Self Healing Concrete by Eco Friendly Material (Urea)

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Abstract- *Concrete which forms major components in the construction Industry as it is cheap, easily available and convenient to cast. But drawback of these materials is it is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. The process of damage occurs in the early life of the building structure and also during its life time. Synthetic materials like epoxies are used for remediation .But, they are not compatible, costly, reduce aesthetic appearance and need constant maintenance. In this article we studied self-healing concrete by ecofriendly material. We studied on urease enzymes bacteria induced Calcium Carbonate (limestone) precipitation has been proposed as an alternative and environment friendly crack remediation and hence improvement of strength of building materials.*

Keywords- Self-healing, Micro-cracks, Bacteria, Hydration, Bacillus pasteurii. Etc.

I. INTRODUCTION

1. General:

Concrete which forms major components in the construction Industry as it is cheap, easily available and convenient to cast. But drawback of these materials is it is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. This process of damage occurs in the early life of the building structure and also during its life time. Synthetic materials like epoxies are used for remediation .But, they are not compatible, costly, reduce aesthetic appearance and need constant maintenance .Therefore bacterial induced Calcium Carbonate (calcite) precipitation has been proposed as an alternative and environment friendly crack remediation and hence improvement of strength of building materials.

2. Self-Healing Bacterial 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 0.1mm 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 cement particles present in the concrete matrix. Due to capillary forces water is repeatedly drawn into the 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.

3. Advantages of Using Bacteria in Concrete:

Around five per cent of all manmade carbon dioxide emissions are from the production of concrete, making it a significant contributor to global warming .Finding a way of prolonging the lifespan of existing structures means we could reduce this environmental impact and work towards a more sustainable solution.

- This could be particularly useful in earthquake zones where hundreds of buildings have to be flattened because there is currently no easy way of repairing the cracks and make them structurally sound
- Fills the crack in an efficient period of time so that the life period of a concrete structure can be expected over 200 years
- Prevents the use of cement in future used as a maintenance structure by drilling and grouting process, so in this way, less use of cement can be seen
- As we know more of cement content, more will be carbon dioxide gases released causing global warming, affecting the ozone layer .By using this bacteria, the structure does not need to be repaired except for the less cases and so results in less use of cement.

4. Objective :

1) Preparation of bacterial concrete by urease enzyme
2) Compression test on self healing concrete
3) Flexural test on self healing concrete
4) Spilling tensile test on self healing concrete
5) Corrosion test on self healing concrete

II. AUTHOR REVIEW

1) H. M. Jonkers

Conclusion: Main objective of this study was to establish whether bacteria immobilized in porous expanded clay particles prior to concrete mix addition can substantially increase bacterially-mediated self-healing in comparison to direct unprotected addition of bacteria to the concrete mixture as was done in a previous study. The results of this study appear promising as 100% healing.

2) Gandhimathi, N. Vigneswari, et.al

Conclusion: Main focus on cracks in concrete structures which will lead to less durability, Corrosion of reinforcement, leakage in liquid retaining structures. In main part of the research will focus on the topic, how can the right condition be created for the bacteria not only to survive in the concrete but to produce as much calcite as needed to repair the cracks. Hence it is not a living organism. But it will produce the calcite to reduce the cracks.

3) Chintalapudi Karthik, Rama Mohan Rao

Conclusion: The phenomenon formation of micro-cracks in concrete is common, this leads to costly maintenance. Concrete needs to be repaired. This causes degradation of concrete leads to ingress of deterious substances into concrete, results in deterioration of structures. To overcome these situations self-healing techniques are adopted. By the addition of urease producing bacteria along with calcium source results in calcite precipitation in concrete. Bio- mineralization techniques give favorable results in sealing the micro-cracks in concrete. The freshly formed micro-cracks can be sealed up by continuous hydration process in concrete.

III. METHODOLOGY AND INVESTIGATION

1. Main points:

1) Carbonatation process: Carbon dioxide from air can react with the calcium hydroxide in concrete to form calcium carbonate. This process is called carbonatation, which is essentially the reversal of the chemical process of calcination of lime taking place in a cement kiln. Carbonatation of concrete is a slow and continuous process progressing from the outer surface inward, but slows down with increasing diffusion depth

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3$$

2) Ureas : It is an enzyme that catalyzes the hydrolysis of urea into carbon dioxide and ammonia. The reaction occurs as follows:

$$(NH_2)_2CO + H_2O \longrightarrow CO_2 + 2NH_3$$

More specifically, urease catalyzes the hydrolysis of urea to produce ammonia and carbamate; the carbamate produced is subsequently degraded by spontaneous hydrolysis to produce another ammonia and carbonic acid. Urease activity tends to increase the pH of its environment as it produces ammonia, a basic molecule. Ureases are found in numerous bacteria, fungi, algae, plants and some invertebrates, as well as in soils, as a soil enzyme.

3) Calcium lactate: Calcium lactate is a black or white crystalline salt made by the action of lactic acid on calcium carbonate. It is used in foods (as an ingredient in baking powder) and given medicinally. It is created by the reaction of lactic acid with calcium carbonate or calcium hydroxide.

4) Bacillafill: The bacteria would be released as spores which would germinate upon coming into contact with the pH of concrete. Upon germination, the bacteria would descend into cracks in the concrete. The bacteria use quorum sensing to determine when enough bacteria have accumulated, triggering production of a mixture of calcium carbonate and ”bacterial glue", which combines with the bacterial cells to fill the crack. This mixture hardens to be as strong as the surrounding concrete.

IV. TESTS AND OBJECTIVES

1. Preparation Of Bacterial Solution:

- Primarily 12.5g of Nutrient broth (media) is added to a 500ml conical flask containing distilled water.
- It is then covered with a thick cotton plug and is made air tight with paper and rubber band.
- It is then sterilized using a cooker for about 10-20 minutes. Now the solution is free from any contaminants and the solution is clear orange in colour before the addition of the bacteria.

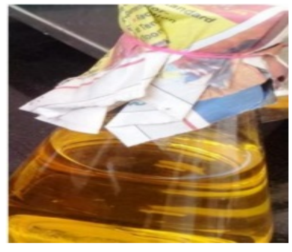

Figure 1. Solution without bacteria (only media)

- Later the flasks are opened up and an exactly 1ml of the bacterium is added to the sterilized flask and is kept in a shaker at a speed of 150- 200 rpm overnight.
- After 24 hours the bacterial solution was found to be whitish yellow turbid solution.

2. Compression Strength Test:

- The cubical Moulds of size 150mm x 150mm x 150mm were cleaned and checked against the joint movement. A coat of oil was applied on the inner surface of the Moulds and kept ready for the concreting operation.
- Mean while the required quantities if cement, fine aggregate and coarse aggregate (passing through IS sieve of 20 mm size and retained on 4.75 mm) for the particular mix are weighed accurately for concreting.
- Fine aggregate and cement were mixed thoroughly in a hand mixer such that the colour of the mixture is uniform.
- Now weighed quantity of coarse aggregate is added to the mixer and then it rotated till uniform dry mixture is obtained.
- Then, calculated quantity of bacterial solution and water was added and mixing was continued for about 3 to 5 minutes to get a uniform mix.
- The wet concrete is now poured into the Moulds and for every 2 to 3 layers and compacted manually. After concreting operations, the upper surface is leveled and finished with a mason's trowel.
- The corresponding identification marks were labeled over the finished surface and they were tested for 7 and 28 day strengths in a compressive strength testing machine.

- COMPRESSIVE STRENGTH = TOTAL FAILURE LOAD/AREA OF THE CUBE

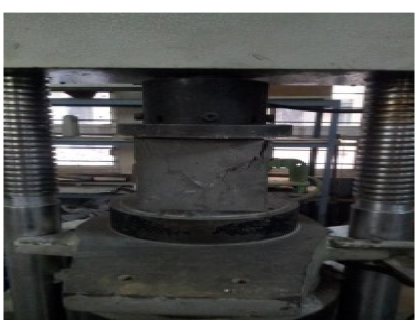

Figure 2. Concrete cube subjected to compression

3. Flexural Strength Test:

- Moulds of 10cm x 10cm x 50cm is used and the Moulds are cleaned and the joints between the sections of Moulds shall be thinly coated with Moulds oil and a similar coating of Moulds oil shall be applied between the contact surfaces of the bottom of the Moulds and the base plate in order to ensure that no water escapes during the filling.
- The interior faces of the assembled Moulds shall be thinly coated with Moulds oil to prevent adhesion of the concrete.
- Meanwhile the required quantities of cement, fine aggregate and corresponding coarse aggregate for the particular mix are weighed accurately for concreting.
- Fine aggregate and cement were mixed thoroughly in a hand mixer such that the colour of the mixture is uniform.
- Then, weighed quantity of coarse aggregate is added to the mixer and then it rotated till uniform dry mixture is obtained.
- Then, calculated quantity of water and bacterial solution was added and mixing was continued for about 3 to 5 minutes to get a uniform mix.
- The wet concrete is now poured into the Moulds in 2 to 3 layers and compacted manually.
- After concreting operations, the upper surface is levelled and finished with a mason's trowel.
- The corresponding identification marks were labelled over the finished surface and the beams were tested for 7 and 28 days strengths.

- FLEXURAL STRENGTH=Pl/b

P – Failure load of the specimen
l - Length of the specimen
b - Breadth of the specimen
d- Depth of the specimen

4. Resistivity Meter for Measuring Reinforcement Corrosion in Concrete:

The corrosion of steel in concrete is an electrochemical process that generates a flow of current. Resistivity of the concrete influences the flow of this current. The lower the electric resistance, the more easily corrosion current flow through the concrete and the greater is the probability of corrosion. Thus, the resistivity of concrete is a good indication of probability of corrosion. Resistivity Meter can measure the electrical resistance of reinforced concrete components. The probable rate of corrosion with respect to value of resistivity of concrete is normally considered as given in table below.

Table 1.

Resistively level (Kilo-ohm / cm)	**Possible corrosion rate**
< 5	Very high
5 to 10	High
10 to 20	Moderate to low
> 20	Insignificant

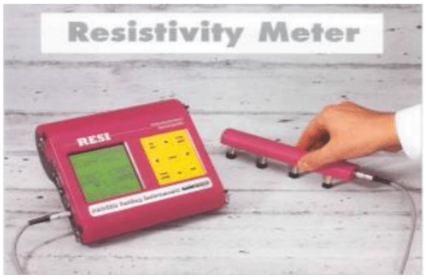

Figure 3. Resistivity level

To measure the resistivity, metallic probes are placed over the concrete surface. A known current is passed on the outer probes and resulting potential drop between inner probes is measured. The resistance is computed by dividing potential drop by the current. A conductive gel is used between probe and concrete surface to make effective contact.

5. Splitting Tensile Test of Concrete:

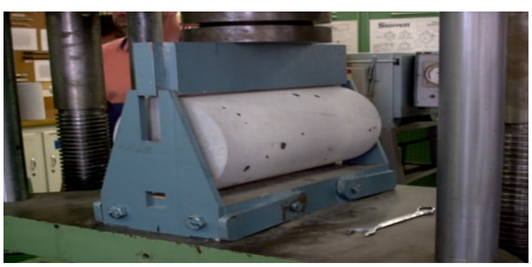

Figure 4.

The cylinder mould shall is of metal ,3mm thick. Each mould is capable of being opened longitudinally to facilitate the removal of the specimen and is provided with a means of keeping it closed while in use. The mean internal diameter of the mould is 15 cm ± 0.2 mm and the height is 30 +/- 0.1 cm. Each mould is provided with a metal base plate mould and base plate should be coated with a thin film of mould oil before use, in order to prevent adhesion of concrete.

Tamping Bar: The tamping bar is a steel bar of 16 mm diameter , 60 cm long and bullet pointed at the lower end.

Compacting of Concrete: The test specimen should be made as soon as practicable after the concrete is filled into the mould in layers approximately 5 cm deep. Each layer is compacted either by hand or by vibration.

Compacting by Hand :When compacting by hand, the standard tamping bar is used and the stroke of the bar should be distributed in a uniform manner. The number of strokes for each layer should not less than 30. The stroke should penetrate in to the underlying layer and the bottom layer should be rodded throughout its depth. After top layer has been compacted, the surface of the concrete should be finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation.

Curing of Specimen: The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. from the time addition of water to the dry ingredients. After this period the specimen should be marked and removed from the woulds and immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to the test. The water or solution in witch the specimen s are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.Concrete cylinder 15 cm diameter &3 0cm long.

NOTE

Cast 6 cylinders (3 for split test &3 for compression test).

- Procedure of Splitting Tensile Test:

1. Take the wet specimen from water after 7 days of curing
2. Wipe out water from the surface of specimen
3. Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
4. Note the weight and dimension of the specimen.
5. Set the compression testing machine for the required range.
6. Keep are plywood strip on the lower plate and place the specimen.
7. Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
8. Place the other plywood strip above the specimen.
9. Bring down the upper plate to touch the plywood strip.
10. Apply the load continuously without shock at a rate of approximately 14-21kg/cm2/minute (Which corresponds to a total load of 9900kg/minute to 14850kg/minute)
11. Note down the breaking load(P)

V. APPLICATION OF BACTERIA IN CONSTRUCTION AREA

- The use of microbial concrete in Bio Geo Civil Engineering has become increasingly popular.
- From enhancement in durability of cementations materials to improvement in sand properties, from repair of limestone monuments, sealing of concrete cracks to highly durable bricks, microbial concrete has been successful in one and all.
- This new technology can provide ways for low cost and durable roads, high strength buildings with bearing capacity, long lasting river banks, erosion prevention of loose sands and low cost durable housing.
- Another issue in conventional building materials is the high production of greenhouse gases and high energy consumed during production of these materials and these greenhouse gases leads to global warming.
- High construction cost of building materials is another drawback in such cases. These drawbacks have lead to use of novel , eco-friendly ,self-healing and energy efficient technology where microbes are used for remediation of building materials and enhancement in the durability characteristics.

Figure 5. application of bacterial concrete in construction area

VI. ADVANTAGES AND DISADVANTAGES OF BACTERIAL CONCRETE

1. Advantages:

1. Microbial Concrete in Crack Remediation: Specimens were filled with bacteria, nutrients and sand. Significant increase in compressive strength and stiffness values as compared to those without cells was demonstrated.
2. Improvement in Compressive Strength of Concrete: Compressive strength test results are used to determine that the concrete mixture as delivered meets the requirements of the job specification .So the effect of microbial concrete on compressive strength of concrete and mortar was studied and it was observed that significant enhancement in the strength of concrete and mortar can be seen upon application of bacteria
3. Better Resistance towards Freeze: Thaw Attack Reduction: Application of microbial calcite may help in resistance towards Freeze –thaw reduction due to bacterial chemical process and also it can reduce the permeability than freezing process decreased.
4. Reduction in Permeability of Concrete: Effect of microbial concrete on permeation properties was studied by different researchers .Permeability can be investigated by carbonation tests as it is increasingly apparent that decrease in gas permeability due to surface treatments results in an increased resistance towards carbonation and chloride ingress .Carbonation is related to the nature and connectivity of the pores, with larger pores giving rise to higher carbonation depths.
5. Reduction in corrosion of reinforced concrete: application of microbial calcite may ingress and improves the life of reinforced concrete structures

2. Disadvantages:

1. Cost of bacterial concrete is double than conventional concrete
2. Growth of bacteria is not good in any atmosphere and media
3. The clay pellets holding the self-healing agent comprise 20% of the volume of the concrete.
4. Design of mix concrete with bacteria here is no available any IS code or other code
5. Investigation of calcite precipitate is costly

3. Comparison Of Conventional And Bacterial Concrete:

1. Cost:

The cost of self-healing concrete is about double that of conventional concrete, which is presently about 5690/- rupees per cubic metre. At around 12800/- per cubic metre, self-healing concrete would only be a viable product for certain civil engineering structures. Presently the majority of the extra cost comes from the calcium lactate which is very expensive.

2. Quality:

where the cost of concrete is much higher on account of being much higher quality, for example tunnel linings and marine structures where safety is a big factor – or in structures where there is limited access available for repair and maintenance. In these cases the increase in cost by introducing the self-healing agents should not be too enormous.

3. Life of structure:

Added to this, if produced on an industrial scale it is thought that the self- healing concrete could come down in cost considerably. If the life of the structure can be extended by 30%, the doubling in the cost of the actual concrete would still save a lot of money in the longer term.

4. Future Growth:

Research is currently working on the development of an improved and more economic version of the bacteria-based healing agent which is expected to raise concrete costs only by a few rupees. If we focus on ecofriendly bacteria-based healing agent then we have large scale of reduction of cost.

VII. CONCLUSION

1. Bacterial concrete technology has proved to be better than many conventional technologies because of its eco-friendly nature, self-healing abilities and increase in durability of various building materials.
2. Work of various researchers has improved our understanding on the possibilities and limitations of biotechnological applications on building materials.
3. Enhancement of compressive strength, reduction in permeability, water absorption, reinforced corrosion have been seen in various cementitious and stone materials.
4. In bacterial concrete interconnectivity of pores is disturbed due to plugging of pores with calcite crystals. Since interconnected pores are significant for permeability, the water permeability is decreased in bacteria treated specimens.
5. Cementation by this method is very easy and convenient for usage. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.
6. The application of bacerial concrete to construction may also simplify some of the existing construction processes and revolutionize the ways of new construction processes.

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