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An Experimental Study on Bacterial Concrete by Partial Replacement of Coarse Aggregates with Recycled Aggregates

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Abstract - *Concrete is the only construction material which satisfies the properties of strength and durability. Concrete, which is brittle, by the nature has a tendency of developing cracks with the passage of time. The development of cracks induces serer problems on the reinforcement with the intrusion of salts, chlorides and water through these cracks. So in order to counter this problem, the concept of self-Healing concrete with the use of Bacillus subtilis is carried out in this research work. Also, the enemas use of concrete is to excavation of natural aggregates and the demolished concrete waste is occupying vast areas as dumping yards. This is causing a great harm to the environment, which can be minimized by the use of these demolished materials as recycled aggregates. In this research, an attempt is made by adding 5ml, 10ml, 15ml and 20ml bacteria to the concrete in which the coarse aggregates replaced with 10%, 20% and 30% of recycled aggregates.*

Key Words: *Bacillus subtilis*, *Aggregates*, *Recycled aggregates*, *coarse aggregates, salts, Chlorides.*

1. INTRODUCTION

Concrete is the universally accepted construction material for its idiosyncratic properties. It is very good in compression and very weak in tension. This is the reason why reinforcement is introduced into the concrete. In reinforced concrete structures, all tensile forces are taken by the reinforced and the compression forces by the concrete. In order to have a homogeneous behavior against the loads these should be a sound bond between the concrete and the reinforcement. Also these should be a sufficient concrete cover to the reinforcement may react with the salts and chlorides and it may be depleted. Of all the positives of concrete, the property of brittleness is one of the important properties to be rectified. Because of which, cracks are developed in concrete and they may lead to intrusion of harmful salts, chlorides and water through these cracks which will affect the properties of reinforcement by causing the corrosion of reinforcement thereby decreasing the integrity of the structure. So to put an end to the problem of cracking, self-healing concrete is developed by the mixing the concrete using the bacteria named Bacillus subtilis.

With the increase in population, based on the requirements, old building which were out of date are being demolished, and also due to the natural calamities some of the concrete structures are being collapsing. This demolished concrete is occupying lot of place in dump yards, and it is also causing severe damage to environment. In the present research, the recycled aggregates from the aged concrete is taken and the natural coarse aggregates is replaced with 10%, 20% and 30% of recycled aggregates, with addition of 5ml, 10ml, 15ml and 20ml of Bacillus subtilis with water.

2. OBJECTIVE OF STUDY

The main objective of the project is to

- Study the bacterial concrete performance and comparing it with conventional concrete.
- To find the optimum percentage(%) of bacteria concrete with various trials
- Determine and compare the mechanical properties such as compressive strength and split tensile strength of Bacterial concrete with partial replacement of recycled aggregate concrete with conventional concrete.

3. OBJECTIVE OF STUDY

The pure culture is maintained constantly on nutrient agar slants. It forms irregular dry white colonies on nutrient agar. Whenever required a single colony of the culture is inoculated into nutrient both of 200ml in 500ml conical flask and the growth conditions are maintained at 37 degree temperature and placed in 125 rpm orbital shaker. The medium composition required for growth of culture is Peptone, NaCl, yeast extract. Stock cultures of bacillus subtilis jc3 were maintained on nutrient agar slants. The culture was streaked on agar slants with an inoculating loop and the slants were incubated at 37 degree celsius. After 2-3 days of growth slant cultures were preserved under refrigeration (4 degree celcius) until further use. Sub culturing was carried out for every 90 days. Contamination from other bacteria was checked periodically by streaking on nutrient agar plates.

Fig -1: preparation of Bacteria (Bacillus subtilis)

4. PREPARATION OF RECYCLED AGGREGATES

Aged concrete which has been demolished by the natural and man causes, and which has been removed from the pavements, foundation, bridges is crushed. Reinforcing steel another embedded materials are removed and core is taken so as to prevent it from mixing with any dirt or other building materials like gypsum, plaster and plastic pipes. Then sieve analysis carried out and the material taken from the sieves is washed using pressure washing to remove the attached mortar on the aggregates and is dried for 30min in natural sun light.

Fig -1: preparation of recycled aggregates

5. TEST DATA FOR MATERIALS OF CONCRETE

The materials like cement, Fine aggregate, coarse aggregate and recycled aggregates were tested for their properties and compared with Indian standards before mixing of concrete.

5.1. Cement

Ordinary Portland cement of 53 grade of ACC brand used for experimental purpose. Physical properties of cement were determined as per IS 12269 (1987) and tabulated in Table 1.

Table.1 properties of cement

Property	Experimental Result	IS Code requirement
Specific gravity	3.15	3.10-3.15
Initial Setting Time	32 min	>30 min
Final Setting Time	590 min	<600 min
Fineness (%)	8%	<10%

5.2. Fine Aggregate

Fine aggregate is tested for its specific gravity, fineness modulus and water absorption. It was found that all the properties shown in Table.2 are within the limits and useful in preparation of concrete.

Table.2 properties of Fine aggregate

S. No.	Property	Value Obtained
1	Specific gravity	2.605
2	Fineness modulus	2.87
3	Water absorption	1%
4	Grading Zone	Zone II

The fineness modulus of the aggregate is found to be 2.605 and based on IS383:1970 it was found that the fine aggregate belongs to zone II shown in Table.3. Based on this the proportion of fine and coarse aggregate were decided in mix design.

5.3. Coarse Aggregate:

Coarse aggregate is crushed type and tested for its specific gravity, fineness modulus and water absorption. It was found that all the properties shown in Table.3 are within the limits and useful in preparation of concrete.

Table.3 Properties of Course aggregate

S. No.	Property	Result
1.	Specific gravity	2.884
2.	Type	Crushed
3.	Fineness modulus	6.52
4.	Water absorption	0.5%

The max size of aggregate used is 20mm retained shown in Table.5 and for manufacturing of concrete aggregate 20mm retained and 10mm retained are used in 60% and 40% respectively.

5.4 Recycled aggregates

Recycled aggregate is crushed and tested for its specific gravity, and water absorption. It was found that all the properties bellow tale are within the limits and useful in preparation of concrete.

Table.4 Properties of recycled aggregate

S. NO.	Property	Result
1.	Specific gravity	2.29
2.	Type	Crushed
3.	Size	20mm
4.	Water absorption	5.33%

6. TEST DATA FOR MATERIALS OF CONCRETE

For the concrete mix, OPC of 53 grade is used .The fine aggregate used is confined to Zone-II and maximum size of

coarse aggregate is 20mm. The workability tests are carried out immediately after mixing of concrete using the compaction factor testing apparatus in accordance with IS: 10510-1983.10ml reference of bacteria (Bacillus subtilis) was added to every 500 ml of water while mixing concrete, so the total amount of bacteria was added to required liters of water used and 0%, 10%, 20% and 30% reference of recycled aggregates was replaced on natural coarse aggregates for mixing cement concrete.

The mixing process is carried out in electrically operated mixer. The materials are laid in Uniform layers, one on the other in the order – recycled aggregates, coarse aggregate, fine aggregate and cement. Dry mixing is done to obtain a uniform colour. Mix design has been done based on IS10262:2009 is followed and the water cement ratio considered as 0.40. The water content is taken as 176liters. Based on this the mix proportion obtained is as shown in Table.6.

Table.5 Mix proportion

S. No	Material	Weight of material (Kg/m^3)	Mix ratio with respect to cement
1.	Cement	443.86	1
2.	Fine Aggregate	757.3	1.50
3.	Coarse Aggregate	1192.92	2.86
4.	Water	176 lit	0.40

Following table represents various mix trials casted during this research and throughout the paper the same convention used to represent the mix.

Table.6 Mix Designation of Bacteria

Mix Designation	Amount of Bacteria added for every 500 ml water
M1	5ml
M2	10ml
M3	15ml
M4	20ml

Table.7 Mix Designation of Recycled aggregates

Mix Designation	Percentage Of Recycled Aggregates Replaced
R1	0%
R2	10%
R3	20%
R4	30%

7. RESULTS AND ANALYSIS

Bacteria with replacement of recycled aggregate Concrete have been tested for fresh properties like workability and mechanical properties like Compressive strength and split tensile strength.

7.1. Workability

Workability of concrete is tested for each mix when it was casted as per IS1199-1959. For mix design the slump value of 25mm to 50mm is adopted and all the mixes gave the slump values in the given range. In all the mixes, the type of slump was true.

Table.7 Slump values

Mix designation	Slump value (mm)	Type of slump
R1	36	True
R2	43	True
R3	39	True
R4	41	True

7.2. Compressive strength

Compressive strength is most important property of the hardened concrete. The concrete cubes were casted, cured and tested accordance with the IS standard and 7, 14, 28 and 56 days.

Fig. 3 compressive strength

7.2.1 Bacteria concrete

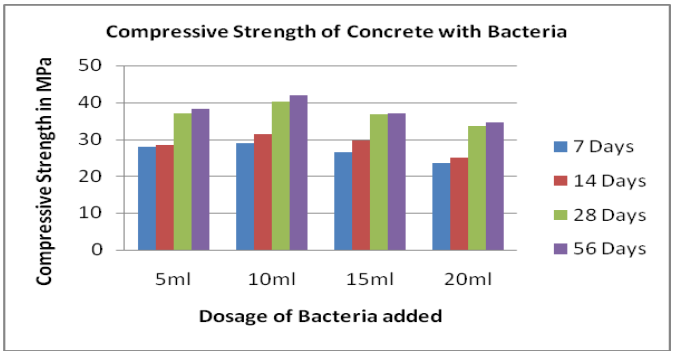

Fig.4 Compressive strength of Concrete with bacteria

S.No	Age of concrete	Average compressive strength in MPa			
		5ml	**10ml**	15ml	20ml
1	7 days	27.89	**28.92**	26.56	23.56
2	14 days	28.45	**31.26**	29.66	25.12
3	28 days	37.12	**40.25**	36.78	33.66
4	56 days	38.15	**41.85**	37.12	34.56

Table.8 compressive strength values

7.2.2 Bacteria with recycled aggregates concrete

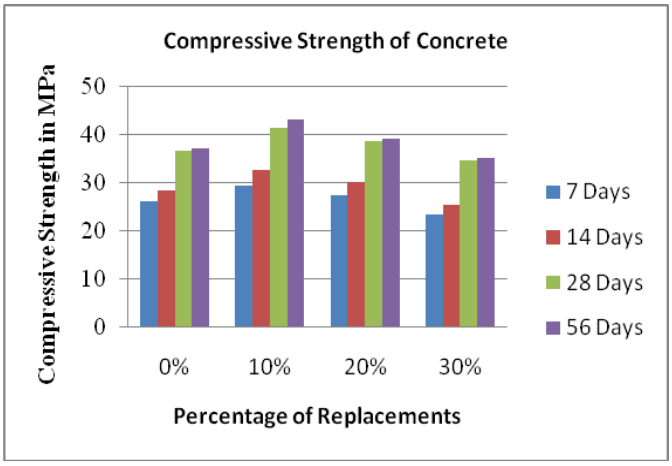

Fig.5 Compressive strength of Concrete

S.No	Age of concrete	Average compressive strength in MPa			
		0%	**10%**	20%	30%
1	7 days	26.13	**29.38**	27.45	23.44
2	14 days	28.33	**32.61**	30.125	25.27
3	28 days	36.67	**41.23**	38.54	34.47
4	56 days	37.13	**42.97**	38.95	35.03

Table.9 compressive strength values

The greatest improvement in compressive strength occurs at of 10% at 28 days. Also this improvement in compressive strength is due to deposition on the microorganism cell surfaces and within the pores of cement–sand matrix, which plug the pores within the mortar. The extra cellular growth produced by the microorganism is expected to contribute more to the strength of cement mortar with a longer incubation period and thus the strength improvement is found to be more at 28 days. The compressive strength of concrete for various mixes, Figure was drawn between compressive strength and curing periods for the various mixes. From the result, the optimum strength is obtained at replacement of 10% of coarse aggregate by recycle aggregates by weight of concrete. Further increase in percentages shows a gradual decrease than the 10% replacement but has high compressive strength than conventional till a replacement of 30%.

7.3 Split tensile strength

Split tensile strength test has been conducted on cylinder of 150mm diameter and 300mm height as shown in the fig. the results are mentioned in table.

Fig. 6 split tensile strength test

7.3.1 Bacteria Concrete

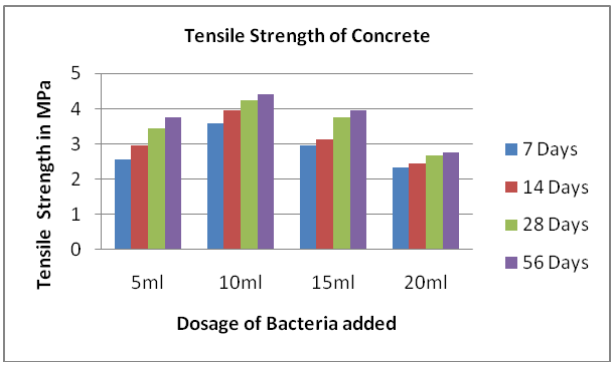

Fig.7 Split tensile strength of Concrete with Bacteria

S.No	Age of concrete	Average Tensile strength in MPa			
		5ml	**10ml**	15ml	20ml
1	7 days	2.17	**3.42**	3.11	2.03
2	14 days	2.86	**3.53**	3.37	2.27
3	28 days	3.01	**3.97**	3.79	2.35
4	56 days	3.16	**4.01**	3.86	2.45

Table. 10 Split tensile strength values

7.3.2 Bacteria with recycled aggregates concrete

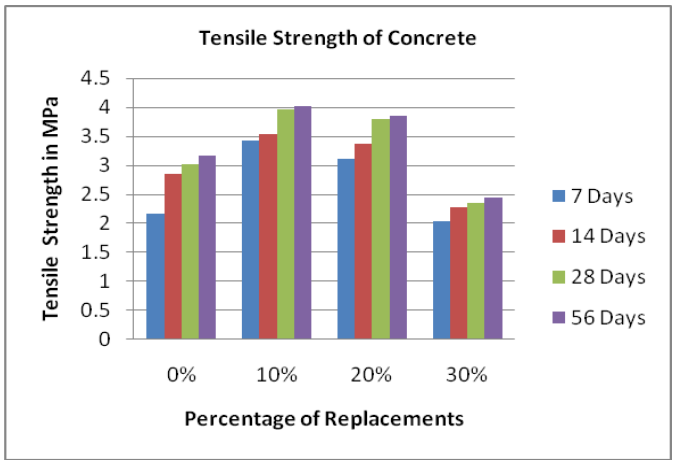

Fig.8 Split tensile strength of Concrete

S.No	Age of concrete	Average Tensile strength in MPa			
		0%	**10%**	20%	30%
1	7 days	2.56	**3.59**	2.95	2.32
2	14 days	2.96	**3.95**	3.12	2.45
3	28 days	3.45	**4.23**	3.75	2.67
4	56 days	3.75	**4.39**	3.96	2.76

Table 12. Split tensile strength values

7.5. Durability Studies

To study durability characteristics, the specimens are subjected to 5% solution of H2SO4 for 28 days. In this investigation, the weight loss and strength loss of concrete is compared with the concrete specimens cured under water. It is found that the bacterial concrete made with 10mml addition of bacteria with 10% replacement recycled aggregate concrete lost less weight and strength when compared with other mixes. So based on the durability test, the R2 is found to give optimum results.

Table 12. After acid test compressive strength results

Type of mixes	Compressive strength (28 days) MPa	Compressive strength (90 days)MPa
R1	36.67	34.20
R2	41.23	39.40
R3	38.54	37.38
R4	34.47	32.74

Table 13. After acid test cube weight lose results

Type of mixes	Weight of cube (28 days) kg	After acid test weight of cube (90 days) kg
R1	8.87	8.60
R2	8.65	8.47
R3	8.55	8.29
R4	8.43	8.21

8. CONCLUSION

Based on the results from experimental investigation, the following points can be concluded

- Addition of bacteria at any content improves the compressive and tensile strengths of the concrete. But the optimum content of bacteria can be added is 10ml for each 500ml of water for M30.
- So based on the results 10 ml bacteria for each 500 ml of water is considered as optimum for M30.
- According to the comparative studies undertaken it is clear that with 10% replacement of coarse aggregate by recycled aggregates a maximum compressive strength and tensile strength values which are more than the conventional concrete was obtained. The optimum percentage obtained is 10%.
- When bacteria with recycled aggregate added to the concrete, its performance is increased in the presence of H_2So_4 compared with conventional concrete and best performance found at 10ml dosage of bacteria with 10% replacement of recycled aggregate.

Scope for Future Work

- The work may also be extended with other different type of bacteria's and also with different dosages.

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