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Performance of Ordinary Grade Bacterial Concrete with Fly Ash as Partial Replacement for Cement

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***Abstract*:- Cracks in the concrete are common no matter how carefully it is designed and casted. These micro cracks are undesirable because they provide an open pathway for the ingress of water and other deleterious substances and corrode the steel reinforcement. So it is necessary to prevent cracks or limit crack width to enhance the durability of the structure. The most common crack treatments include using acrylics, epoxy injections, polyurethanes or latex treatment and grouting. Major problem is that the chemicals used in these treatments are harmful to the environment, expensive, and sometimes cannot reach the deeper portions of the cracks in the structural member. If an effective method and material is found that can repairs cracks in concrete automatically (self healing) with sustainable approach, then the performance of the structure would enormously increase. On the other hand it would also save money, time and material. One effective method for repairing cracks is self healing mechanism and material used is bacteria. The bacteria used in concrete works by the phenomenon called Microbiologically Induced Calcite Precipitation (MICP) or Bio mineralization and the concrete is called Bacterial Concrete or Selfhealing Concrete. Bio mineralization is process where common soil bacterium like Sporosarcina Pasteurii, Bacillus subtilis produce calcite. This calcite fills the cracks and eventually compressive strength and durability of concrete is improved. Suitable addition of mineral admixtures such as fly ash, silica fume, ground granulated blast furnace slag, rice husk ash, and metakaolin in concrete and induction of suitable bacteria in concrete improve the strength and durability of concrete due to considerable improvement in the microstructure of the concrete. Also, utilizing the environmental friendly sustainable construction materials like fly ash which can improve the strength and durability of concrete structures has developed interest in self healing Bacterial Concrete with Fly Ash. 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 by 0%, 10%, 20%, and 30% as replacement for cement and bacteria (Sporosarcina Pasteurii) is kept constant at 10^6 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 10^6 cells/ml bacteria and 20% Fly Ash (MB20620) has given optimum performance in terms of compressive strength, split tensile strength, strength loss, weight loss and water absorption.**

Keywords: Concrete, Self healing, Bacteria, Fly Ash, MICP, Strength, 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. 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

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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

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.

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.

Coarse Aggregate

Crushed granite angular aggregate of size 20 mm nominal size from local source with specific gravity of 2.62 is used.

Water

Locally available potable water conforming to IS 456 is used.

Fly Ash

Fly Ash of class ‘F’ with 2.28 specific gravity is used

Bacteria

Sporosarcina Pasteurii, a soil bacterium of 10^6 cells/ml concentration is cultured at Laboratory of Biotechnology Department

Grade designation: M20 grade concrete

Culture of Bacteria

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 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 g/lit., NaCl: 5 g/lit., Yeast extract: 3 g/lit, Urea: 20 g/lit and Calcium Chloride 5 g /lit.

4. 0 EXPERIMENTAL PROGRAM

Table 4.1 Mix Cases Considered for the Study

Mix Designation	Bacteria (cells/ml)	Fly Ash (%)
M20NC	0	0
MB20600	10^6	0
MB20610	10^6	10
MB20620	10^6	20
MB20630	10^6	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.

4.2 Split Tensile Strength Test

A diametric compressive load will be applied along the length of 150x300mm concrete cylinder 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.

4.3 Flexural Strength

The flexural strength is expressed as modulus of rupture in MPa, which represents the maximum stress at the extreme fibres in bending. This test is carried out on 100 mm x 100 mm x 500 mm prisms subjecting to two-point loading as per IS : 516 - 1959.

4.4. Durability (Acid test)

The chemical resistance of the concretes was studied through chemical attack by immersing 150x150mm concrete cubes in an acid solution. After 28 days period of curing, the specimen were immersed in 5% H_2SO_4 and reading for weight and compressive strengths were recorded for all concrete mixtures at 7, 28, 56 and 90 days.

4.5. Water Absorption

Water Absorption test was carried out on 100 mm cube specimen as per ASTM C642-97.

5.0 TEST RESULTS

5.1 Compressive Strength

Cube compressive strength is determined at 7, 28, 56, 90 days curing period and the values are tabulated in Table 5.1

Table 5.1 Compressive Strength of M20 Grade Concrete Mixtures

Mix Designation	Compressive Strength, MPa			
	7 days	28 days	56 days	90 days
M20NC	17.0	26.6	27.2	28.0
MB20600	19.2	29.4	33.2	36.2
MB20610	15.3	24.1	29.4	35.8
MB20620	16.8	27.9	32.2	38.3
MB20630	16.1	23.7	29.0	34.3

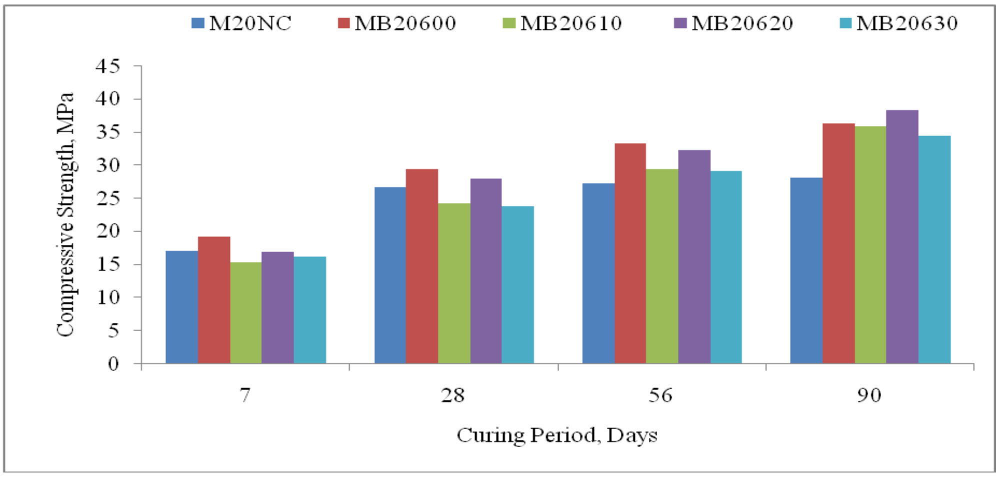

Figure 5.1 Compressive Strength of M20 Grade Concrete Mixtures

5.2 Splitting Tensile Strength

Concrete cylinders are used to determine splitting tensile strength at 28 and 90 days curing period and the values obtained are depicted in Table 5.2.

Table 5.2 Splitting Tensile Strength of M20 Grade Concrete Mixtures

Mix Designation	Splitting Tensile Strength, MPa	
	28 days	90 days
M20NC	2.9	3.1
MB20600	3.0	3.5
MB20610	2.9	3.5
MB20620	3.0	3.6
MB20630	2.8	3.4

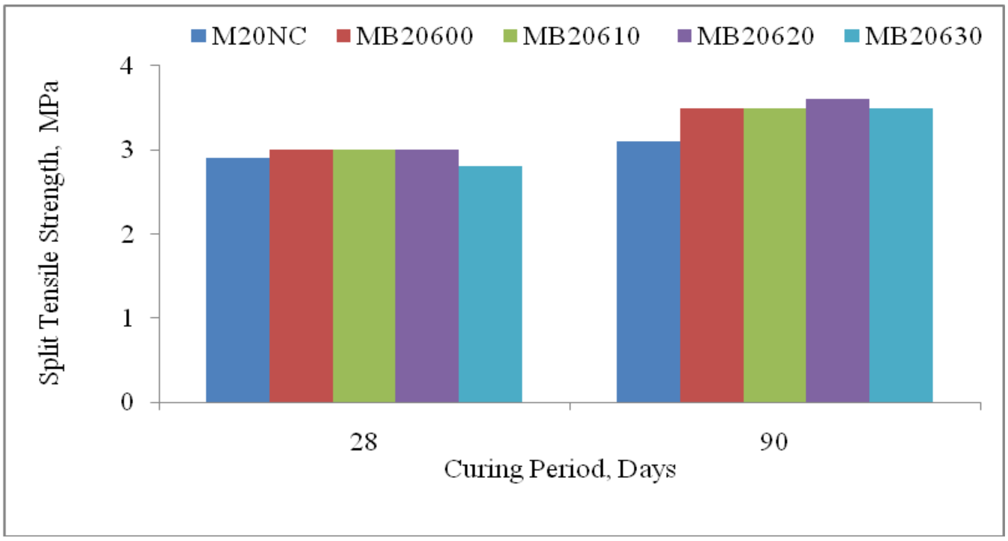

Figure 5.2 Splitting Tensile Strength of M20 Grade Concrete mixtures

5.3 Flexural Strength

Concrete prisms are used to determine flexural strength at 28 and 90 days curing period and the values obtained are shown in Table 5.3.

Table 5.3 Flexural Strength of M20 Grade Concrete Mixtures

Mix Designation	Flexural Strength, MPa	
	28 days	90 days
M20NC	3.3	3.6
MB20600	3.5	4.1
MB20610	3.3	4.1
MB20620	3.3	4.2
MB20630	3.2	4.0

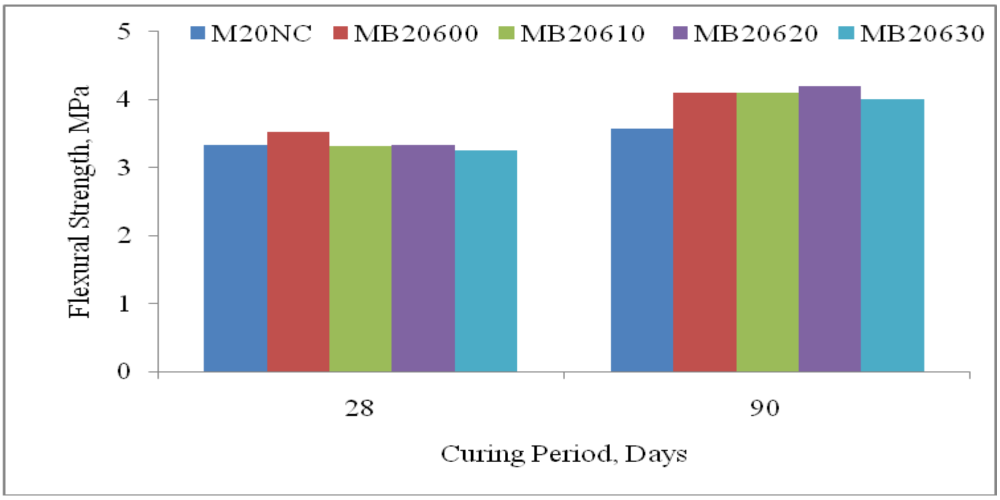

Figure 5.3 Flexural Strength of M20 Grade Concrete Mixtures

5.3. Durability

5.3.1 Weight Loss

Residual weights of concrete cubes after immersion in acid are depicted in Table 5.3.1.1 and percentage weight loss of cubes are shown in Table 5.3.1.2

Table 5.3.1.1 Weight of Concrete Cubes after Immersion in Acid

Mix Designation	Initial Weight	7 days	28 days	56 days	90 days
M20NC	8.351	8.237	8.174	7.827	7.697
MB20600	8.277	8.138	8.044	7.949	7.776
MB20610	8.211	8.036	7.977	7.859	7.698
MB20620	8.109	8.020	7.895	7.819	7.642
MB20630	8.041	7.848	7.788	7.658	7.566

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Table 5.3.1.2 Percentage Weight Loss after Immersion in Acid

Mix Designation	Weight Loss, %			
	7 days	28 days	56 days	90 days
M20NC	1.4	2.1	6.3	7.8
MB20600	1.7	2.8	4.0	6.1
MB20610	2.1	2.8	4.3	6.2
MB20620	1.1	2.6	3.6	5.8
MB20630	2.4	3.1	4.8	5.9

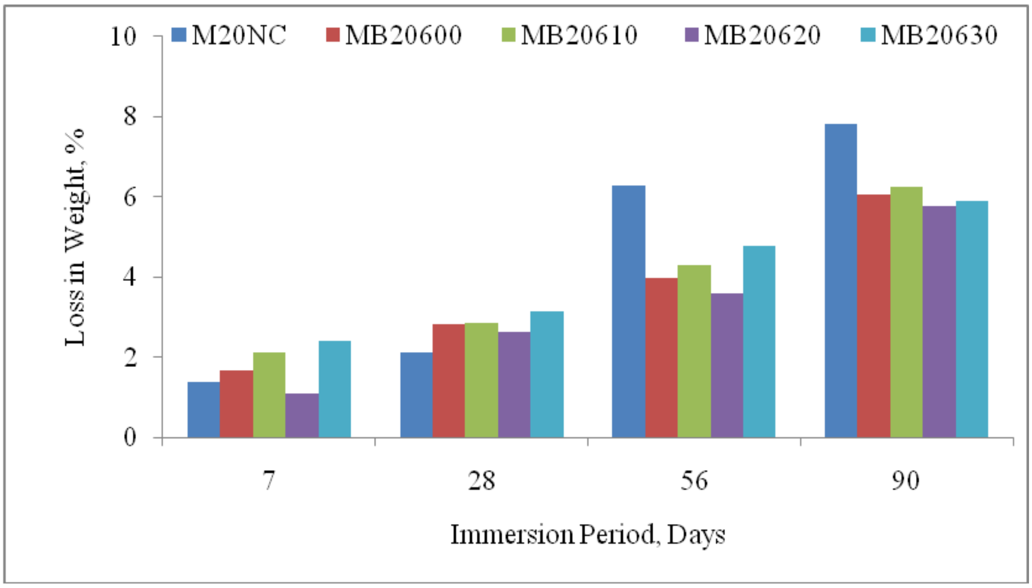

Figure 5.3.1.1 Percentage Weight Loss after Immersion in Acid

5.3.2 Strength Loss

Residual strength of concrete cubes after immersion in acid are depicted in Table 5.3.2.1 and percentage strength loss of cubes are shown in Table 5.3.2.2

Table 5.3.2.1 Compressive Strength values of Concrete Mixtures after Immersion in Acid

Mix Designation	Initial Strength	7 days	28 days	56 days	90 days
M20NC	26.55	26.07	25.39	24.52	21.91
MB20600	29.37	28.96	28.02	27.59	25.62
MB20610	24.12	23.43	22.96	22.28	20.89
MB20620	27.86	27.15	26.56	25.79	24.22
MB20630	23.69	22.95	22.51	21.88	20.48

Table 5.3.2.2: Percentage Compressive Strength Loss of Concrete Mixtures after Immersion in Acid

Mix Designation	Strength Loss, %			
	7 days	28 days	56 days	90 days
M20NC	1.8	4.4	7.6	17.5
MB20600	1.4	4.6	6.1	12.8
MB20610	2.9	4.8	7.6	13.4
MB20620	2.5	4.7	7.4	13.1
MB20630	3.1	5.0	7.6	13.6

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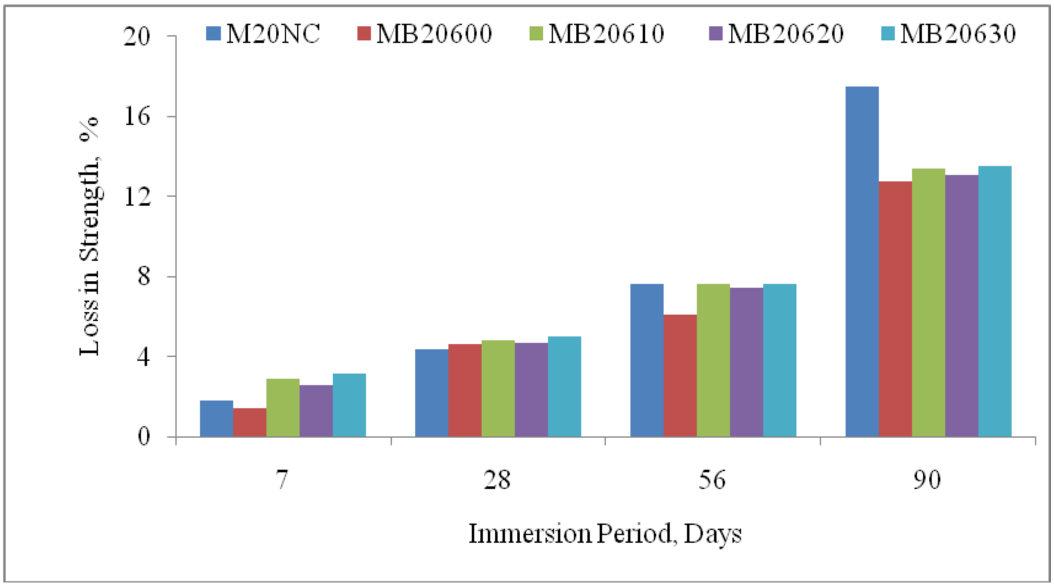

Figure 5.3.2.1: P e r c e n t a g e Compressive Strength Loss of Concrete Mixtures after Immersion in Acid

5.3.3 Water Absorption

Water absorption values and reduction of water absorption in percentage are shown in Table 5.3.3

Table 5.3.3 Water Absorption values of Concrete Mixtures

Water Absorption, %				
Mix Designation	28 days	Reduction	90 days	Reduction
M20NC	4.42	-	4.01	-
MB20600	3.16	15	3.03	20
MB20610	3.01	21	2.85	29
MB20620	2.95	22	2.81	30
MB20630	2.94	24	2.83	29

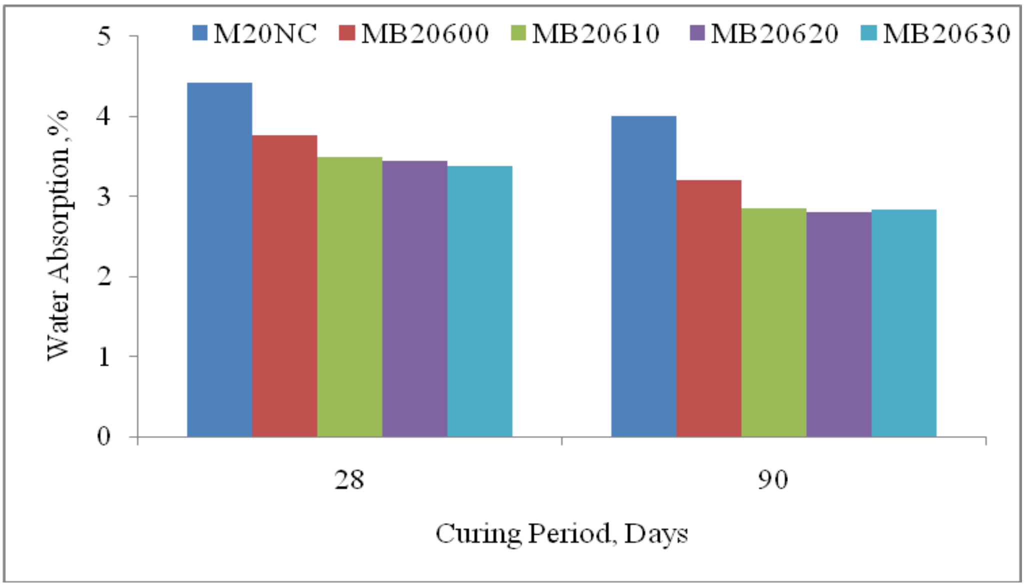

Figure 5.3.3 Water Absorption values of Concrete Mixtures

6.0 DISCUSSIONS

Mix with 10^6 cells/ml bacteria and 0% Fly Ash (MB20600) has given maximum compressive strength at 28 days but mix with 10^6 cells/ml bacteria and 20% Fly Ash (MB20620) has given maximum compressive strength at 90 days as shown in Figure 5.1, as Fly Ash has the property of gaining strength at later ages.

Mix with 10^6 cells/ml bacteria and 20% Fly Ash (MB20620) has given maximum splitting tensile strength and flexural strength at 90 days as shown in Figure 5.2 and 5.3

Increase in compressive strength, splitting tensile strength and flexural strength values at 90 days are indicating 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 and property of Fly Ash reacting with calcium hydroxide at later stages contributing to strength of concrete.

From the Figures 5.3.1.1 and 5.3.2.1, the values indicate mix with $1x10^6$ cells/ml bacteria and 20% Fly Ash (MB20620) shown better resistance to deterioration of material in terms of weight loss and strength loss in concrete matrix. This is due to closely arranged fly ash particles in the matrix and secretion of calcite crystals by bacteria spores that helped in filling the micro cracks. Also MB20620 mix has the lowest water absorption rate compared to other concrete mixtures.

7.0 CONCLUSIONS

Concrete mix with 10^6 cells/ml bacteria and 20% Fly Ash (MB20620) has given maximum compressive, splitting tensile and flexural strength compared to other mixes.

Concrete mix with 10^6 cells/ml bacteria and 20% Fly Ash (MB20620) has shown better resistance to acid attack and water absorption compared to other mixes.

8.0 REFERENCES

[1] Ramakrishnan, V. ‘IMPROVEMENT OF CONCRETE DURABILITY BY BACTERIAL MINERAL PRECIPITATION’

[2] 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

[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] M.V.Seshagiri Rao, ‘Performance of Microbial Concrete Developed Using Bacillus Subtilis JC3’, ‘*Journal of the Institution of Engineers (India) Series A* 98(10), DOI: 10.1007/s40030-017-0227-x, October 2017.

[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] 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

[7] 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.

[8] 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.

[9] 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.

[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.