An Experimental Study on High Strength Bacterial Concrete with Partial Replacement of Cement with Fly Ash and Fine Aggregates with Quarry Dust.

M.Mouika[1], M.Jesse Leo Pragnan.[2]

Abstract*: Concrete is the only construction material which satisfies the properties of strength and durability. Concrete, which is brittle by its nature, has a tendency of developing cracks with the passage of time. The development of cracks induces so many problems on the reinforcement. So in order to control this problem we can use Bactria in the Concrete such as 'Bacillus Subtilis' which has the Nature of Self-Healing prosperity. It also increases the Strength and durability of the concrete. In this research, we are using the Waste material like Fly ash and Quarry dust. Fly ash is the by-product combustion from the coal; whereas Quarry dust is the material coming from the Quarry while quarrying the Rocks in to different size of aggregates. Both the materials are waste materials which are abundant and leaving them as such may lead to occupying of much space and may also have an impact on the environment. We can use those materials as partial replacement in concrete to reduce the cost of the concrete. Also fly ash has the nature of taking less water than the cement and quarry dust has more strength and durability than the nominal fine aggregates. So an attempt is made to study the strength parameters by adding 5ml, 10ml, 15ml and 20ml bacteria in every 500ml of water to the concrete in which the cement is replaced with 10%, 20% and 30% of fly ash and fine aggregates replaced with 10%, 20% and 30% of quarry dust respectively.

Key Words*: High strength concrete, Self-healing concrete, Bacillus subtilis, Aggregates, Fly ash, Quarry Dust.

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 there should be a sufficient concrete cover to the reinforcement, so that it may not react with the salts and chlorides and it may be depleted. Of all the properties of concrete, the property of brittleness is one of the important properties to be rectified. Because of poor design or poor workmanship or poor usage of materials, cracks are developed in concrete and they may lead to intrusion of harmful salts, chlorides and water through these cracks which will affect the 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. In this present study, bacteria by the name "Bacillus subtilis" is used.

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. Taking environmental impact of this waste into account, in the present study, Cement is replaced with 10%, 20% and 30% of Fly ash respectively and Fine aggregates is replaced with 10%,20% and 30% of Quarry dust respectively with addition of 5ml, 10ml, 15ml and 20ml of "Bacillus subtilis" bacteria with water respectively for different samples.

2. OBJECTIVE OF STUDY

The objectives of this study are

- To study the performance of bacterial concrete and comparing it with conventional concrete.
- To find the optimum percentage (%) of bacterial concrete that is required to achieve good strength with various trials.
- To determine and compare the mechanical properties such as compressive strength and split tensile strength of Bacterial concrete with partial replacement of cement with fly ash and fine aggregates with quarry dust.

3. PREPARATION BACILLUS SUBTILIS

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 in refrigeration (4 degree Celsius) 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 Bacteria (Bacillus subtilis)

4. Mechanism of Bacterial Concrete

The Microbial Organism used for manufacturing the bacteria concrete should be able to possess long term effective crack sealing mechanism during its life time serviceability.

The principle behind crack healing mechanism is that the bacteria should be able to transform soluble organic nutrients into insoluble inorganic calcite crystals, which seals the cracks. For effective crack healing, both bacteria and nutrients incorporated into concrete should not disturb the integrity of cement sand matrix pore-diameter and should not negatively affect other important fresh and hardened properties of concrete. In concrete cracks up to 0.2mm wide are healed autogenously. Such micro cracks are acceptable as these do not directly influence the safety and strength of concrete. The in-built bacteria-based self-healing process was found to heal cracks completely up to 0.5mm.

5. WHAT IS FLY ASH AND QUARRY DUST

Fly ash is the by-product one of three general types of coal combustion. It affects the plastic properties of the concrete to improving workability and reducing water demand, reducing segregation, bleeding and lowering heat of hydration.

Quarry dust is a waste from the stone crushing unit accounts 25% to 30% of the final product from stone crushing unit. Quarry dust is used as aggregates for low cost concreting works, especially we can use as fine aggregates. In present study the quarry dust which is obtained from rocks was sieved and that which is retained on 4.35mm sieve is used as a partial replacement for fine aggregates.

Fig.2 Fly Ash and Quarry Dust

6. MATERIALS USED

The materials like cement, Fine aggregate, coarse aggregate Fly ash and Quarry dust are used in this study. They are all tested for their properties and compared with Indian standards before mixing in concrete.

6.1. 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%

6.2. 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.

6.3. 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.4 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.

6.4 Specific Gravity of Quarry Dust and Fly Ash

The water absorption of the Quarry Dust will be greatly affects the workability of the concrete. The ratio to increase in the weight of sample to the weight dry sample is called water absorption

Fly Ash is the material as fine as cement so we have to take the specific gravity test as cement test that we have been taken before

Table.4 Properties of Quarry Dust

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

7. 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 in Flu ash and Quarry Dust.

The mixing process is carried out in electrically operated mixer. The materials are laid in Uniform layers, one on the other in the order – fly ash and Quarry dust, coarse aggregate, fine aggregate and cement. Dry mixing is done to obtain a uniform color. 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 in (Kg/m^3)	Mix ratio with respect to cement
1	Cement	425.76	1
2	Fine Aggregate	702.3	1.53
3	Coarse Aggregate	1077.12	2.35
4	Water	186 lit	0.4

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

Table.6 Mix Designation of Bacteria

Mix/Trial Designation	Amount of Bacteria added for every 500 ml water
M1	0 ml
M2	5 ml
M3	10 ml
M4	15 ml

Table.7 Mix Designation of Quarry Dust and Fly Ash

Mix Designation	Percentage Of Quarry Dust and Fly Ash
M1	0%
M2	10%
M3	20%
M4	30%

8. RESULTS AND DISCUSSIONS

Bacteria with replacement of Cement with Fly ash and fine aggregates with Quarry dust in concrete has been tested for fresh properties like workability and mechanical properties like Compressive strength, split tensile strength and flexural strength.

8.1. 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 within the permissible range. In all the mixes, the type of slump is found to be true.

Table.8 Slump values

Mix designation	Slump value (mm)	Type of Slump
M1	36	TRUE
M2	43	TRUE
M3	39	TRUE
M4	41	TRUE

8.2. COMPRESSIVE STRENGTH

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing 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.4 Compressive strength test - Bacterial concrete specimen.

8.2.1 BACTERIA

Graph.1 Compressive strength of Concrete with bacteria

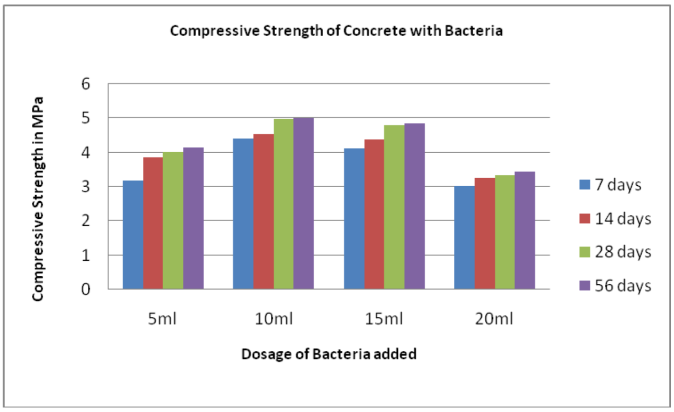
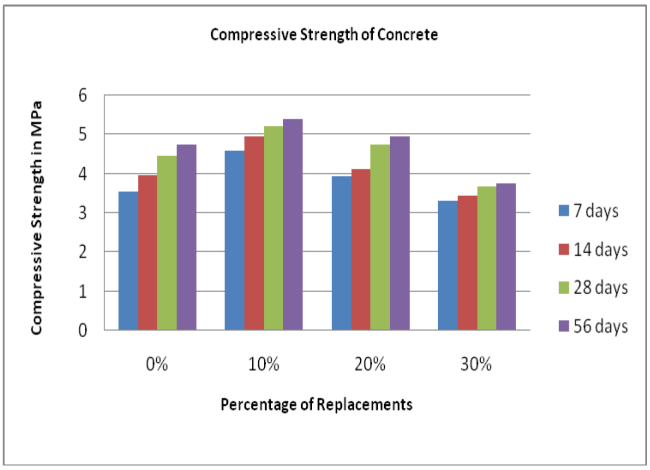


Table.9 Dosage of Bacteria increase & its corresponding strength values in MPa

S.No	Age of concrete	Average compressive strength in MPa			
		5ml	**10ml**	15ml	20ml
1	7 days	37.9	**38.9**	36.6	33.6
2	14 days	38.5	**41.3**	39.7	35.1
3	28 days	47.1	**50.3**	46.8	43.7
4	56 days	48.2	**51.9**	47.1	44.6

Fig.5 Compressive Strength Testing

8.2.2 BACTERIA WITH FLY ASH AND QUARRY DUST



Graph.2 Compressive strength vs. % replacement

Table.10 Percentage increase of fly ash and quarry dust with Mixes for 7, 14, 28 and 56 days

S.No	Age of concrete	Average compressive strength in Mpa			
		0%	**10%**	20%	30%
1	7 days	36.1	**39.4**	37.45	33.4
2	14 days	38.3	**42.6**	40.13	35.3
3	28 days	46.7	**51.2**	48.54	44.5
4	56 days	47.1	**53**	48.95	45

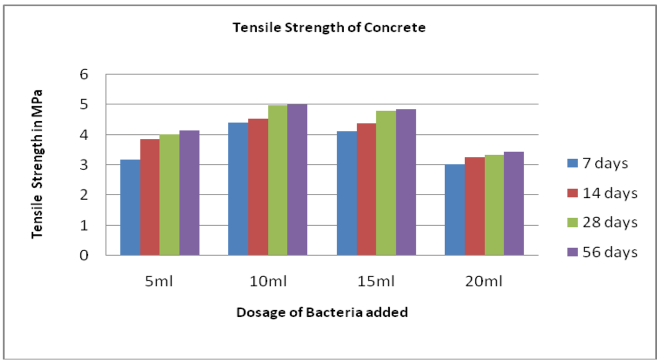
The greatest improvement in compressive strength occurs at of 10% at 28 days. Also this improvement in compressive strength is due to deposition on the microorganism cell surfaces and within the pores of cement–sand matrix, which plug the pores within the mortar. The extra cellular growth produced by 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. A graph is drawn between compressive strength and curing periods for the various mixes. From the result, it is evident that the optimum strength is obtained at replacement of 10% of Cement with Fly Ash and Fine Aggregates with Quarry Dustin the concrete mixture. Further increase in percentage addition of fly ash and quarry dust shows a gradual decrease than the 10% replacement but has high compressive strength than conventional concrete till 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.5, the results of the same are mentioned in table.

Fig.6 Tensile strength

8.3.1 BACTERIA

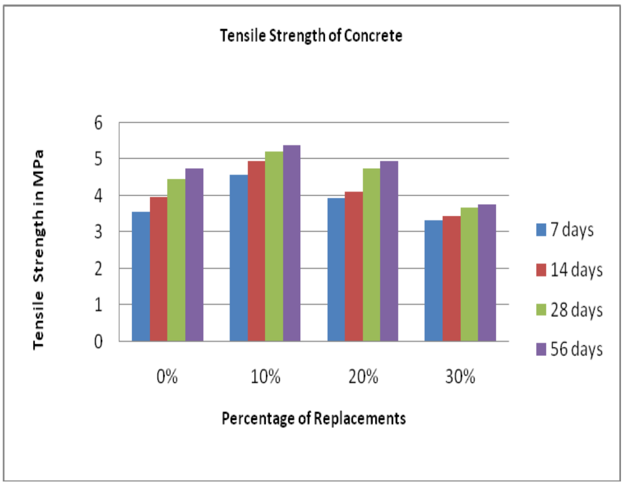


Graph.3 Tensile Strength vs. Dosage of Bacteria (ml)

Table.11 Split Tensile Strength Values

S.No	Age of concrete	Average Tensile strength in MPa			
		5ml	**10ml**	15ml	20ml
1	7 days	3.17	**4.42**	4.11	3.03
2	14 days	3.86	**4.53**	4.37	3.27
3	28 days	4.01	**4.97**	4.79	3.35
4	56 days	4.16	**5.01**	4.86	3.45

8.3.2 Bacteria with Fly Ash and Quarry Dust



Graph.4 Tensile strength vs. Percentage replacement

Table.12 Percentage increase of fly ash and quarry dust for 7, 14, 28 and 56 days & their corresponding strength

S.No	Age Of Concrete	Average Tensile Strength in MPa			
		0%	**10%**	20%	30%
1	7 days	3.56	**4.59**	3.95	3.32
2	14 days	3.96	**4.95**	4.12	3.45
3	28 days	4.45	**5.23**	4.75	3.67
4	56 days	4.75	**5.39**	4.96	3.76

7.4. 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 10ml addition of bacteria with 10% replacement with cement by Fly ash and Fine Aggregates with Quarry dust in 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.

Fig.6 Cubes after Immersion in Acid

Table.13 After acid test compressive strength results

Type of mixes	f_{ck}	f_{ck}
	(28 days) Mpa	(56 days) Mpa
R1	46.67	44.2
R2	**51.23**	**49.4**
R3	48.54	47.38
R4	44.47	42.74

Table 14. After acid test cube weight lose results

Type of mixes	Weight of cube (28 days) kg	After acid test weight of cube (56 days) kg
R1	9.87	9.6
R2	9.65	9.47
R3	9.55	9.29
R4	9.43	9.21

8. CONCLUSION

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

- Addition of bacteria at any content improves the compressive strength of the concrete. But the optimum content of bacteria can be added is 10ml for each 500ml of water for M30.
- Split tensile strength and Flexural strength of the concrete are increasing with addition of bacteria up to 10ml of bacteria (for each 500ml of water) and then strength are decreasing with increasing in addition of bacteria for M30.
- So based on the results 10 ml bacteria for each 500 ml of water is considered as optimum for M30.
- The compressive strength of concrete containing 10% Quarry Dust and Fly Ash has strength in close proximity to that of normal concrete.
- Tensile splitting test shows that concrete has good tensile strength when replace of Fly Ash in Cement and Quarry Dust in Fine Aggregates with 10%.
- According to the comparative studies undertaken it is clear that with 10% replacement Fly Ash and Quarry Dust a maximum compressive strength which is more than the conventional concrete was obtained. The optimum percentage obtained is 10%.
- Usage of Fly Ash and Quarry Dust is Waste and by using this materials the usage of cement and Fly ash is partially reduced in concrete, there by the mining activities can be minimized and also minimizing the waste by using this materials.

SCOPE FOR FUTURE WORK

- The work may also be extended with other different type of bacteria's and also with different dosages.
- The work may also be extended by incorporating other different type of waste materials with varying percentage of partial replacements.

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AUTHORS PROFILE

1. **M.Mounika** P.G. (Structural Engineering) Student, Department of Civil Engineering, Lingayas Institute Of Management And Technology, Vijayawada, Andhra Pradesh, India.

2. **Mr. Merugolu Jesse Leo Pragnan** of Vijayawada received P.G. (Structural Engineering) from Vignan's University, Guntur, Asst.Professor, Department of Civil Engineering, Lingayas Institute Of Management And Technology, Vijayawada, Andhra Pradesh, India.