MICROBIAL CARBONATE PRECIPITATION IN RECYCLED AGGREGATES FOR ENHANCEMENT OF THE STRENGTH OF CONCRETE

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Abstract: ***A huge amount of water wastage reflecting the environmental degradation is the main drawback of usage of recycled aggregates in concrete which on contrast is used for the idea of preventing vulnerability of environmental degradation by decreasing the concrete as to decrease dumping sites of concrete waste.***
The another important environment friendly aspect is of the self-repairing properties of Microbial concrete which nowadays attracts the attention of researchers. A novel strategy that restores or remediates proposed structures is bio-deposition method of calcium carbonate using bacteria, such as those in the genus of the Bacillus species.
Treatment of the recycled aggregates in the bacterial culture and nutrients for its survival to be done. After this we will see the changes due to bacteria in aggregates. After studying the effect - Experiments to be carried out on the concrete made up of optimum replaced recycled aggregates as well as aggregates treated by bacteria to check the strength it gains to be performed with compression test, split tensile strength test and aggregate compaction value test and aggregate impact value test. The paper will do the advancement in this direction which will decrease the permeability as its usual crack filling nature as well increase the life and dumping problems.

Index Terms – Bacillus Pasteurii, Compression strength test, Split tensile strength.

I. INTRODUCTION

The crises that we are facing nowadays because of the cement industries are enumerated below:

- The cement industry alone contributes about 7% to the global anthropogenic CO2 emissions.
- The amount of CO2 emitted by the cement industry is nearly 900 kg of CO2 for every 1000 kg of cement produced.
- In some circumstances, mainly depending on the origin and the composition of the raw materials used, the high temperature calcination process of limestone and clay minerals can release in the atmosphere, gases and dust rich in volatile heavy metals such as thallium, cadmium and mercury are the most toxic.

Thus, need was felt for the eco-friendly method that can increase the service life and durability of our conventional concrete so as to decrease the production of the concrete. Then came the discovery of the microbial carbonate precipitation in the concrete by inducing bacteria thus procuring the good quality and strong concrete with long life.
Bacterial concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures.

II. WORKING OF BIO-CONCRETE

A novel technique has been developed for the remediation of damaged structural formations that employs a selective microbial plugging process, in which microbial metabolic activities promote precipitation of calcium carbonate in the form of calcite. As a microbial sealant, CaCO3 exhibited its positive potential to selectively consolidate simulated fractures and surface fissures in granites and sand plugging. Previous studies with aerobic microorganisms (Bacillus pasteurii and Pseudomonas aeruginosa as self healing agents) showed a significant improvement (about 18%) in compressive strength of cement mortar.

III. MICROBIAL CARBONATE PRECIPITATION.

Selection of Bacteria

There are many types of bacteria present on the environment and that can be used in the microbial carbonate precipitation.
They are listed below on the basis of the literature review:

1. Bacillus Sphaericus
2. Escherichia coli
3. Bacillus subtillis
4. Bacillus cohni
5. Bacillus balodurans
6. Bacillus pseudofirmus
7. Bacillus pasteurii

Fig 1 Sporosarcina pasteurii bacteria

The bacteria mostly used in the concrete or and carbonate precipitation were of genus *Bacillus* that gives amicable performance. In our study we are going to use the bacteria named ***Bacillus Pasteurii*** which will be provided to us from the Parul Institute of Pharmacy from the Parul University campus itself. Also known as Sporosarcina pasteurii frequently. It is a bacterium with the ability to precipitate calcite and as a result solidifies sand given a calcium source and urea, through the process of microbiologically induced calcite precipitation or biological cementation. *S. pasteurii* has been proposed to be used as an ecologically sound biological construction material.

All the species of Bacillus are mostly rod-shaped as we can see in the case of sporosarcina pasteurii/ Bacillus pasteurii in figure 1.

Cultivation of Bacteria

The culture of Bacteria in our case Bacillus Pasteurii is preserved in nutrient broth and Urea sterile medium, concentration of 10^6 cells/mL. The bacteria will be cultured in the mediums and nutrients as per recommendations of the supplier institute. Most probably the growth medium will consist of nutrient broth, urea and in semi solid phase the nutrient agar will be introduced for keeping it alive. Deposition medium will contain the Urea along with Ca- Nitrate or Ca- Chloride.

Nutrient Agar in general is a medium which supports growth of wide ranged non Fastidious organisms. It contains (mass/volume):

1. 0.5% Peptone- it provides organic nitrogen
2. 0.3% beef extract/yeast extract- its water soluble content contains vitamins, nitrogen, carbohydrates and salts.
3. 0.5% Sodium Chloride- contributes to the mixture proportions similar to that of the cytoplasm of most organisms.
4. 1.5% agar- gives mixture solidity
5. Distilled water- it serves as transport medium for agars various substances
6. pH adjusted to neutral (6.8) at 25 ºC.

These ingredients are combined and boiled for 1 minute approximately to sterilize them. Then they are cooled at 50 degree then poured into petri dishes which are covered immediately. Once the dishes hold solidified agar, they are stored upside down and refrigerated until they are used. The warm dishes proves to be efficient than cooled ones for inoculation: even if they are refrigerated for storage, the dishes must be again warmed pre- inoculation.

IV. WORK METHODOLOGY

Preparation and growth of Bacteria

From sample to 200ml solution

- Firstly after approaching to Parul Institute of Pharmacy, the bacteria was grown from the sample tube to 200 ml solution of bacteria. So, to achieve that growth we added the SOB Growth medium that contains ingredients like Tryptone (20 gms/litre), Yeast extract (5gms/litre), Sodium chloride(0.50gms/litre), $MgSO_4$, $7H_2O$ (5gms/litre). After addition of this nutrient we added the Urea (20gms/Litre). After thoroughly mixing of this we heated this mixture in Autoclave, then after the mixture got it cooled the bacteria was added to it from the sample in tube and then it was kept in Bacteriological Incubator at the temperature of 37 ºC for the growth of bacteria for 24 hrs.
- After 24 hrs the 200ml bacterial solution was further added in the container carrying the 10litre of distilled water to increase the bacterial concentration as we needed to immerse the Recycled aggregates in the bacterial solution as accordingly the amount we needed was about 10 litre of bacterial solution which have concentrations of bacteria from minimum 10^6 cells/ml to 10^9 cells/ml maximum.

From 200ml solution to 10 litre solution

- The solution of 10 litre was similarly treated as was treated in case of 200ml solution and accordingly the proportions of growth media and urea were added in the 10 litre solution which was further kept in autoclave to get heated with vapour pressure and was kept to get cooled. After the distilled water containing the growth medium nutrients and urea, that was further added with the solution of bacteria with 200ml and again this solution was kept in Bacteriological Incubator for the growth of the bacteria for 24hrs.
- After 24hrs the bacteria which had growth of 2.6 x 10^7 cells/ml was taken from Pharmacy Lab to CT lab for immersion treatment of Recycled aggregates.

Figure 2: 200ml bacterial solution

Figure: 3.Autoclave

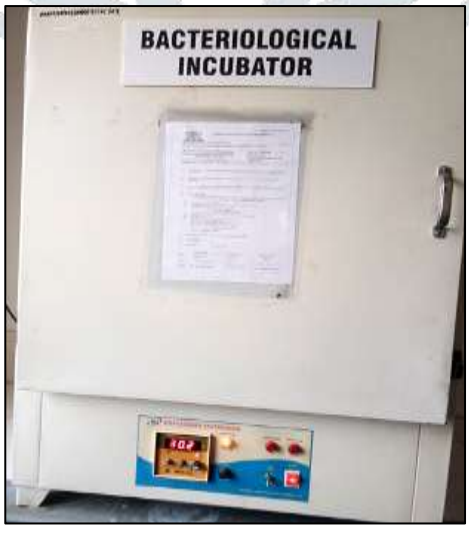

Figure 4: Bacteriological Incubator

Treatment of Recycled aggregates in Bacteria

- The bacterial solution was brought at Concrete Lab of PIET in which the recycled aggregates which was obtained by crushing the tested cubes were immersed in the bacterial solution for its treatment and bacterial curing. The curing treatment by bacteria was done for 8 days.

- After the removal of aggregates from this solution, the aggregates were used in replacement of about 20% to the Natural aggregates i.e MA and cubes were casted after the concrete mixing. Which were tested after the 7 days of curing,whose results are incorporated in the next chapter.

V. RESULTS:

Physical Properties of Ordinary Portland Cement:

Table 4 Physical properties of cement

Sr No.	Characteristics	Value
1	Consistency	32%
2	Initial Setting time	120min
3	Final Setting time	210min
4	Specific gravity	3.148

Properties of Fine Aggregates

Table 7 Physical properties of FA

Sr. No.	Characteristics	Value
1	Specific Gravity of (oven dry basis)	2.59
2	Fineness Modulus	4.04
3	Grading Zone(Based on percentage passing 60µm sieve)	Zone III

Properties of Coarse aggregates

We will be using the replacement of Natural coarse aggregates with the Recycled Coarse Aggregates by 20% of the total Aggregates to be used to see the effects that recycled aggregates makes on the strength of the concrete as we can derive from the Literature review that we can replace the Natural Aggregates by Waste concrete aggregates to between 20%-30% and it won't make any effect on the strength of concrete. Thus we will test both the Natural as well as Recycled coarse Aggregates.

Aggregate Impact Value [IS 2386 (Part 4)-1963]

For determining of aggregates impact value of coarse aggregates, which passing through 12.5 mm IS sieve and retained to 10 mm IS sieve.

Table 12 Aggregate Impact Value

Sr. no	Sample taken	Sample 1	Sample 2
1	Total weight of dry sample taken = W1 grams	535 gms	572 gms
2	Weight of portion passing 2.36 mm sieve = W2 grams	79 gms	110 gms
3	Aggregates impact value (%) = (W2/W1) x 100	14.76 %	19.23%

Calculation:

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate impact value = (W2/W1) x 100,

For sample 1,

Aggregate impact value = (W2/W1) x 100 = (79/535) x 100 = 14.76 %

For sample 2,

Aggregate impact value = (W2/W1) x 100 = (110/572) x 100 = 19.23 %

Table 13 Aggregate Impact Value RCA

Sr. no	Sample taken	Sample 1	Sample 2
1	Total weight of dry sample taken = W1 grams	528gms	516gms
2	Weight of portion passing 2.36 mm sieve = W2 grams	158gms	152gms
3	Aggregates impact value (%) = (W2/W1) x 100	24.24%	29.45%

Calculation:

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate impact value = (W2/W1) x 100,

For sample 1,

Aggregate impact value = (W2/W1) x 100 = (128/528) x 100 = 24.24 %

For sample 2,

Aggregate impact value = (W2/W1) x 100 = (152/516) x 100 = 29.45 %

Table 14 Aggregate Impact Value of bacterially treated RCA

Sr. no	Sample taken	Sample 1	Sample 2
1	Total weight of dry sample taken = W1 grams	530gms	576gms
2	Weight of portion passing 2.36 mm sieve = W2 grams	112gms	119gms
3	Aggregates impact value (%) = (W2/W1) x 100	21.13%	20.65%

Calculation:

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate impact value = (W2/W1) x 100,

For sample 1,

Aggregate impact value = (W2/W1) x 100 = (112/530) x 100 = 21.13 %

For sample 2,

Aggregate impact value = (W2/W1) x 100 = (119/576) x 100 = 20.65 %

Aggregate crushing Value [IS 2386 (Part 4)-1963]

For determining of aggregates impact value of coarse aggregates, which passing through 12.5 mm IS sieve and retained to 10 mm IS sieve.

Table 15 Aggregate Crushing Value of Natural Aggregates

Sample Taken	2300gms
Loading apply	400 kN
Aggregate Crushing Strength	17.81 N/mm^2

Table 16 Aggregate Crushing Value of Recycled Aggregates

Sample Taken	2000gms
Loading apply	400 kN
Aggregate Crushing Strength	17.93 N/mm^2

Table 19 Physical properties of Natural coarse aggregates

Sr. no	Characteristics	Value	
		CA-1	CA-2
1	Type	Crushed	Crushed
2	Maximum nominal size	20 mm	10 mm
3	Specific gravity	2.86	2.91
4	Fineness modulus	9.09	10.18

Table 20 Physical properties of coarse aggregates

Sr. no	Characteristics	Value	
		CA-1	CA-2
1	Type	Crushed	Crushed
2	Maximum nominal size	20 mm	10 mm
3	Specific gravity	2.644	2.65
4	Fineness modulus	9.83	10.32

M25 concrete containing MA1 and MA2

The concrete of M25 containing Natural aggregates (80%) with replacement by Normal Recycled aggregates (20%) (M1) and by Microbially treated Recycled aggregates (20%) (M2) were tested and the results are incorporated below in graphs and tables.

Compressive strength of M25 concrete

According to Indian standards specifications of BIS: 516-1959 the cubes were casted of the size 150mmx150mmx150mm for the compressive strength tests. Compressive strengths are shown in the tables and graphs shown below. We have got the 7 days results that showed the differing results. We will be getting the 28 days results after two fortnights and the conclusions will be derived accordingly.

Table 22 Compressive strength of specimens after 7 days of curing period

Sr. No.	Description of specimen	Peak load(kN)	Compressive strength(N/mm^2)	Average Compressive Strength(N/mm^2)
1.	Mix 1	413	18.35	20.20
		401	17.8	
		550.4	24.46	
2.	Mix2	442.3	19.66	19.13
		450	20	
		399.1	17.73	

Table 23 Compressive strength of specimens after 28 days of curing period

Sr. No.	Description of specimen	Peak load(kN)	Compressive strength(N/mm^2)	AverageCompressive Strength(N/mm^2)
1.	Mix 1	512.3	25.43	23.12
		438.6	19.49	
		550	24.44	
2.	Mix2	713.8	31.72	31.67
		660.5	29.35	
		764.3	33.96	

Split tensile strength of concrete (IS: 5816-1999)

We have performed the Tensile strength tests based on the IS: 5816-1999 on the cubes as we have seen earlier. Thus based on that test, the results of the tests are incorporated.

Table 24 Split tensile strength of specimens after 7 days curing

Sr. No.	Description of specimen	Peak load (kN)	Split tensile strength(N/mm^2)	Average Split tensile Strength(N/mm^2)
1.	Mix 1	51.7	2.3	2.247
		49.9	2.217	
		50.09	2.226	
2.	Mix2	55.8	2.48	2.41
		54.9	2.44	
		52.2	2.32	

Table 25 Split tensile strength of specimens after 28 days curing

Sr. No.	Description of specimen	Peak load (kN)	Split tensile strength(N/mm^2)	Average Split tensile Strength(N/mm^2)
1.	Mix 1	87.9	3.90	3.018
		55.1	2.47	
		60.39	2.684	
2.	Mix2	83.4	3.70	3.37
		74.1	3.29	
		68.1	3.02	

VI. CONCLUSIONS:

i) In the study from Compression test of cubes for 7 and 28 days we can conclude that on the 7th day the strength doesn't gets effected from the treated aggregates concrete, while we can see that in case of 28th day compressive strength test of M25 concrete showed the significant increase in strength of treated aggregate concrete.

ii) Thus as the time elapsed, the bacterially treated aggregates showed the activity of the bacteria that was introduced.

iii) The split tensile strength also showed similar pattern which increased after 28 days of curing.

iv) The aggregate impact value showed the significant increase in the impact resistance of the aggregates which are treated when tested after 56 days.

v) Thus, it can be concluded that recycled aggregates when treated by the bacteria may be producing the limestone filling the cracks that occurred while preparing the recycled aggregate or any other cracks, thus making it less porous.

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