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Comparative Study on Self-Healing Concrete Using Bascillus Bacteria by Encapsulation Method

K.Vijaya Sundravel[1] , M. Jagadeshwaran[2]

Department of Civil Engineering, K.S.Rangasamy College of Technology, Tamilnadu, India

Department of Civil Engineering, K.S.Rangasamy College of Technology, Tamilnadu, India

ABSTRACT: In this study the characterization of Bacillus Bacteria and strengthening characteristic of GFRP sheets are investigated. And also ,the optimal percentage of Bacillus Bacteria is determined from the tests of mechanical properties. The specimens are casted based on the percentage of replacing Bacillus Bacteria in cement. The replacement of Bacillus Bacteria in cement is 0%, 10%, 20%, 30% 40%, 50% by Encapsulation Method. Totally 24 cubes are casted out of these 3 cubes for each percentage are taken for each test. After 28 days the compressive strength was finding out from the cubes. From the compressive strength test the optimum percentage of Bacillus Bacteria is concluded as 20%. Based on these result columns are casted. Totally 12 columns are casted out of these columns 6 columns are conventional and 6 columns are Bacillus Bacteria replace columns. The axial compressive strength test was carried on 3 conventional and 3 Bacillus Bacteria replaced column to find out the ultimate load carrying capacity. From this ultimate load 70% of load is given to the remaining columns as a preloading. After specified preloading these columns are strengthened by using GFRP sheets and also by Bacteria. The strengthened columns are tested by axial compression test. By this result the Maximum load carrying capacity, deflection, stiffness, and energy absorption of column is determined.

KEYWORDS: Bacillus Bacteria, GFRP sheets, Encapsulation, Preloading, anarobic.

I. INTRODUCTION

A.BACILLUS BACTERIA

Bacillus, (genus Bacillus), any of a cluster of rod-shaped, gram-positive, aerobic or (underneath some situations) anaerobic bacteria broadly found in soil and water. The bacillushas been very much useful in aoverall sense to all tubular or polelike bacteria. The prime known Bacillus species, B. megaterium, is about 1.5 µm (micrometres; 1 µm = 10^{-6} m) across by 4 µm long. Bacillus regularly occur in shackles.

In 1877 German botanist Ferdinand Cohn provided an imposing an explanation of two dissimilar forms of hay bacillus (now known as Bacillus subtilis): one that could be slain upon revelation to warmth and one of that has resistant to heat. He called the heat-resistant forms “spores” (endospores) and naked that these dormant forms could be converted to a vegetative, or actively growing, state. Today it is known that all Bacillus species can form resting spores under adverse conservational conditions. These endospores may continue anfeasible for long periods of time. Endospores are hardly resistant to heat, chemicals, and sunlight and are generallydisseminated in nature, mostly in soil, from which they invade sandparticles. Some kinds of Bacillus bacteria are injurious to humans, plants, or other creatures. For illustration, B. cereus occasionally causes decomposition in canned foods and food poisoning of short duration. B. subtilis is a common pollutant of research laboratory cultures (it plagued Louis Pasteur in many of his experiments) and is frequently found on human skin. Most strains of Bacillus are not pathogenic for humans but may, as soil creatures, taint humans parenthetically. A noteworthy exception is B. anthracis, which causes diseases and anthrax in humans and domestic animals. B. thuringiensis genrates a toxin (Bt toxin) that causes disease in insects. This in turn reduces the cracks in the structures

B. GLASS FIBER REINFORCED POLYMER (GFRP) SHEETS

Glass fiber is called as fiber glass which is completely made from extremely fine fiber of glass fibreglass is light weight, tremendously strong, and robust material. The glass fiber reinforced polymer is divided into three types. They are

- Chopped Strands Mat (CSM)
- Uni-Directional Cloth (UDC)

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- Woven Roving (WR)

Continuous fiber reinforced materials with polymeric matrix (FRP) can be measured as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behavior up to failure. Generally, Glass and Carbon fibers are castoff as reinforcing material for FRP. Epoxy helps as the binding material in between fiber layers. For this study, GFRP sheet was used during the tests i.e., a bidirectional FRP with the fibre oriented in both longitudinal and crosswise directions, due to the elastic nature and comfort of handling and application, the FRP sheets are used for shear strengthening. Throughout this study, E-glass was also used.

The FRP strips are dropdown at the bottom (tension) zones for strengthening of slab. The strengthening result in better flexural performance, until the tensile resistance of the slabs is taken by the tensile strength of FRP. The effectiveness of FRP strengthening mainly depends on the performance of the resin chosen for bonding. The one side bonding or U-wraps is useful for strengthening of member in shear zone. The columns are wrapped with FRP around their boundary, as with fully closed or complete wrapping. This solidification results in higher shear resistance and itoutcomes in increased compressive strength under axial loading. The polymerization or addition of polymerization is commonly used to produce the polymers. The procedure of changing the material properties or collective with various agents of polymers the result is stated as a plastic. The composite plastics used the fiber materials to enhance the strength and elasticity of plastics and the fibre-reinforced plastics are under this category. The matrix referred to as original plastic material without fiber reinforcement. They are tough but relatively weak plastic that is enhanced by stronger stiffer reinforcing filaments. The fiber-reinforced plastic strength and elasticity depends on the properties are the matrix, their volume relative to one another, fiber, fiber length and orientation within the matrix. A laminated structure is used to characterise the two dimensional fibre-reinforced polymers by in which the fibres are only aligned along the plane in y-direction and x-direction of the material. This means in z-direction that no fibres are aligned in the through thickness, this lack of alignment on through thickness can cause a disadvantage in processing and cost. The conventional processing techniques used to fabricate composites cause the costs and labour increase, such as, autoclave and resin transfer moulding, wet hand lay-up, require a high amount of capable labour to mound, cut and merge into a preformed component. The three dimensional fibre componentintegrate fibres in the all three directions. The manufacturing of three-dimensional orientations from industry's need to reduce fabrication costs, to improve impact damage tolerance and to increase through-thickness mechanical properties, all were problems associated with two dimensional fibre-reinforced polymers.

Depending on the degree of strengthening and exposed faces of the member FRP can be applied in several configurations, this includes: U-wraps (U-jackets), and side bonding, closed wraps (complete wraps). Side bonding involves FRP applying to the sides of the beam only. The minimum amount of shear strengthening becauseof failures instigated by de-bonding from the surface of concrete at the free edges in FRP. The FRP is applied continuously in a 'U' shape around the sides and bottom (tension) face of the beam in the U wrap. The use of closed wraps is desirable as they provide the most strength enhancement if all faces of a beam are accessible. Closed wrapping involves FRP applying around the entire perimeter of the member, such that there are no typical failure mode is rupture of the fibres and free ends. The FRP can be applied along the length of the member as a discrete strips or continuous sheet as, having a minimum spacing and width for all wrap configurations.From the literature study the points taken as,

1. The workability of concrete increases due to replacement of BACILLUS Bacteria with cement.
2. The setting time of concrete is increased.
3. The corrosion resistance property of concrete is drastically increased.
4. From the above investigation results, it is verified that GGBS can be used as an one of the alternative materials for cement which reducing cement consumption and reducing the totalcost of construction.
5. And also it makes Eco friendly materials.

II. REVIEW OF LITERATURE

1. International journal of civil engineering and technology (Feb 2017):

To remediate the structural failure due to cracks and fissures, an approach of using bio mineralization in concrete has evolved in recent years. In this method of enhancing the performance of concrete the calcite precipitating spore forming bacteria is introduced into concrete. when water enters into the cracks it reacts with bacteria is introduced into concrete .when water enters into the concrete , it reacts with bacteria and forms precipitates of calcium carbonate , as a by-product , which fills the cracks and makes crack free concrete.

2. *Cement and Concrete Research, Kim Van Tittelboom(2016):*

As synthetic polymers, currently used for concrete repair, may be harmful to the environment, the use of a biological repair technique is investigated. Ureolytic bacteria such as bacillus spahaericus are able to precipitate $caco_3$ in their micro environment by ammonium and carbonate.

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3. ***Self -healing concrete repairs itself with bacteria, Ashley P.taylor (2014):***

Concrete cracks for many reason, just for starters, the heating and cooling of changing seasons make it expand and contract and the stress produced can also cause cracks. But Dutch researchers are testing a new way to deal with a problem of cracking concrete. Bacteria that when exposed to water, from limestone.

III. METHODOLOGY OF STUDY

The methodology of the project work is shown in fig.1. This is discussed below.

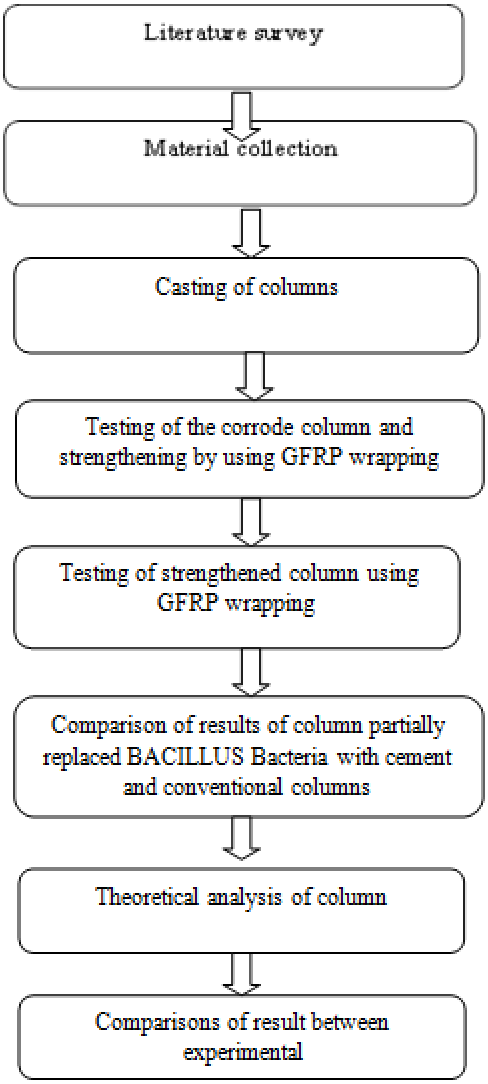

Fig.2.1 Methodology for the project

Fig 2.1 Methodology

IV. MATERIAL SPECIFICATION

The ingredients used to cast the specimen are described in this chapter. The material to be collected is cement, fine aggregate, coarse aggregate, steel reinforcement, BACILLUS BACTERIA and GFRP sheets.

A.Concrete

Concrete mix design is to be used for casting the specimen. M_{20} grade of concrete is chosen for the column specimen with characteristics compressive strength(fck) of 20 N/mm^2. The designed mix proportion is 1:1.48:2.91. The material for productionof concrete are selected as follows.

B. Cement

Ordinary Portland cement 53 grade with specific gravity of 3.15 is to be used.

C. Fine Aggregate

The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.65. The grading zone of fine aggregate was zone II as per Indian standards specification (IS 383).

D. Coarse Aggregate

The maximum size of coarse aggregate used for his investigation is 20mm and the specific gravity is 2.7.

E. Water

Water should be potable and free from acids, oils, alkalies and other organic impurities.

F. Reinforcement

High Yield Strength deformed(HYSD) bars of 12mm diameter are used as longitudinal bars for column. The lateral ties are used to be 8mm diameter.

G. BACILLUS BACTERIA

The BACILLUS BACTERIA used to make specimen should be passed through 1 ml as casules. The specific gravity of BACILLUS Bacteria is 3.12.

H. Properties of BACILLUS Bacteria and cement

Chemical composition

BACILLUS Bacteriacontains mainly of CaO, SiO_2, $AL2O_3$, MgO, and forms C-S-H gel. It holds less than 1% crystalline silica, and consist of less than 1 ppm water soluble chromium 1V. It shows the same main chemical constituents as ordinary Portland cement, but in the different proportion. The chemical composition of BACILLUS Bacteria is shown in table 3.1.

Table 3.1 Chemical compositions of BACILLUS Bacteria and CEMENT

Chemical composition	**Portland cement**	**BACILLUS Bacteria**
CaO	65%	40%
SiO_2	20%	35%
AL_2O_3	5%	10%
MgO	2%	8%

Sincechemical similarities of the BACILLUS Bacteriaare as same it can be replaced for Portland cement mixes by as much as up to 95%.

I. Physical properties

The physical properties of BACILLUS Bacteria are shown in the table 3.2.

Table 3.2 physical properties of BACILLUS Bacteria

Physical properties	**BACILLUS Bacteria**
Color	Off white powder
Bulk density(loose)	1.0-1.1 tons/m^3
Bulk density(vibrate)	1.2-1.3 tons/m^3
Surface area	400-600m^2/kg
Specific gravity	3.14
Soundness	3.5
Initial setting time	150 min

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J. *GFRP Sheets*

In the thesis, Chopped Strands Mats (CSM) are castoff for the strengthening process.

Fig 3.1 GFRP sheet

K.Epoxy Resin

In this thesis the GP resin is used to make the binding between the column and GFRP sheets. Previously, binding the resin is mixed with the
accelerator and the catalyst. The strengthening behaviour is mainly depends on the resin binding capacity.

Fig.3.2 GP resin

Table 3.3. properties of GP resin

Property	**Units**	**Standard value**
Apperance		Light yellow/ clear
Viscosity @ 30˚c	Ford cub 'b4' in seconds	45- 70
Acid value	Mg KOH/g	< 28
Volatile contant	%	33-38
Specific gravity		1.08-1.15

IV. COMPRESSIVE STRENGTH RESULTS

The cubes are fabricated to determine the optimum percentage of BACILLUS Bacteria. Totally 24 cubes are casted. The BACILLUS Bacteria replaced with cement is 0%, 10%, 20%, 30%, 40%, 50%. As capsule. The 4 cubes are casted for each percentage of replacement. The mean value is find out from the 3 cubes for each percentage of replacements. The mean compressive strength is shown in the table 3.4.

Type of concrete	**Crushing load (kg)**	**Compressive strength N/mm2**
Control concrete	954	28.27
10% BACILLUS Bacteria	982	29.11
20% BACILLUS Bacteria	1099.9	32.59
30% BACILLUS Bacteria	1042.8	30.90
40% BACILLUS Bacteria	1019.25	30.20
50% BACILLUS Bacteria	936.2	29.0

Table 4.1. Compressive strength of BACILLUS BACTERIA

From the compressive strength result the optimum percentage of BACILLUS Bacteria replaced with cement is found out as 20%. Based on this result the columns are casted.

V. SPECIMEN DETAILS

Entirely 12 columns has been casted in which 6 is control column specimen. And another 6 columnis of BACILLUS Bacteria partially substituted in place of cement. This Column is designed as short columns. A square cross section is implemented for this column with a traverse dimension of 100mm x 100mm. The Span of the column is 600mm. All the columns are tested under axial compression test. The extreme diameter of longitudinal bar the column is taken as 12mm diameter and 8mm for ties are used.

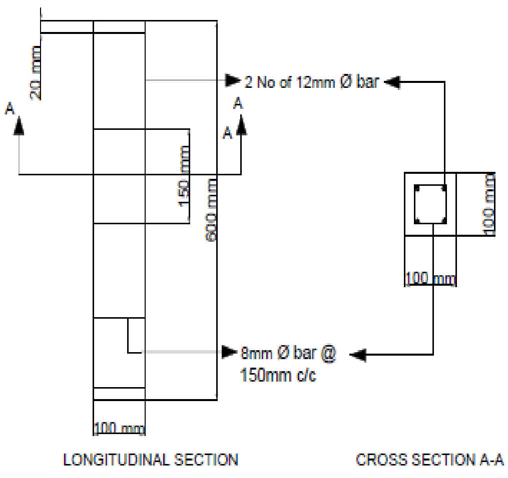

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Fig.5.1. Longitudinal and cross section detailing of compressive member

A. *Experimental Test Setup for Specimens*

A totally12 columns were castedand Out of 12 Columns the six columns are casted as a conventional column and six were casted based on optimum percentage of BACILLUS Bacteria. Altogether the columns are tested for compression in universal testing machine (UTM) of capacity 1000 kN. The two LVDT is used for testing process. The LVDT's are used to find out the lateral deflection and the buckling of the columns. The loads are gradually increased up to the ultimate load carrying capacity of the column. The load vs deflection graph is shown in the curve 5.6 and 5.7.

Fig 5.2. Testing of conventional R.C column

Fig 5.3 Testing of BACILLUS Bacteria replaced R.C column

Fig 5.4 Testing of GFRP wrapped BACILLUS Bacteria column

Fig 5.5. Testing of GFRP wrapped conventional column

The 4 conventional and BACILLUS Bacteria replaced columns are tested up to ultimate load. The preloading is given to another 4 conventional and BACILLUS Bacteria replaced columns. Once preloading is given then they are strengthened by using GFRP sheets. The strengthening characteristics of the GFRP sheets are found out from the columns. The graph 5.1 shows the ultimate load carrying capacity of the conventional and BACILLUS Bacteria replaced columns.

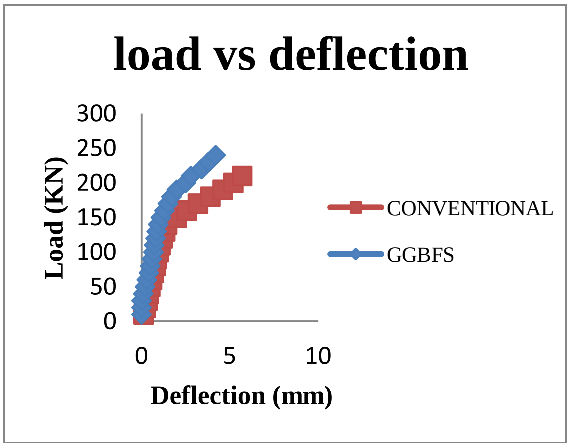

Fig.5.6. Ultimate load vs. deflection for conventional and BACILLUS Bacteria replaced columns.

The BACILLUS Bacteria replaced column gives the strength more than the conventional column. The BACILLUS Bacteria replace column gives load carrying capacity more than the conventional column and also the deflection is reduced than the conventional column. Other four conventional and BACILLUS Bacteriasubstituted columns are given to a preloading (70% of ultimate load). After given preloading they are strengthened by using GFRP wrapping. The GFRP wrapped columns are tested by axial compression test. The load carrying capacity and the deflection are found out from this test.

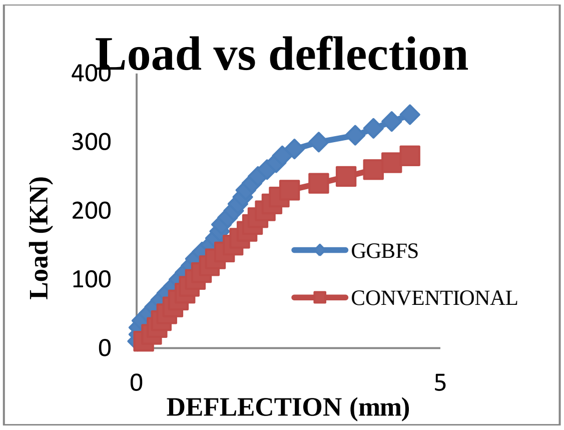

Fig. 5.7. Ultimate load vs. deflection for strengthened conventional and BACILLUS Bacteria replaced columns.

The above graph shows the maximum load carrying capacity is more than the conventional column. From these results concluded the BACILLUS Bacteria replaced column gives the better results than conventional column.

VI. CONCLUSION

From the examined result the succeeding points are concluded,

1. The cubes testing results shows the optimum percentage of BACILLUS Bacteria with cement is 20%.
2. The substitution of BACILLUS Bacteria with cement by capsules minimize the concrete cost. The economy concrete will be produced due to replacement of BACILLUS Bacteria with cement.
3. The compressive strength of controlled concrete is 28.27 N/mm^2. The compressive strength of conventional concrete is32.59 N/mm^2.
4. The columns were casted based on the optimum percentage of BACILLUS Bacteria.
5. The axial compression test is conducted on the all columns to find out the ultimate load carrying capacity of column.
6. The LVDT is used to find the lateral deflection of the columns. Based on these values the load deflection curve is plotted.
7. The BACILLUS Bacteria replaced column load deflection curve shows the ultimate load carrying capacity is high and the deflection is lower than the conventional column.

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