International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

A Study on Mechanical & Durability Aspects of M-20 grade Bacterial Concrete with Fly Ash

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***Abstract*:- Cracks in the concrete are common which affects the durability of a structure. These cracks should be repaired to increase the strength and durability of the structure, using either epoxy injections or latex treatment. Major problem is that the chemicals used in these treatments cannot reach the deeper portions of the cracks in the structural member and also are expensive. If an effective method and material is found that repairs cracks in concrete automatically (self healing) then the durability of the structure would enormously be increase. Primary motto is to enhance the strength and durability of the structure by treating these cracks with the help of bacteria. The search for new environmental friendly construction materials that improves the strength and durability of concrete structures has developed interest in self healing bacterial concrete with Fly Ash. Bacteria helps in calcite ($CaCO_3$) precipitation through a process called bio mineralization. Bio mineralization is process where common soil bacterium like Sporosarcina Pasteurii, Bacillus subtilis produce calcite. This calcite fills the cracks and compressive strength and durability of concrete is improved. In the present study an attempt is made to understand the effect of bacteria and fly ash on performance of M20 grade concrete. Fly ash content has been varied in 0%, 10%, 20%, and 30% as replacement for cement and bacteria (Sporosarcina Pasteurii) is kept constant at $1x10^7$cells/ml concentration. Cubes and cylinders were cast and strength is monitored for 7, 28, 56 & 90 days. Based on the results, mix with combination of $1x10^7$ cells/ml bacteria and 10% Fly Ash (BCF10) has given optimum performance in terms of compressive strength, split tensile strength, strength loss and weight loss.**

Keywords: Concrete, Self healing concrete, Fly Ash, Bacteria, Mechanical properties, Durability.

1.0 INTRODUCTION

Concrete is a widely used building material in construction industry. Due to various reasons it has the tendency to crack. These cracks vary in size, from a few microns to a few centimeters and often they may occur at places which cannot be accessed. Cracks allow moisture to enter in to it and causes corrosion of reinforcement and impart irregular stress distribution across the section. This makes the section weak to carry any further load. Hence, theese cracks should be treated as early as possible to ensure the safety of structure. To minimize crack width extra reinforcement should be provided or it has to be treated. Providing extra reinforcement means increase in steel quantity in turn increase in cost of the project. Second option is treatment of cracks. Cracks can be treated by using chemicals which is again a costly and tedious process. Reaching the deeper portions of the cracks which are away from the surface, in a structural element is very hard and sometimes it is not possible. If a concrete is developed that can repair the cracks automatically(Self-Healing), it would save time and money both on the cost of injection fluids for cracks and also on the extra steel that is used in structures only to limit crack widths. For structural reasons this extra steel has no meaning. A reliable self-healing method for concrete would lead to a new way of designing durable concrete structures, which is beneficial for national and global economy.

For the structures which are exposed to sea water or salts, initiation period is a major concern. The initiation period is defined as the time taken from initial exposure to until a concentration of reinforcement able to initiate corrosion. The largest economic benefits are obtained by prolonging the initiation period through proper durable concrete mix, smart structural design and proper on-site placement of the concrete among others. In both developed and developing countries recent researchers are aiming at the energy conservation in the cement and concrete industry, focused on the use of less energy intensive materials such as fly-ash, slag and natural pozzlolanas. Later some attention has been given to the use of fly ash as partial replacement to Portland cement. However, environmental concerns, stemming from high-energy expense and CO_2 emission associated with cement manufacture, have brought pressures to reduce consumption through the use of supplementary materials like fly ash.

Bacteria precipitate Calcium Carbonate (Calcite, $CaCo_3$). The physical and mechanical properties of calcite are closely similar to those of hardened concrete and hence it can be used as a crack filling agent for concrete structures. It is produced biologically and does not possess any harmful chemicals. Also, its production is self-sustained, happens without any human support and has the potential to remediate every minute crack. These properties of calcite make it a perfect filling material of cracks developed in concrete. The bacteria are incorporated into the concrete while mixing. This type of concrete is called Bacterial Concrete. It is also called Self-Healing concrete as the healing process is independent and autonomous. The bacteria become active as soon as they get in contact with water and precipitate Calcite eventually, facilitating the filling of minute voids generated on the account of the physical structure of the constituents of concrete. This process takes place till there is an availability of water. Once the concrete hardens, the water supply is cut off, the bacteria becomes inactive and remains dormant till there is any further supply of water. Hence, it increases the strength of concrete and also repairs the cracks formed, protecting the structural integrity. Bacterial spores are specialized cells which can endure extreme mechanical and chemical stresses and spores of this specific genus are known to remain viable for up to 200 years. Spores are dormant but viable bacterial spores immobilized in the concrete matrix will become metabolically active when revived by water entering freshly into the concrete.

2.0 RESEARCH SIGNIFICANCE

Cracks in a concrete structure reduces the life and cracks of dimension smaller than that of cement (micro cracks) cannot be filled with chemicals. Crack treatment processes involve harsh materials such as cement and chemicals adding to the pollution of environment. There have been instances of allergic reactions due to chemicals faced by the inhabitants and handlers. Bacteria secretes calcite which fills the cracks and compressive strength and durability of concrete is improved.The environmental impacts of poor disposal of mineral wastes like fly ash, GGBS need to be addressed. Use of fly ash in the manufacture of concrete reduces its interaction with the environment as well plays an important role in imparting strength and durability to the concrete. As there is limited literature available on the study of properties and characteristics of such combination, it is intended to investigate in this direction.

3.0 MATERIALS

3.1 Cement

Ordinary Portland cement of 53 grade available in local market conforming to specifications of IS: 12269-1987 having specific gravity of 3.06 is used.

3.2 Fine Aggregate

Locally available clean, well-graded, natural river sand conforming to specifications of IS 383-1970 having specific gravity of 2.57 is used.

3.3 Coarse Aggregate

Crushed granite angular aggregate of size 20 mm nominal size from local source with specific gravity of 2.65 is used.

3.4 Water

Locally available potable water conforming to IS 456 is used.

3.5 Fly Ash

Fly Ash of class ‘F’ with 2.23 specific gravity is used

3.6 Microorganisms

Sporosarcina Pasteurii of $1x10^7$cells/ml concentration, a soil bacterium which is cultured and grown at Laboratory of Biotechnology Department, CBIT, is used.

3.7 Grade designation: M20 grade concrete

3.8 Culture of Bacteria

The pure culture was isolated from the soil sample and 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 glass bottles containing nutrient broth of 13 grams in 1000 ml of distilled water and the growth condition is maintained at 37°C temperature. The medium composition required for growth of culture is Peptone: 5 gm/lit., NaCl: 5 gm/lit., Yeast extract: 3 gm/lit.

3.9 Maintenance of Stock Cultures

Stock cultures of Sporosarcina Pasteurii were maintained on nutrient agar slants. The culture was streaked on agar slants with an inoculating loop and the slants were incubated at 37°C. After 2-3 days of growth, slant cultures were preserved under refrigeration (4°C) until further use. Contamination from other bacteria was checked periodically by streaking on nutrient agar plates.

4. 0 EXPERIMENTAL PROGRAM

Table 1: Types of Mix

Mix	Bacteria (cells/ml)	Fly Ash (%)
NC	0	0
BC	$1x10^7$	0
BCF10	$1x10^7$	10
BCF20	$1x10^7$	20
BCF30	$1x10^7$	30

4.1 Compressive Strength Test

In the present investigation, compressive strength is determined as per the procedure given in IS 516:1959. Compressive strength is determined on 150 x 150 mm cubes using UTM at a loading rate of 140kg/cm ^{2}/min. Compressive strength = P /A

P - Maximum load applied on the specimen during the test in Newton

A - Cross-sectional area calculated from the mean dimensions of the section in mm^2

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4.2 Split Tensile Strength Test

A diametric compressive load will be applied along the length of the sample at a continuous rate until failure occurs. This loading induces tensile stresses on the plane containing the applied load, causing tensile failure of the sample. IS 5816:1999 formed the basis for the development of this procedure. The measured splitting tensile strength of the specimen shall be calculated using the following formula $F_{ct}=2P/\Pi$ dl

P = Maximum load applied on the specimen during the test in Newton

l = length of the specimen in mm

d = cross sectional dimension of the specimen in mm

4.3. Durability (Acid test)

The chemical resistance of the concretes was studied through chemical attack by immersing concrete blocks in an acid solution. After 28 days period of curing, the specimens were removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial weights were measured and the specimens were identified with number. The specimens were immersed in 5% $H2SO_4$ and HCL and reading for weight and compressive strengths were recorded for all mix types at 7, 28, 56 and 90 days. The solution was replaced at regular intervals to maintain constant concentration throughout the test period.

Acid Durability Factor (ADF) can be designed as follows. [5]

Acid Durability Factor (ADF) = Sr N / M

where, Sr = relative strength at N days, (%)

N = number of days at which the durability factor is needed.

M = number of days at which the exposure is to be terminated.

Acid attack test was terminated at 90 days. So, M is 90 in this case.

5.0 TEST RESULTS

5.1 Compressive Strength

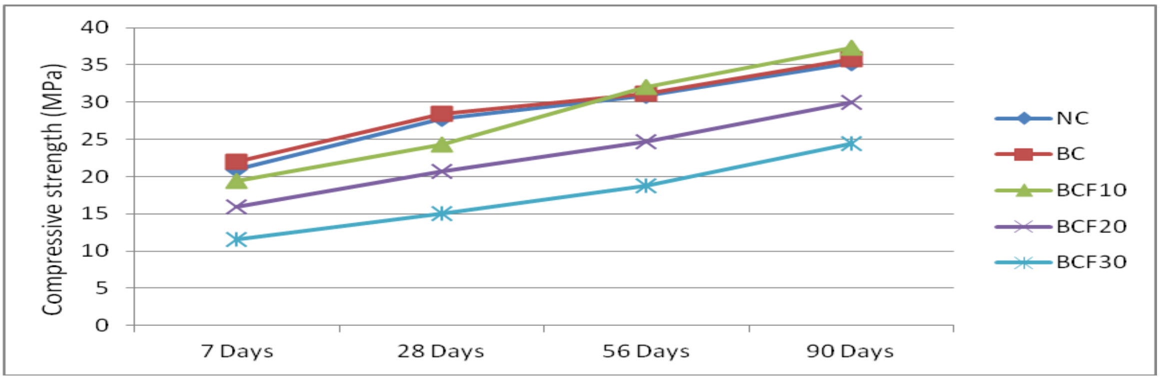

Fig.1: Compressive strength values for different curing periods

5.2 Split tensile Strength

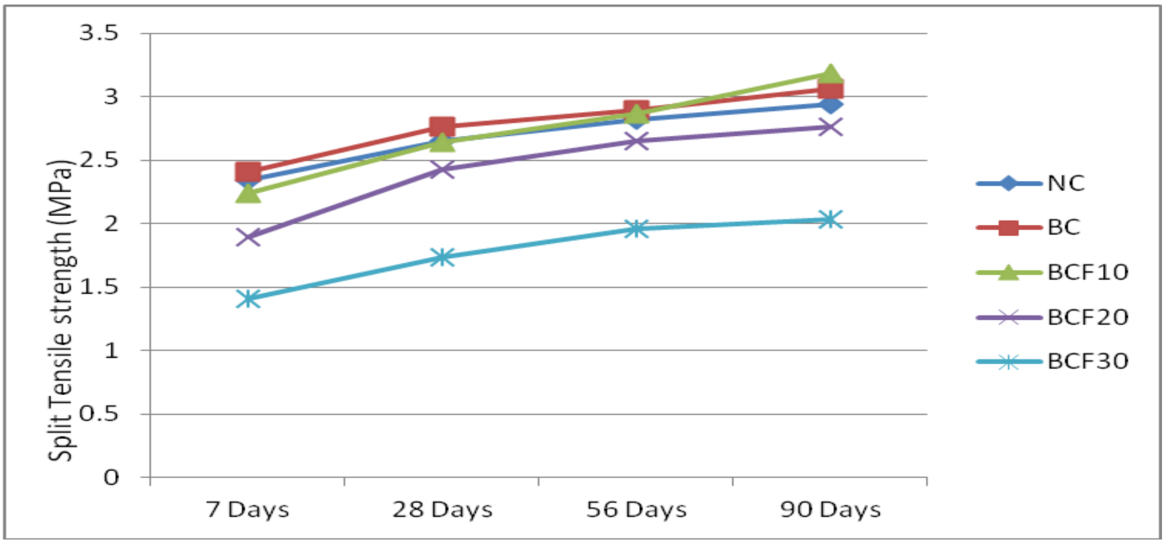

Fig.2: Split Tensile strength values for different curing periods

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5.3. Durability

5.3.1 Acid Test

Table 2: Compressive strength values after immersion in acid

		Compressive strength (N/mm^2)			
Mix	**Initial strength**	**7 Days**	**28 Days**	**56 Days**	**90 Days**
NC	26.55	25.97	25.29	24.18	22.83
BC	30.05	29.48	28.84	27.44	26.31
BCF10	24.71	23.91	23.24	22.46	21.08
BCF20	25.39	24.87	23.97	23.18	22.05
BCF30	23.67	22.89	22.24	21.69	20.08

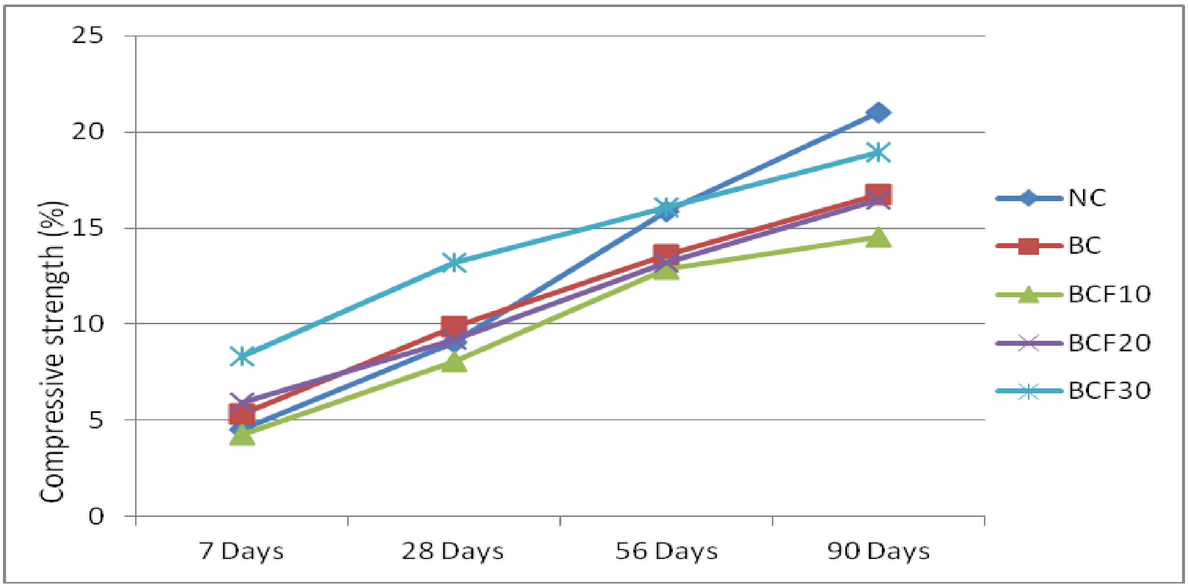

Fig.3: Percentage reduction in compressive strength values

Table 3: Weight of concrete cubes after immersion in acid

		Weight in Kg			
Mix	**Initial Weight**	**7 Days**	**28 Days**	**56 Days**	**90 Days**
NC	8.126	8.049	7.914	7.787	7.607
BC	8.186	8.120	8.009	7.911	7.716
BCF10	8.109	8.013	7.900	7.807	7.633
BCF20	8.076	7.982	7.851	7.788	7.666
BCF30	7.940	7.840	7.693	7.538	7.496

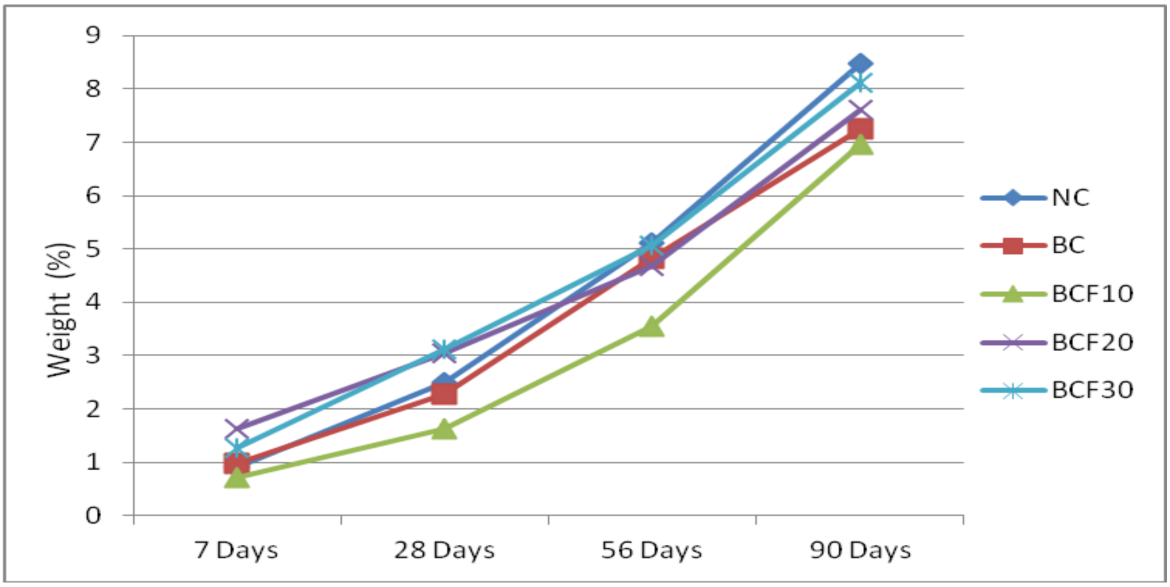

Fig.4 Percentage reduction in weight of concrete cubes after immersion in acid

Table 4: Relative compressive strength (%) and Acid durability factor of NC mix at various days of immersion in acid

Days of immersion	**Relative compressive strength (Sr) %**	**N**	**M**	**ADF**
7	**97.81**	**7**	**90**	**7.60**
28	**95.25**	**28**	**90**	**29.63**
56	**91.07**	**56**	**90**	**56.66**
90	**85.98**	**90**	**90**	**85.98**

Table 5: Relative compressive strength (%) and Acid durability factor of BC mix at various days of immersion in acid

Days of immersion	**Relative compressive strength (Sr) %**	**N**	**M**	**ADF**
7	98.10	7	90	7.63
28	95.97	28	90	29.85
56	91.31	56	90	56.81
90	87.55	90	90	87.55

Table 6: Relative compressive strength (%) and Acid durability factor for BCF10 mix at various days of immersion in acid

Days of immersion	**Relative compressive strength (Sr) %**	**N**	**M**	**ADF**
7	96.76	7	90	7.52
28	94.05	28	90	29.26
56	90.89	56	90	56.55
90	85.30	90	90	85.30

Table 7: Relative compressive strength (%) and Acid durability factor for BCF20 mix at various days of immersion in acid

Days of immersion	**Relative compressive strength (Sr) %**	**N**	**M**	**ADF**
7	97.95	7	90	7.61
28	94.40	28	90	29.37
56	91.29	56	90	56.80
90	86.84	90	90	86.84

Table 8: Relative compressive strength (%) and Acid durability factor for BCF30 mix at various days of immersion in acid

Days of immersion	**Relative compressive strength (Sr) %**	**N**	**M**	**ADF**
7	96.70	7	90	7.52
28	93.95	28	90	29.23
56	91.63	56	90	57.01
90	84.83	90	90	84.83

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Table 9: Acid durability factors for all mixes at various days of immersion in acid

	Acid durability factor			
Mix	**7 Days**	**28 Days**	**56 Days**	**90 Days**
NC	7.60	29.63	56.66	85.98
BC	7.63	29.85	56.81	87.55
BCF10	7.52	29.26	56.55	85.30
BCF20	7.61	29.37	56.80	86.84
BCF30	7.52	29.23	57.01	84.83

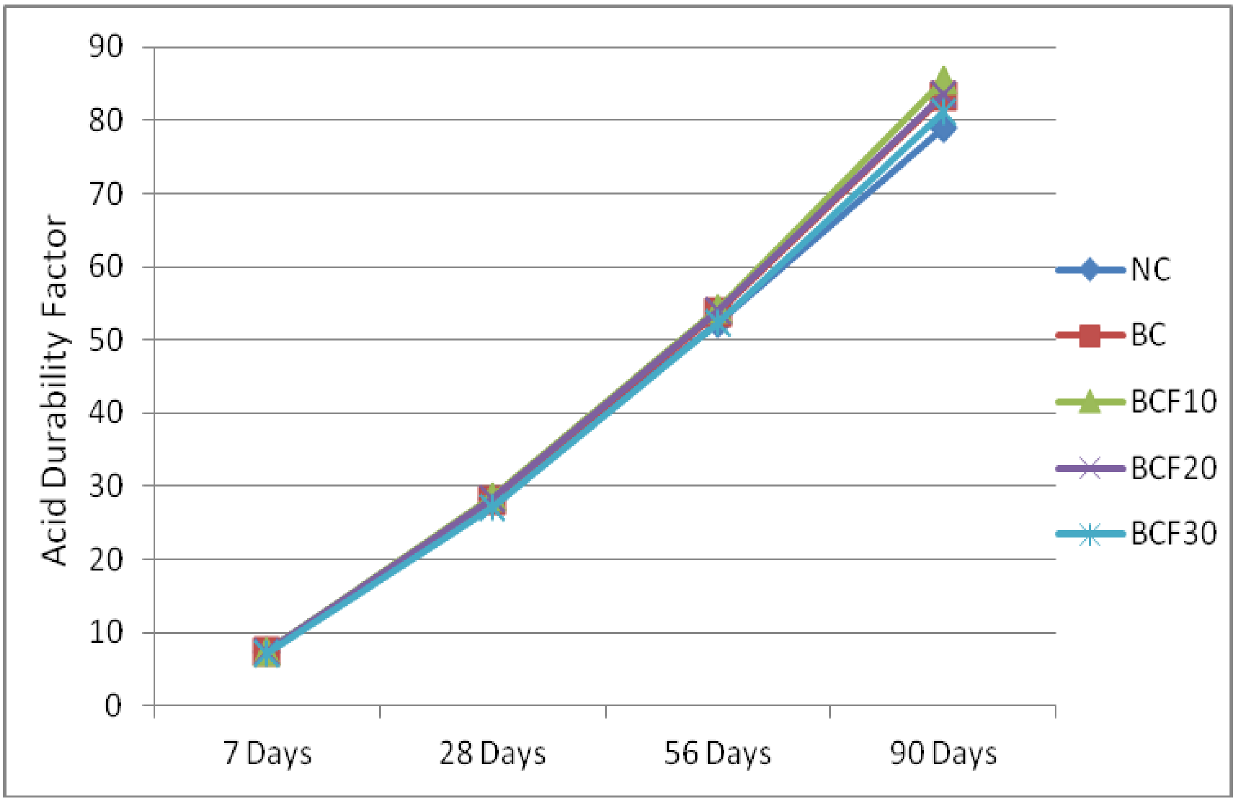

Fig 5. Acid durability factors for all mixes at various days of immersion in acid

Observation: After testing, a portion of crushed test specimen is placed in the nutrient broth and it is observed that there is considerable bacteria growth.

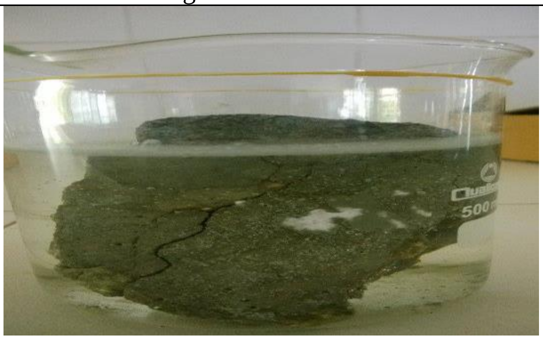

Fig.6 Crushed test piece placed in nutrient broth

Fig.7 Growth of live bacteria cells.

6.0 MICROSTRUCTURE

Scanning Electron Microscope (SEM): The microstructure of the fly ash-based bacterial concrete with different calcium contents was observed by SEM. It was notable that the Figure 7 of normal concrete matrix was not homogeneous and contained small pores and cracks. Figure 8, indicates bacterial concrete sample had depositions of calcium carbonate in cracks and less number of pores are seen in comparison to the samples of normal concrete. And it is consistent with the values of higher compressive strength for bacterial concrete compared to normal concrete. Figure 9, shows a good amount of calcium content along with greater amount of silica due to addition of fly ash. From the micrographs it can be seen that increase in calcium content caused a more compact and finer and denser matrix indicate fly ash particles fills in the gaps in concrete. Due to

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reaction of silica with free lime at longer period forms calcium silicate hydrate compound. Because of this hydrated compound the values of compressive strength for bacterial concrete with addition of fly ash are higher at 90 days compared to normal concrete and concrete with bacteria alone.

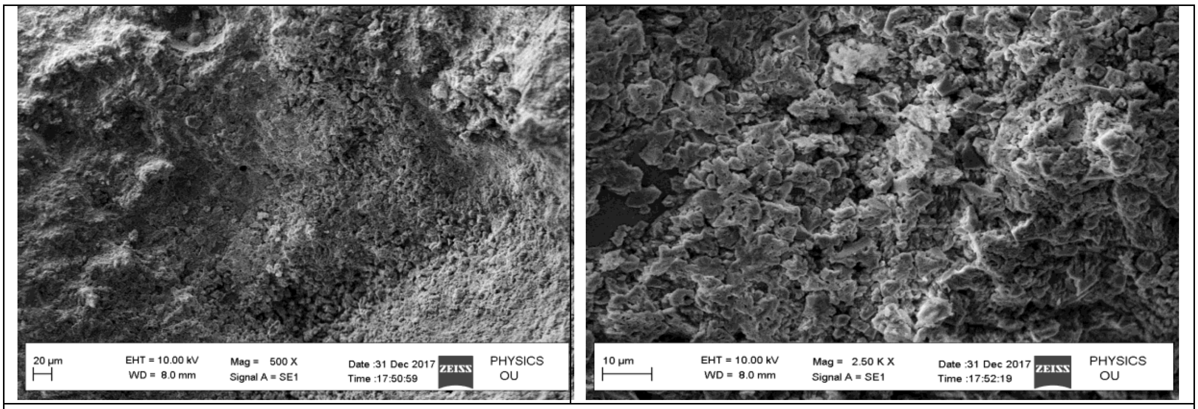

Fig.8: SEM Image of Normal Concrete @ 90 Days

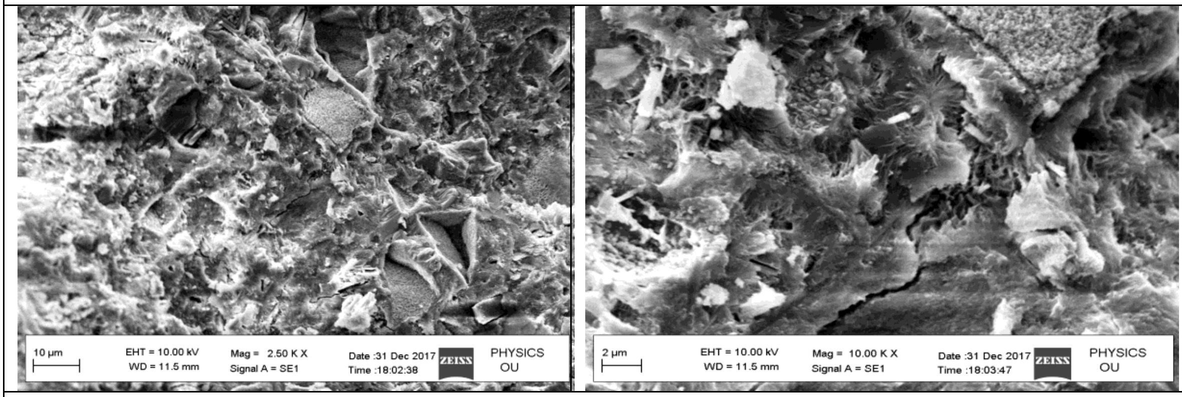

Fig.9: SEM Image of Bacterial concrete @ 90 Days with Bacteria

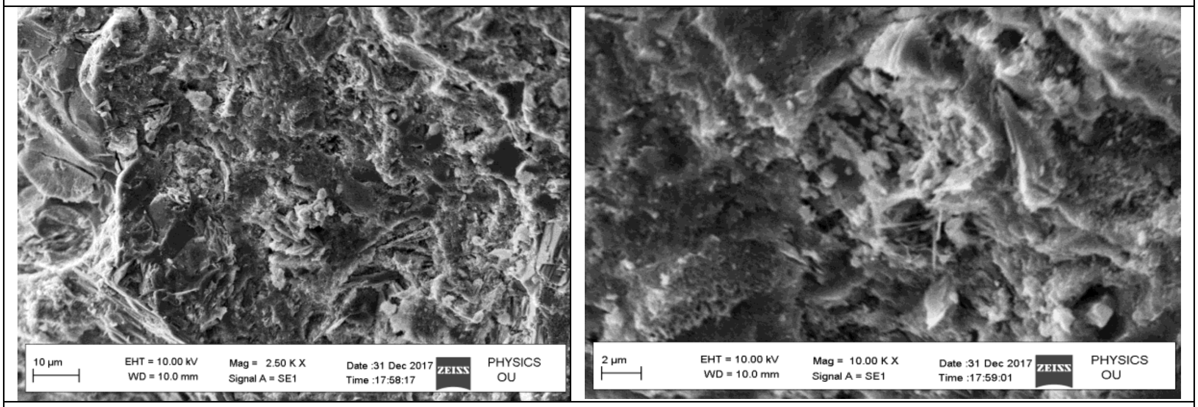

Fig.10: SEM Image of Bacterial concrete with Fly Ash @ 90 Days with Bacteria & Fly Ash

7.0 DISCUSSIONS

Mix with $1x10^7$ cells/ml bacteria and 0% Fly Ash (BC) has given maximum compressive strength at 28 days but mix with $1x10^7$ cells/ml bacteria and 10% Fly Ash (BCF10) has given maximum compressive strength at 90 days as shown in Figure 1, as fly ash has the property of gaining strength over longer period and it is observed that compressive strength is decreasing with increase in fly ash content.

Mix with $1x10^7$ cells/ml bacteria and 0% Fly Ash (BC) has given maximum split tensile strength at 28 days but mix with $1x10^7$ cells/ml bacteria and 10% Fly Ash (BCF10) has given maximum split tensile strength at 90 days as shown in Figure 2, as fly ash has the property of gaining strength over longer period.

Increase in compressive strength and split tensile strength values has shown that the density of the concrete has been increased due to filling of cracks with calcium carbonate crystals secreted by the bacteria induced in concrete as seen from Fig.8.

Mix with $1x10^7$ cells/ml bacteria and 10% Fly Ash (BCF10) has shown reduction in both compressive strength and weight when immersed in acid and tested after 7, 28, 56 and 90 days as mentioned in Table 2 & 3.

Reduction in percentages of strength and weight of concrete cubes is shown in Figure 3 & 4. The values indicate mix with $1x10^7$ cells/ml bacteria and 10% Fly Ash (BCF10) shown better resistance to deterioration of material in concrete matrix. This is due

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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to closely arranged fly ash particles in the matrix and secretion of calcite crystals by bacteria spores that helped in filling the micro cracks as shown in Fig.9.

Mix with 1x10^7 cells/ml bacteria and 10% Fly Ash (BCF10) and BC has shown better durability in terms of "Acid Durability Factor" than other mixes as shown in table 9

8.0 CONCLUSIONS

Concrete mix with 1x10^7 cells/ml bacteria and 10% Fly Ash (BCF10) has given maximum compressive strength and split tensile strength compared to other mixes.

Concrete mix with 1x10^7 cells/ml bacteria and 10% Fly Ash (BCF10) has shown better resistance to acid attack compared to other mixes.

REFERENCES

[1] Ramakrishnan, V. 'IMPROVEMENT OF CONCRETE DURABILITY BY BACTERIAL MINERAL PRECIPITATION'
[2] Ter Heide, N.et Al (2007) ,'EXPERIMENTAL STUDY OF CRACK HEALING OF EARLY AGE CRACKS', Proceedings of the First International Conference on Self Healing Materials 18-20 April 2007, Noordwijk aan Zee, The Netherlands
[3] De Muynck, et. al, 'IMPROVEMENT OF CONCRETE DURABILITY WITH THE AID OF BACTERIA, Proceedings of the First International Conference on Self Healing Materials 18-20 April 2007, Noordwijk aan Zee, The Netherlands
[4] Henk M. Jonkers et al. 2012, "A TWO COMPONENT BACTERIA-BASED SELF-HEALING CONCRETE", Concrete Repair, Rehabilitation and Retrofitting II – Alexander et al (eds) © 2009 Taylor & Francis Group, London, ISBN 978-0-415-46850-3
[5] S. Sunil Pratap Reddy, M. V. Seshagiri Rao, P. Aparna and Ch. Sasikala. "PERFORMANCE OF ORDINARY GRADE BACTERIAL (BACILLUS SUBTILIS) CONCRETE", International journal of earth science and engineering, vol. 3, no. 1, 2010, pp 116-124.
[6] C. C. Gavimath et Al. 2012, "POTENTIAL APPLICATION OF BACTERIA TO IMPROVE THE STRENGTH OF CEMENT CONCRETE", 'International Journal Of Advanced Biotechnology And Researchissn 0976-2612, Vol 3, Issue 1, Page 541 To 544.
[7] C.Marthong And T.P.Agrawal et Al. 2012, 'EFFECT OF FLY ASH ADDITIVE ON CONCRETE PROPERTIES', 'International Journal Of Engineering Research And Applications, Vol. 2, Issue4, Pa ge 1986 To1991.
[8] Vijeth N Kashyap and Radhakrishna et al. 2013, 'A STUDY ON EFFECT OF BACTERIA ON CEMENT COMPOSITES', 'IJRET: International Journal of Research in Engineering and Technology, IC-RICE Conference Issue', Page 356 to 360.
[9] Srinivasa Reddy V, 'STUDIES ON PERMEABILITY OF SELF-HEALING BUILT-IN BACTERIA CONCRETE', International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-1, Issue-6, January 2013
[10] Keerthi.S et Al. 2014, 'AN EXPERIMENTAL STUDY ON STRENGTH AND DURABILITY PARAMETERS OF CONCRETE BY USING BACTERIAL MINERAL PRECIPITATION', 'Association For Development In Engineering Research,Volume 1, Issue 1', Page 1 To 7.
[11] P. R. Wankhede and V. A. Fulari et al. 2014, 'EFFECT OF FLY ASH ON PROPERTIES OF CONCRETE', 'International Journal Of Emerging Technology And Advanced Engineering', P, Volume 4, Issue 7 , Page 284 To 289.
[12] Ravindranatha,et.al, 'EFFECT OF BACTERIA ON PARTIAL REPLACEMENT OF CONCRETE WITH FLY-ASH AND GGBS', IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308, Volume: 03 Special Issue: 03 | May-2014 | NCRIET-2014.