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Research Article

Post Construction Cracks Repair by Spray Culture of Spore Bearing Non-Pathogenic Actinomycetes screened from VIT Vellore

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Abstract

The term concrete is the vital building material in construction civil engineering arena. When the external pressure and forces become predominant over the load design, compressive forces pave way for deterioration and produce cracks in the structural member. Commonly used technique for repair works is by chipping and applying mortar, epoxy grouting or demolish the structure and reconstruct it, which is not feasible for every individual. To overcome these problems of post construction cracks, we have come up with a way that aims to heal the micro cracks through microbial activity. Generally, many non-pathogenic spore forming *Actinomycetes* species contribute to the precipitation of mineral carbonates. Hence, their selection is very significant due to its compatibility with extreme surrounding and environmental conditions in concrete. We would be culturing some species of these *Actinobacteria* i.e. potential actinomycete The *Streptomyces* are soil bacteria that occupy about 5% of approximately 16,000 bacterial species which are reported earlier. About 80% of natural products that are biologically vital with medical uses are produced which made this genus a specific place in the microbial world (Chater, 2006; Wohlleben., *et al*. 2016) after sequence analysis based on sequencing of nucleotide sequence of 16SrRNA gene and it was successfully submitted to (Gene bank) with accession No: KM875468 which would heal the cracks that appear on old structures and monuments. Today, restoration of monuments and remediation of cracks in structures is one of the challenges in concrete which is mostly neglected and hence is our concern in this research study.

Keywords: Design Load; Compressive Forces; Disintegration; Mineral Carbonates; Non-pathogenic *Actinomycetes*

Figure 1: Pyrolysis products from microwave pyrolysis of agro-residue.

Highlights

Crack Formation in structures built of concrete.

Preparation and Spraying of *Actinomycetes* in cracks formed on concrete.

SEM Analysis of *Actinomycetes* that produce a firm deposition on concrete so as to heal the cracks.

NDT Tests will be employed on the concrete samples.

Introduction

In the recent era, researchers are focused on microbial self-healing processes for concrete crack repair because of its long-lasting capacity, cost-effective and eco-friendly. Buildings and infrastruc-

ture were affected by liquefaction which causes extensive damage (Kim., *et al.* 2017). Due to complexity and a variety of influential factors, interactions at the soil-reinforcement interface are not fully studied. The unorganized sectors are growing faster to work within the construction and make it inefficient. The opportunities are also less to makes it profitable from the perspective (Abdi and Mirzaeifar, 2017). The occurrence of cracks in concrete structures is inevitable. Micro cracks are normally formed in the building concretes. The development of cracks will minimize the ability to withstand extreme factors (Schlangen and Joseph, 2009). The factors which influence these cracks are dry shrinkage, aggregation due to alkaline reaction, deficient construction, the temperature difference in the concrete, design mistakes and leakage problems (Basheer., *et al*. 1996). Earlier studies showed that microbial potential of precipitation or surface repair in the enhancement of concrete persistence. The phenomenon of this precipitation is mainly due to the enzymatic reaction (De Muynck., *et al*. 2008; Jonkers., *et al*. 2010). The first patent filed on microbial assisted crack healing is studied on ornamental stone. The best results of this method inspired scientists to investigate substitute approaches and incorporation of different strains, methods for its best performance. The positive approach towards "bio-concrete" is mainly due to the bacterial activity to improve the crack healing process by induction of $CaCO_3$ precipitation. The self-healing process helps in decreasing the concrete structure repair and makes it cheaper (Wu., *et al*. 2012). The self-healing of cracks are advantageous by preventing the crack, leakage durability of structures can be retrieved (Tang., *et al*. 2015). Earlier studies have been carried out by utilizing microbial-induced carbonate precipitation to increase concrete robustness and it can increase the resistant towards environmental changes (Zhang., *et al*. 2017). Water leakage problem in concrete cracks can be prevented by autogenous crack healing by calcium carbonate precipitation have been reported (Joshi., *et al*. 2017). One of the earlier studies proposed that bacteria which were inoculated into the concrete were immobilized by a high alkaline reaction which results in minimization of the viability of spores and the ability to form compounds in old bacteria. They have reported that crack healed up to 0.46 mm-wide cracks while 0.18mm-wide cracks only get healed up in case of control specimens after the bacterial concretes are being submerged for 100 days (Wiktor and Jonkers, 2011). Wang., *et al*. (2014) investigate the encapsulation of bacterial spores for autogenous healing of concrete. The circumstances are more complicated in case of practical scenarios compared to the laboratory. The problems faced in this methodology after a long period of bacteria will decease inside concrete cracks during intolerable conditions and strengthen the concrete Structure is one of the most important component that showcases any country's infrastructure development, its course of history. But due to application of external compressive load that exceeds its limit load, the structure comes under threat of deterioration due to appearance of cracks. Post construction cracks are one of the major threats encountered by construction industry [11]. Integrity of a structural member is the essence of structural engineering that deals with the load bearing capacity of a structure, its ability to withstand a specific load designed without collapsing or disintegrating. In past few years, there have been instances of various structural failures of concrete structures wherein cracks posed to be a crucial/predominant factor for loss of structural integrity. Collapse of structures results in not only catastrophic loss of infrastructure, but it also triggers loss to the mankind in terms of injuries, death and monetary losses. In the recent past, historical buildings and monuments have been on the verge of deterioration due to presence of cracks owing to the structural failure and hence, need to be paid urgent attention to. For instance, The Great Wall of China, China is also under the same kind of peril. Various other structures e.g. Savar Building collapse, Bangladesh (2013), Thane building collapse, India (2013), Sampoong Department Store collapse, Korea (1995) have seen development of cracks and were neglected. The effect was immediately shadowed upon the world as a threat.

There are two modes by which cracks appear on structural members. One of the primary reasons of crack formation is plastic shrinkage on unhardened concrete which triggers off micro cracks in the post construction stage. Whereas, the other mode of failure occurs over the years due to static load and dynamic load such as the failure due to seismic forces actuating cracks in under-reinforced structural elements. Once cracks occur in any structure, it poses not a single threat but many. It exposes the reinforcement to the atmosphere, exposing to the risk of corrosion. Once corroded, the reinforcement is entitled to fail, hence pushing the structure towards its collapse.

Nowadays to counter these failures, restoration techniques are usually employed. Synthetic polymers such as epoxy resin, some grouting techniques etc. are being used for the repairs. The techniques available are epoxy grouting and retrofitting, where the latter is quite costly and on the other hand the use of epoxy resins poses to be baleful to mankind [7]. This leaves us in search of a better alternative.

A few years back, Self-healing bacteria got the undivided attention on the front of better alternative solution to cracks [8]. A lot of work has been done on self-healing concrete in which bacteria was added at the time of mixing itself. Some of the bacteria of genus Bacillus have been used. In their work they have mixed the bacteria along with calcium lactate (as vital nutrient for bacteria). This technique is capable of healing cracks that appear on new concrete only [12].

Our work focuses on old structures and monuments which have already been constructed in which non-pathogenic spore bearing *Actinomycetes* would be used to counter the crack formation [10]. The characteristic of being non-pathogenic, spore forming is instrumental in drafting a solution to be adapted in easily accessible parts of structures. If it is pathogenic in nature, it would pose high possibilities of the people getting into direct contact with the affected part and would impart great risk of infection and diseases.

Methods

The work would commence with the identification of the prime location of the hairline cracks or the internal micro cracks in the structural elements such as beams and columns as shown in figure 1a and 1b NDT techniques would be used to do so. After identification of the crack's location in the member or on the surface of the member, we would spray screened potential *Actinomycetes* so as to have better interpretation of the possible crack repair mechanism [2].

Collection of material and screening of *Actinomycetes*

The concrete specimen cubes (100 mm x 100 mm x 100 mm) and cylindrical specimens (100 mm x 200 mm) using M20 grade of concrete are to be casted. After curing over a period of 7 days and 28 days respectively, the compressive strength would be tested in the Compressive Testing Machine (ASTM C39). The cracked concrete cubes would be subjected to spray culture technique using spore bearing non- pathogenic *Actinomycetes*.

For the isolation of organisms, soil samples collected from different places of fruit industries would be used. The superficial loose soil layers would be removed and the underlying soil sample would be dug. The samples would be collected in polythene bags, labeled and would be transported to the laboratory and screened**.** Soil is a good source of microorganisms due to nutrient-rich environments, where there is a high proliferation of microorganisms. For preparing the solution to heal cracks, we would be using *Actinomycetes* in the solution of carbohydrates which would act as a prime source of food [6]. The media would be consisting of spore bearing non-pathogenic *Actinomycetes* basophilic and thermophilic, which are supposed to survive in the highly alkaline medium in range of 12 to 13.5 pH and a temperature up to 57^0 C. *Actinobacteria* feed on carbohydrates and they start to germinate in this medium [6]. This reaction would cause carbonate precipitation after which they would combine with the surrounding $Ca^{(2+)}$ ions and ultimately they would seal the surface of the structural member [4]. After this, we would again test the member using NDT. The difference in results will form a basis for a comparative study after designing suitable media.

Figure 2: Screening of potential *Actinomycetes* by baiting technique.

The prepared cultures were inoculated into the CSPYME media (100 mL) for pectinase yield and kept for incubation at 30°C, 100 RPM for 72 hrs. The culture was sprayed after the spore formation was observed.

CSPY-ME Media composition with inoculation strategies

K_2HPO_4 0.51, casein 3.0, starch 10.0, peptone 1.5, yeast extract 1.0, pectin 1.0, malt extract 10.0 g l^{-1} in an Erlenmeyer flask and then incubated for three days under agitation 100 rpm at 28 ± 2°C.

Reaction involved

CO_2 (g) ↔ CO_2 (aq.)

CO_2 (aq.) + H_2O ↔ H_2CO_3

H_2CO_3* ↔ H^+ + HCO_3^-

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$

With H_2CO_3* = CO_2 (aq.) + H_2CO_3

Comparison

The specimens undergoing cracks will be subjected to spray culture. After the application of the *Actinomycetes* and the expected disappearance of cracks, the same specimens would undergo several tests [3]. For ensuring of better crack repair mechanism, we would be conducting tests in two stages. One would be Compressive Strength Test and the other would be Ultrasonic Pulse Velocity Test [9]. As time passes by, Compressive Strength would form a basis of comparison to check the variation in strength before and after application of the spray culture. Whereas, Ultrasonic Pulse Velocity Test would be a non-destructive test on hardened

concrete which would tell us about the intensity of cracks present in the structure [1]. The structure before and after application of *Actinomycetes* would be undergoing these tests. Corresponding to the results noted, a comparative study would be done.

Economics

The overall technique would be quite cheaper than the available methods. Using starch as medium would have influence on overall cost of this post construction repair technique. This would save immensely the cost of reconstruction and would extend the life of structures.

Results and Discussion

Our work would provide a method which is applicable for structures that have already being constructed and are on the verge of threat of collapse. Our work has the capability to heal the post construction cracks present on old structures and monuments through microbial activity [5]. The material would be consisting of bacteria which is non-pathogenic is nature, that could survive in harsh concrete medium for long time. By simply applying the liquid on the affected cracked sites, it would heal the cracks and provide a smooth firm surface through precipitation of carbonated minerals. The effectiveness of the repairs work would be confirmed again by conducting NDT tests. The aim is that the material should be within the reach of common man. This would also be a better way of repairing old monuments, as for them, mortar repairs techniques are not an aesthetically effective solution.

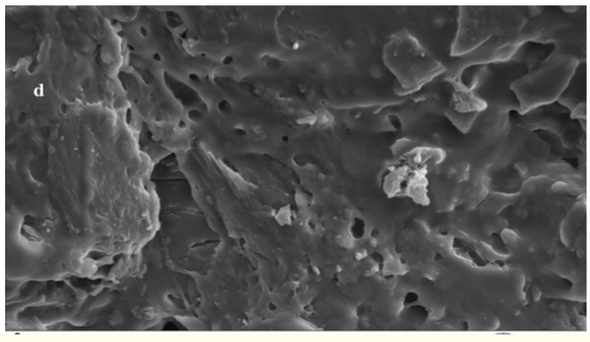

Figure 3: SEM analysis of cracks repair mechanism.

The viability of actinomycete endospores present in cement was investigated by inoculating endospores into cement simultaneously with the inclusion of water. Spore survivability in the cement paste was analyzed by total number of viable spores after 93 days. The isolate (1g) was granulated utilizing motor and pestle, vortexing was carried out to improve separation of spores. The serial dilution of culture (1ml) were carried out with sterilized Tris-HCl buffer. (Wiktor and Jonkers, 2011).

Figure 4: Phase-contrast microscopic view of isolated *Actinomycetes.*

Figure 5: Sporulation (%) determined with stained spores.

Figure 6: Survivability of Actinobacterial spores in bio-concrete.

Figure 7a: Cracks formed on the cement paste.

Figure 7b: Demonstration cracks repair healing by spray culture of spore bearing non-pathogenic *Actinobacteria* screened from VIT Vellore.

Conclusion

Our method is different from previous research as their work focuses on new concrete. The other methods which are available for post construction cracks repairs are costly, harmful to user. But this cracks repair method would be cheaper and effective than available repairs methods like epoxy resin method. *Actinomycetes* when sprayed on cracked sites would be able to heal the post construction cracks and finally repairs them. The structure which would be subjected *Actinomycetes* would have less or no cracks and would be confirmed by the tests performed.

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