Comparative Study on Improvement on the Concrete Cracks by Using Bacillus sphaericus With Fly Ash and ennore Sand

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Abstract- **Cracks are one of the naturally weaknesses of concrete and they are irreversible. Bacillus Sphaericus, a common soil bacterium induce the precipitation of calcite exhibited its positive potential in selectively consolidating simulated fractures in the consolidation of sand. A compression strength tested on mortar cubes treated with bacteria were studied. The effect of different depth of crack on the compression and flexural of concrete was studied. It was found that all the increase in depth of crack reduce the strength of cubes and beams improved by Bacillus Pasteruii.**

***Index Terms*—Bacterial Concrete, Bacillus Sphaericus, Crack Repair, Self-Healing Concrete**

I. Introduction

Concrete is mostly used artificial material used in the construction industry. Concrete will continue to be the most important building material for infrastructure. All concrete structure prone to cracks due to temperature gradients, confined shrinkage, imposed deformations, differential settlement, External loads, atmospheric reactions, expansive reactions, etc. Small cracks on the surface of the concrete make the whole structure vulnerable. In the case of historic buildings and monuments, these cracks are inevitable and destroy the whole structure. Water and other salts seep through these cracks, corrosion initiates, and thus reducing the lifespan of concrete. Without immediate and proper treatment, cracks tend

Fig – 1 Bacillus Sphaericus
(Image Courtesy - AMBERGENE CORPORATION)

Fig 2 compression test setup

To expand further and eventually require costly repair. Durability of concrete is also impaired by these cracks, since they provide an easy path for the transport of liquids and gasses that potentially contain harmful substances. If micro-cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded when it is exposed to water and oxygen, and possibly carbon dioxide and chlorides. Micro-cracks are therefore precursors to structural failure [1].

In 1995, Gollapudi et al. ([2] as quoted by [3]), were the first to introduce this novel technique in fixing cracks with environmentally friendly biological processes. Bacterially induced calcium carbonate precipitation has been proposed as an alternative and environmental friendly crack repair technique. Bacillus Sphaericus produces urease, which catalyzes urea to produce CO_2 and ammonia, resulting in an increase of pH in the surroundings where ions Ca_2^+ and CO_3^{2-} precipitate as $CaCO_3$.

The first three factors are provided by the metabolism of the bacteria while the cell wall of the bacteria will act as a nucleation site [4].Possible biochemical reactions in medium to precipitate $CaCO_3$ at the cell surface that provides a nucleation site can be summarized as follows.[5]

$$CO(NH2)2 + H2O \leftrightarrow NH2COOH + NH3$$
$$NH2COOH + H2O \rightarrow NH3 + H2CO3$$

Fig. 4 – Inserting paste of Bacillus Sphaericus mixed with Fly ash in cracked portion

$H_2CO_3 \leftrightarrow HCO_3^- + H +$
$2NH_3 + 2H_2O \leftrightarrow 2NH^4+ + 2OH^-$
$HCO_3^- + H + + 2NH_4+ + 2OH^- \leftrightarrow CO_3^{2-} + 2NH_4+ + 2H_2O$
$Ca^{2+} + Cell \rightarrow Cell\text{-}Ca^{2+}$
$Cell\text{-}Ca^{2+} + CO_3^{2-} \rightarrow Cell\text{-}CaCO_3 \downarrow$

II. EXPERIMENTAL PROGRAM

A soil bacterium, Bacillus Sphaericus was obtained from national chemical laboratory. It forms irregular dry white colonies on nutrient agar. The culture is introduced into nutrient broth of 25 ml in 100 ml conical flask and the growth condition are maintained at 37^{o}C temperature and placed in 130 rpm orbital shaker for 24 hours. The concentration of cells (10^9 cells/ml) of water was maintained.

A. Compressive strength study

Mortar samples were made by using ordinary Portland cement. The composition of the mortar mix is Cement and Ennore sand ratio is used as 1:3 (by weight). Moulds with dimensions of 70.6 mm× 70.6 mm× 70.6 mm. After casting, all moulds were placed in a normal temperature of room with a relative humidity of more than 90% for a period of 24h. After de-moulding, the specimens were placed for the curing for 28 days. At 28th day artificial cracks depth of 15 mm, 20 mm and 25 mm were developed by marble cutter on the upper surface as shown in figure-3. In that cracks paste of Bacillus Sphaericus mixed with Ennore sand and Fly ash inserted as shown in figure-4. After that bacteria's (Bacillus Sphaericus) were feed P-Urathine (food – Urea based) at every 6 hours interval for 28th days as shown in figure - 5. And After it Compression test carried out at 7th, 28th and 56th day.

B. Flexural strength study

Concrete Beams grade M20 were made by using ordinary Portland cement. Moulds with dimensions of 500 mm× 100 mm× 100 mm. After casting, all moulds were placed in a normal temperature of room with a relative humidity of more than 90% for a period of 24h. After de-moulding, the

Fig. 5 applying food to Bacillus Sphaericus with pipette

specimens were placed for the curing for 28 days. At 28th day artificial cracks depth of 10 mm, 20 mm and 30 mm were developed by marble cutter on the upper surface. In that cracks paste of Bacillus Sphaericus mixed with Ennore sand and Fly ash inserted. After that bacteria's (Bacillus Sphaericus) were feed P-Urathine (food – Urea based) at every 6 hours interval for 28th days after that Flexural test carried out at 28th and 56th day.

C. Durability study

After 28 days of casting, each cube is tested for weight an accelerated experimental test program is conducted on ordinary Portland cement concrete. The specimens are arranged in such a way that the clearance around and above the specimen is not less than 30 mm. The solution has been changed for an interval of every 15 days .Before testing; each specimen is removed from the tubs, and brushed with a soft nylon brush and rinsed in tap water. This process removes loose surface material from the specimens. The percentage weight loss, percentage compressive strength loss is taken for a set of cubes at 56 days.

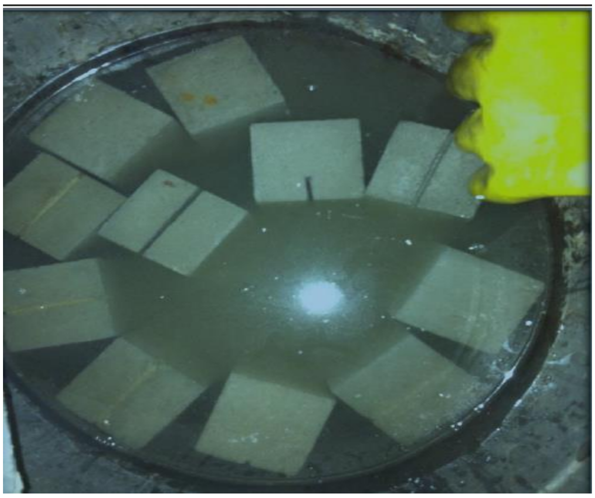

Fig. 6 Mortar cubes immersed in $MgSo_4$ Solution for Durability test

III. TEST RESULTS

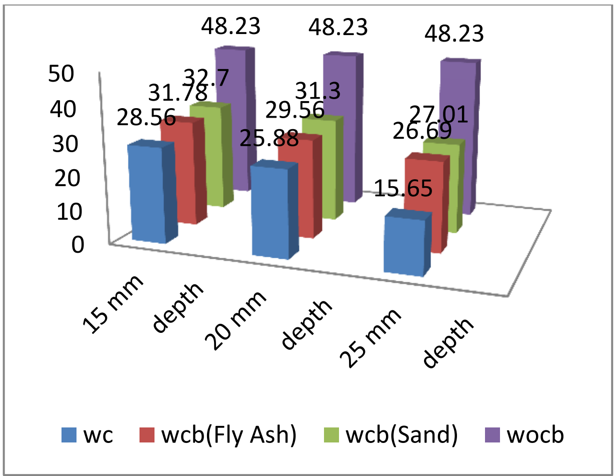

Chart – 1 Compressive Strength at 7th day

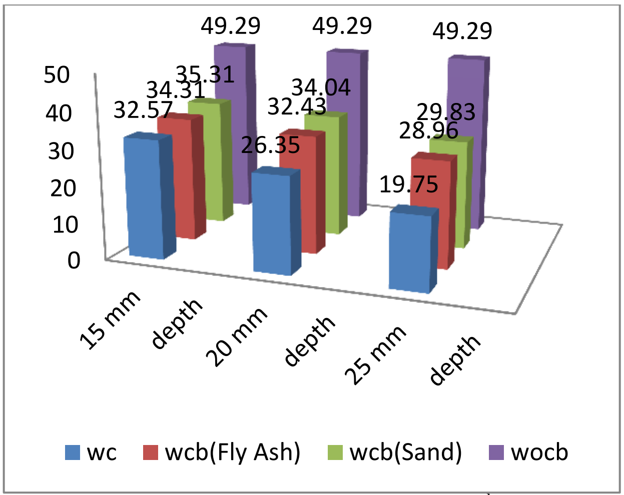

Chart – 2 Compressive Strength at 28th day

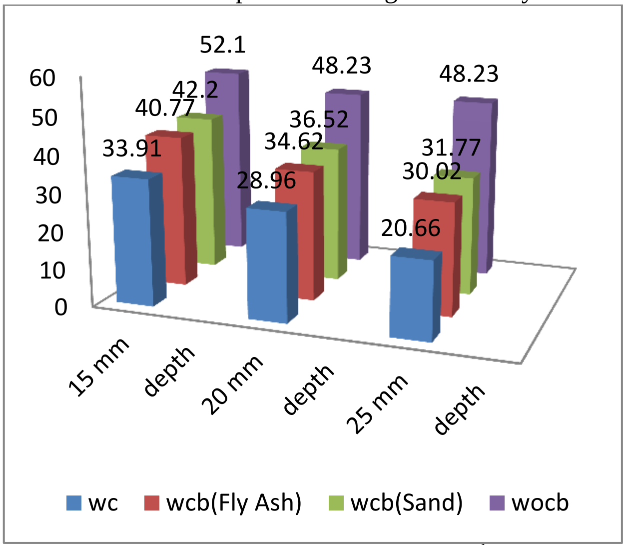

Chart – 3 Compressive Strength at 56th day

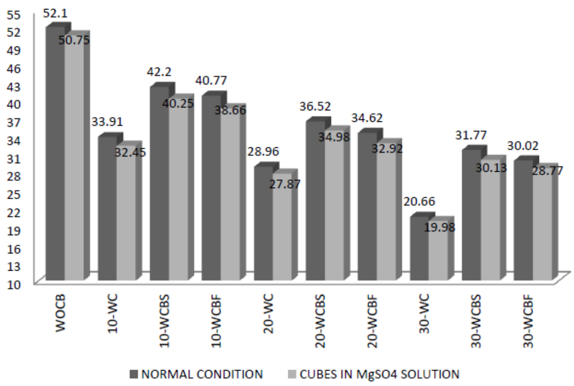

Chart – 4 Compressive strength loss after durability test(N/mm^2)

Type	P (kN)	f_{cr} (N/mm^2)
wocb	16.67	6.67
wc-10	11.67	4.67
wcbs-10	12.31	4.92
wcbf-10	12.02	4.81
wc-20	10.67	4.27
wcbs-20	11.33	4.53
wcbf-20	10.98	4.39
wc-30	9.67	3.87
wcbs-30	10.29	4.12
wcbf-30	10	4.00

Table – 1 Flexural Strength at 56th Day

IV. Discussion

Depth of cracks, Number of days applying food to bacteria, type of material mix with bacteria in cracked portion are the factors affecting the improving strength of concrete. The lesser the depth of crack improvement in compressive strength is more.

V. Conclusions

From the experimental program improvement of the Compressive strength as well as flexural strength reduces with the finer material mixed to fulfill the crack portion. Fly ash is finer than Ennore sand, so improvement in strength due to Mix with Fly ash is compared to less than mixes with Ennore sand. It might be because of at the greater depth bacteria might not be proper contact with air due to less voids. The use of this biological repair technique is highly desirable because the mineral precipitation induced as a result of microbial activities is pollution free and natural.

VI. Acknowledgment

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