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SELF HEALING CONCRETE: AN EMERGING TECHNOLOGY IN CIVIL ENGINEERING

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ABSTRACT:

Cracking of concrete is a common phenomenon without 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. Cracks and fissures are a common problem in building structures, pavements and historic monuments. We have introduced a novel technique in fitting cracks with environmentally friendly biological process that is a continuous self-remediating process. In this study Bacillus Sphaericus that is abundant in soil has been used to induce $CaCO_3$. It is therefore vital to understand the fundamentals of microbial participation in crack remediation. Cracks in concrete form an open pathway to the reinforcement can lead to durability problems like corrosion of the steel rebar's. Furthermore cracks can cause leakage in case of liquid retaining structures, due to alkali, sulphate and drying shrinkage In order to overcome this problem, a variant of smart concrete is rapidly developing, which is known as "Self-healing concrete". The self-healing concrete is one that senses its crack formation and reacts to cure itself without human intervention. The impact of ECO- friendly micro- organism has been made use of the self-healing process in the current project.

Keywords- Bacillus Sphaericus, Micro-Organism, Calcium Carbonate, Tiny Cracks, Nutrient Agar, Concrete Structures

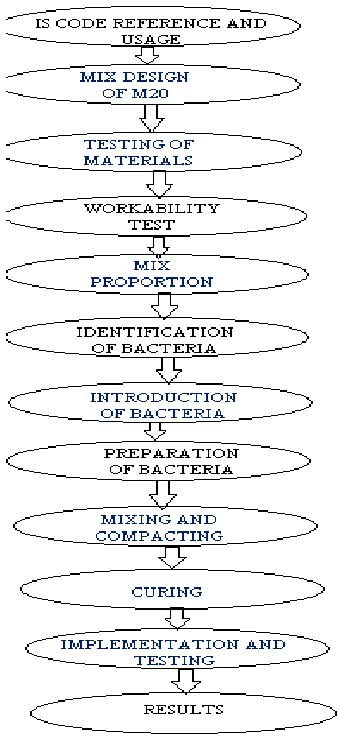
INTRODUCTION:

Concrete is used more than any other man-made material in the world. There are many benefits of using concrete to build commercial properties such as resource efficiency, durability, thermal mass, reflectivity, ability to retain storm water, and minimal waste. But what makes concrete a worldwide used material is its compressive strength. Concrete will continue to be the most important building material for infrastructure but most concrete structures are prone to cracking. Tiny cracks on the surface of the concrete make the whole structure vulnerable because water seeps in to degrade the concrete and corrode the steel reinforcement, greatly reducing the lifespan of a structure. Concrete can withstand compressive forces very well but not tensile forces. When it is subjected to tension it starts to crack, which is why it is reinforced with steel; to withstand the tensile forces. Structures built in a high water environment, such as underground basements and marine structures, are particularly vulnerable to corrosion of steel reinforcement. Motorway bridges are also vulnerable because salts used to de-ice the roads penetrate into the cracks in the structures and can accelerate the corrosion of steel reinforcement. In many civil engineering structures tensile forces can lead to cracks and these can occur relatively soon after the structure is built. Repair of conventional concrete structures usually involves applying a concrete mortar which is bonded to the damaged surface. Sometimes, the mortar needs to be keyed into the existing structure with metal pins to ensure that it does not fall away. Repairs can be particularly time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height.

VARIOUS TYPES OF BACTERIA USED IN CONCRETE

- Bacillus pasteurizing
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus cohnii
- Bacillus balodurans
- Bacillus pseudofirmus

METHODOLOGY:



HAND MIXING:

Hand mixing is practiced for small scale concrete works. Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers. Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved. This uniform mixture is spread out in a thickness of about 20 cm. This operation is continued till such a good time a good uniform, homogenous concrete is obtained. It is a particular importance to see that the water is not poured but it is only sprinkled. Water in a small quantity should be added towards the end of the mixing to get the just required consistency. At that stage, even a small quantity of water makes difference. After that the bacteria medium is sprinkled over the concrete mixture.

PLACING:

It is not enough that a concrete mix correctly designed, batched, mixed, it is of utmost importance that the concrete must be placed in systematic manner to yield optimum results. The precautions to be taken and methods adopted while placing concrete in the moulds.

HANDCOMPACTION:

Hand compaction of concrete is adopted in case of small concrete works. Sometimes, this method is also applied in such situation, where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. Hand compaction consists of rodding, ramming or tamping. When hand compaction is adopted, the consistency of concrete is maintained at a high level. Tamping is one of the usual methods adopted in compacting roof or floor slab or road pavements where the thickness of concrete is comparatively less and the surface to be finished smooth and level.

CURING:

Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement, so that the hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service. The casted cubes and cylinders are immersed in water tanks for 3 days, 7days, 14 days and 28 days.

WORKABILITY OF CONCRETE:

Workability is the amount of useful internal work required to produce full compaction of concrete. It depends on,

- Types of aggregate
- Grading of coarse and fine aggregate
- Quantity of cement paste
- Consistency of the cement paste

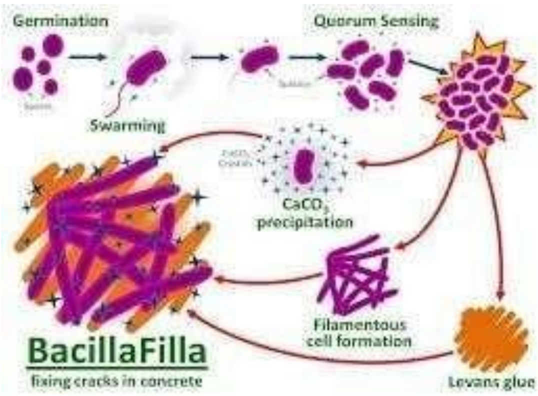
SLUMP TEST:

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. The deformation shows the characteristics of concrete with respect for segregation the thickness of the metallic sheet for the mould should not be thinner than 1.6mm. For tamping the concrete, a steel tamping rod 16mm dia, 0.6 meter along with bullet end is used. The mould is then filled in four layers, each approximately ¼ of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subside is referred as slump of concrete.

The value of slump = 90 mm

MIXING, COMPACTION, CURING:

Good concrete can be obtained only through and uniform mixing, better through and uniform mixing, better through compaction and adequate curing. In the laboratory, the concrete was mixed by hand mixing. All the constituent materials were weighed and dry mixing was carried out for about 5 minutes and then water was added. The mixing was continued till concrete of uniform consistency was obtained / the specimens were compacted using table vibrator. After 24 hours, the specimens were remolded and kept immersed curing tank containing potable water till the required curing period of 1:1.27:2.89 with water cement ratio 0.4cement replaced. The mix proportions are given in table. For control specimen the w/c ratio is 0.4. The same amount of water is used for all other specimen. The following table shows the mix proportion used for all other specimens. In this study the effect of Bacillus Sphaericus in concrete is studied. Bacteria added in concrete with 10ml and 20ml proportions and proper curing makes a substantial improvement in enhancing the protection of embedded in concrete.



TEST AND RESULT OF SELF-HEALING OR BACTERIAL CONCRETE AND NORMAL CONCRETE

Standard test were conducted on normal concrete and self-healing concrete. Test conducted were Compressive and flexural strength tests on a concrete cube for 7 and 28 days.

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Table: Compressive Strength Test result for 7 and 28 days for Bacterial Concrete

S.No.	Days	Normal Concrete (N/mm^2)	Bacterial Concrete (N/mm^2)
1	7	20.85	27.10
2	28	30	38.95

Table: Flexural Strength Test result for 7 and 28 days of Bacterial Concrete

S.No	Days	Normal Concrete (N/mm^2)	Bacterial Concrete (N/mm^2)
1	7	3.90	4.6
2	28	7.05	7.80

ADVANTAGES AND DISADVANTAGES OF BACTERIAL CONCRETE

Advantages of Bacterial Concrete:

- Self-repairing of cracks without any external aide.
- Significant increase in compressive strength and flexural strength when compared to normal concrete.
- Resistance towards freeze-thaw attacks.
- Reduction in permeability of concrete.
- Reduces the corrosion of steel due to the cracks formation and improves the durability of steel reinforced concrete.
- Bacillus bacteria are harmless to human life and hence it can be used effectively.

Disadvantages of Bacterial Concrete:

- Cost of bacterial concrete is double than conventional concrete.
- Growth of bacteria is not good in any atmosphere and media.
- The clay pellets holding the self-healing agent comprise 20% of the volume of the concrete. This may become a shear zone or fault zone in the concrete.
- Design of mix concrete with bacteria here is not available any IS code or other code.
- Investigation of calcite precipitate is costly.

CONCLUSION AND RESULTS:

Concrete plays a major role in the construction industry. For a durable structure, good quality concrete must be used. A Self Healing Concrete for the Future which says a common soil bacterium was used to induce calcite precipitation which is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural. The workability test of the bacterial concrete resulted in 90mm of slump value. We have found out that the compressive strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 13.07% and 13.75% respectively. Same way we have found out that the split tensile strength of the bacterial concrete with 10% and 20% of addition of bacillus sphaericus as 3.15% and 7.25% respectively. We have also casted a beam of size 500mm x 100mm x 100mm with 20% addition of bacillus sphaericus and made some tiny cracks by giving little load and the observation of the healing process of the crack is going on.

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