out stretch of time, so these sorts of treatment are required more than once. Also, these are not the permanent solution. Consequently, in such circumstances, a route as self-healing materials ought to be discovered seal the cracks automatically.

Possible biochemical reactions:

Bio-mineralization is characterized as a biologically induced precipitation in which a life form makes a nearby smaller scale condition with conditions that permit ideal extracellular substance precipitation of mineral stages. This microbiologically prompted calcium carbonate precipitation involves a progression of complex biochemical responses. As a feature of metabolism, B.Suntilis, which catalyzes urea to create CO_2 and ammonia, bringing about an expansion of pH in the surroundings where particles Ca^{2+} and CO_3^{2-}accelerate as $CaCO_3$. Conceivable BIOCHEMICAL REACTIONS in urea- $CaCl_2$ medium to encourage $CaCO_3$ at the cell surface can be abridged as takes after.

$$Ca^{2+} + Cell \rightarrow Cell\text{-}Ca^{2+} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Cl^- + HCO^- + NH \rightarrow NH\,Cl + CO^{2-} \ldots\ldots\ldots\ldots (2)$$

$$Cell\text{-}Ca_{2+} + CO_3{}^{2-} \rightarrow Cell\text{-}CaCO_3\downarrow \ldots\ldots\ldots\ldots (3)$$

Chemical process to remediate cracks by bacteria :

Crack infiltrating water would not just disintegrate calcite (CaCO3) particles introduce in mortar lattice, however would likewise respond together with environmental carbon dioxide with not completely hydrated lime constituents, for example, calcium oxide and calcium hydroxide as indicated by the accompanying responses:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$Ca(OH)_2 + CO2 \rightarrow CaCO_3 + H_2O$$

The newly created minerals from the above expressed responses and from dissolved and re-crystallized calcite minerals, hastened on the surface of cracks what brought about crack sealing and accompanying decrease Permeability of the mortar. The recuperating capability of this framework was specifically identified with the measure of non-responded lime particles inside the set mortar.

Calcium carbonate precipitation is a straight forward chemical process administered for the most part by four key elements:

1) Calcium focus
2) Concentration of dissolved inorganic carbon (DIC)
3) The pH
4) Availability of nucleation sites.

The convergence of carbonate particles is identified with the grouping of DIC and the pH of a given oceanic framework. The precipitation of Calcium Carbonate valuable stones happens by heterogeneous nucleation on bacterial cell dividers once super concentration is accomplished. That a wide assortment of microorganisms deliver urease chemical and makes it in a perfect world suited for crack Remediation for building material applications. This precipitation shapes an exceedingly impermeable layer which can be utilized as crack remediation for concrete or some other building material. The hastened calcite has a coarse crystalline structure that promptly holds fast to the concrete surface as scales. What's more it can consistently develop upon itself and it is very insoluble in water.

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CONCLUSION

Bacterial concrete innovation has turned out to be superior to numerous ordinary advancements in view of its eco-friendly nature, self-healing capacities and extremely helpful for use. The use of bacterial concrete to development may likewise improve a portion of the current development forms and revolutionize the methods for new development forms. This novel and imaginative concrete innovation will soon give the premise to an option and astounding structures that will be savvy and environmentally safe. In any case, more work is required to enhance the plausibility of this innovation from both an efficient and commonsense perspectives.

RECOMMENDATIONS FOR FURTHER STUDIES

As the numerous researchers discovered this better and brilliant material although due than its different restrictions, additionally contemplate is require to get a more advantage from this material. In this way, point by point thinks about need to concentrate on various sorts of nutrients and metabolic items utilized for developing calcifying microorganisms, as they impact survival, development, and bio film and crystal formation.

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