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DEVELOPMENT OF FLEXURAL FATIGUE MODEL FOR BACTERIA INDUCED CONCRETE PAVEMENT

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Abstract: Concrete is a widely used material in construction that can withstand compressive load, Because of its brittle nature it is susceptible to cracks. Theses cracks in the field of pavement construction leads to ingress of fluids or substances into the lower layer of roads. Thus the leads to failure of cracks within the life of concrete. To avoid and overcome these cracks, need of increase in strength and durability of concrete. Especially in development of flexural strength of concrete. Introduction of bacteria into the concrete mixture works by precipitation of calcium carbonate to fill up the cracks in concrete. In this research, extensive laboratory investigations have been carried out to study the effect of introducing Bacillus Subtilis Bacteria on the mechanical properties of concrete. With addition to this beams of standard specimen for fatigue test were casted and test was conducted for normal and bacterial concrete for the stress ratio 0.6, 0.7 and 0.8. Then the results were compared. The experimental results of Bacterial Induced Concrete Pavement and plain concrete are discussed for M40 Grade of concrete for two type of cement. The results shows that bacterial induced concrete for OPC mix is 18% increase in compressive strength, 13.84 % increase in flexural strength and 11.32% increase in Split tensile strength when compared with normal concrete. The fatigue behaviour is studied and compared with IRC recommendations.

Index Terms **– Bacterial concrete, Bacillus subtilis, Flexural fatigue model.**

I. INTRODUCTION

Cement plays the chief role in construction industry. Cement act as a binding material in all concrete structures. Worldwide, with an annual production of over seven billion tons, concrete is the most widely used structural material due to its capacity to get casted in any form and shape. Due to the brittle nature of concrete it is susceptible to cracks.

There are many reason for development these minor cracks such as due overloading, improper design, and unskilled labours; quality of materials etc. Presence of cracks promotes the ingress of aggressive and potentially harmful fluids or substances such as sulphate, chlorides and carbonates (Krishna., 2016) Theses aggressive fluids permeate inside the concrete, affecting the reinforcement by corrosion, thereby reducing the durability of concrete structure. Cracks may not be considered as failure of the concrete but the introduction of harmful substances weakens the structure so need to closure these cracks by repairing the structure (Srimathi et al., 2018) The rising costs associated with repairs have led researchers to consider alternatives of crack sealing with growing interests in crack healing. The introduction of bacteria into the concrete mixture is one of such organic methods and works by precipitation of calcium carbonate to fill up cracks in concrete.

Present study has outlined that biotechnology can really be a supportive device to reduce micro cracks in concrete structures by using Bacillus species of bacterial in concrete. This latest advancement of concrete, that is set to fix itself, shows a powerful improvement in community infrastructure's service-life, hereby considerably reducing the maintenance costs and also lowering carbon emissions. Bacillus, a common soil bacterium, can continuously precipitate calcium carbonate (calcite) under favourable conditions. The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens. (Dinesh et al., 2017)

2. MATERIAL AND EXPERIMENTAL STUDIES

2.1 Materials used:

Cement: Ordinary Portland cement of 53 grade and Portland Pozzolana cement conforming to IS: 12269-1987 with specific Gravity 3.15 and 2.9 respectively has been used.

Fine Aggregate and Coarse aggregate: M sand of specific gravity 2.65 and conforming to IS-383-2016 Zone 2 was used. 20mm down 2.70 specific gravity coarse aggregate was used.

Chemical Admixture: Conplast SP430 with specific gravity 1.12 for concrete mix.

Bacteria: Bacillus subtilis of concentration of 30ml per liter of water was used. Bacteria were cultured by Bacillus Subtilis pure culture.

2.2 Mix design for different type of cement

Mix design for M40 grade concrete is derived as per IS 10262-2009. Two type of cement OPC and PPC are used. The bacteria concentration used is 105cells per liter of water. The mix proportion is as shown below Table1.

Table 1 Quantity of material per cubic meter of concrete for OPC and PPC mix

Contents	Values (Kg/m^3)
Cement	383
Water	153
Fine aggregate	678
Coarse aggregate	1250
Super plasticizer	1.92
Water cement ratio	0.40

Contents	Values (Kg/m^3)
Cement	383
Water	153
Fine aggregate	653
Coarse aggregate	1207
Super plasticizer	1.92
Water cement ratio	0.40

2.3 Test conducted on hardened concrete

Flexural strength:

Beams of dimension 100x100x500 mm were casted and tested in Flexural testing machine in accordance with IS 516-1959 to determine the flexural strength of concrete. Figure shows the flexural tesing machine and the failure of beam after flexural load of the beam reached.

Figure 1 Flexural Testing machine

Fatigue Test:

Beams of dimensions 100x100x500mm are casted and tested after 28 days of water curing. As per ASTM E606 fatigue testing conducted to determine the number of repetition of cyclic load with varying stress ratio of 0.6, 0.7 and 0.8. The computer system is setup with the fatigue testing apparatus for controlling the wave form of loading application, magnitude of load applied, frequency and to count the number of load repetitions till the failure of specimen. The input details in to the software like load to be applied repeatedly based on stress ratio, frequency of application of load and wave form of load application are entered in computer. Then the hydraulic system of the fatigue testing apparatus is switched on simultaneously with the computer system also to control the operation. The load applied is decided based on the stress ratio to be applied. The stress level applied in this study is 60%, 70% and 80% of static failure load.

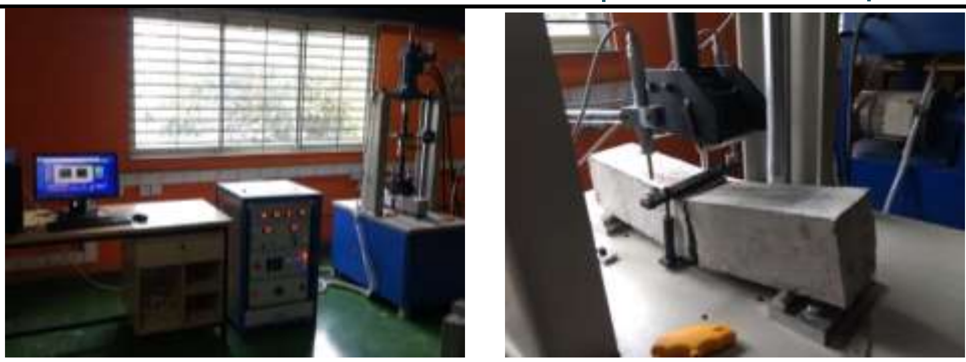

Figure 2 Fatigue testing machine and Failure of beam after fatigue test

3. Result and Discussion

3.1 Flexural strength:

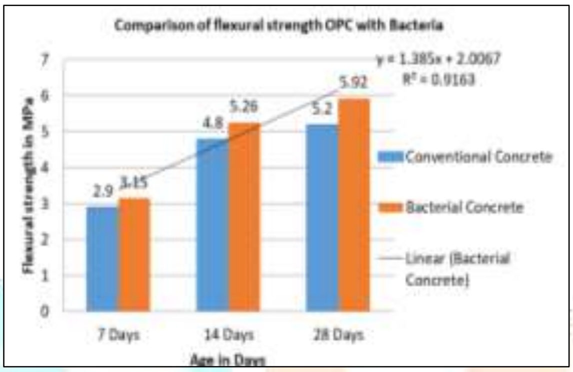

Figure (3)

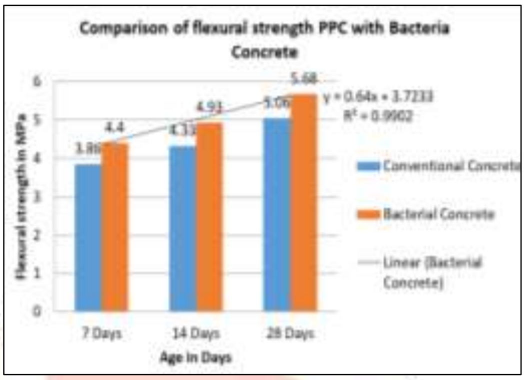

Figure (4)

The above graph shows the comparison of flexural strengthfor both type of mixes. From the present study it is observed that flexural strength of Bacteria induced OPC concrete shows increase of 13.84% when compare to conventional M40 concrete. Also for the PPC with bacteria induced concrete shows 12.25% increase as compares with normal PPc concrete.

3.2 Fatigue Test

In present investigation, flexural fatigue studies on controlled and bacteria concrete with different cement type OPC and PPC. For this concrete beam of 100 mm X 100 mm X 500 mm size used. The specimen are subjected to accelerated half sine wave form of cyclic loading test at two stress levels of 60 %, 70% and 80% of static flexural strength with frequency of load application i.e., two cycles per seconds. Prediction of fatigue life by a direct linear relationship between stress ratio and log (N) values models is attempted and the results are presented in this study. To get realistic value, half sine wave form of loading at two cycles per second is applied.

Table 2 Number of repetition to failure

	Samples	Conventional concrete			Bacterial concrete		
		Stress ratio			Stress ratio		
		0.6	0.7	0.8	0.6	0.7	0.8
OPC	1	29658	5774	1028	42568	6250	1250
	2	35588	5888	998	41526	5895	1123
	3	45236	4539	825	53654	6230	996
	4	32568	2685	1152	49862	5236	985
	5	42562	3564	1085	45562	4985	1025
	Avg	**37122**	**4490**	**1017.6**	**46634**	**5719.2**	**1075.8**
PPC	1	31524	6850	958	38562	7850	525
	2	35622	5546	352	35896	8862	689
	3	31150	8568	1112	34895	9542	975
	4	28652	7554	685	35998	8563	1023
	5	30562	4588	880	39896	8475	943
	Avg	**31502**	**6621.2**	**797.4**	**37050**	**8658.4**	**831**

3.3 To develop a failure prediction Model by Regression analysis

The fatigue equation given by IRC: 58- 2002 code is used to compare the developed linear regression model for Controlled Concrete and Bacteria admixed cement concrete. The models suggest by IRC is shown in below equation.

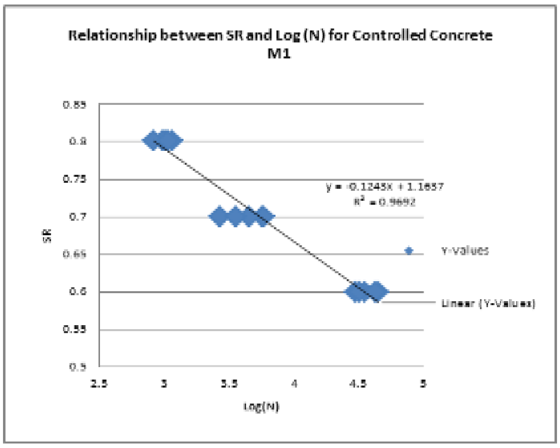

Figure (5)

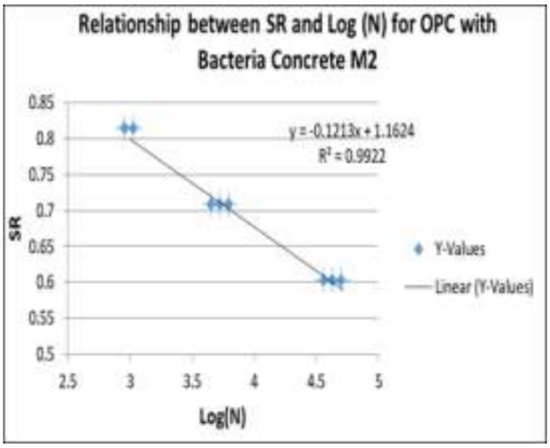

Figure (6)

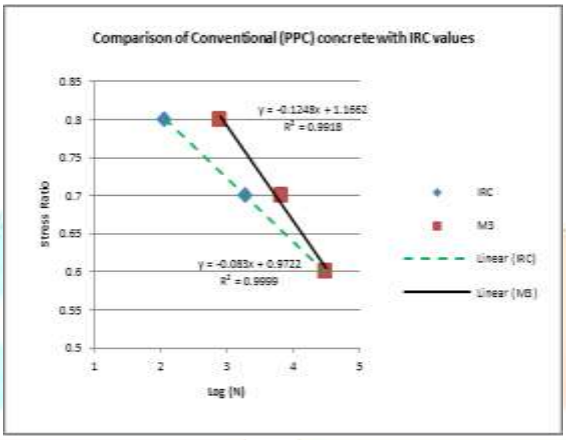

Figure (7)

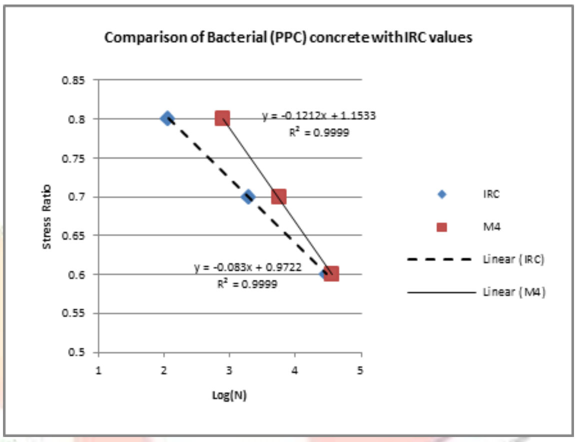

Figure (8)

3.4 Comparison of fatigue life of Bacterial and conventional concrete with IRC values.

SR	IRC		Conventional Concrete		Bacterial Concrete	
	Log (N)	No. Of Rept	Log (N)	No. Of Rept	Log (N)	No. Of Rept
0.55	5.094	1.24×10^5	***	***	***	***
0.6	4.48	3.09×10^4	4.56	37122	4.66	46634
0.65	3.886	7.70×10^3				
0.7	3.29	1970	3.65	4490	3.76	5718
0.75	2.68	477				
0.8	2.07	119	3.00	1018	3.03	1074
0.85	1.48	30				

Table 3

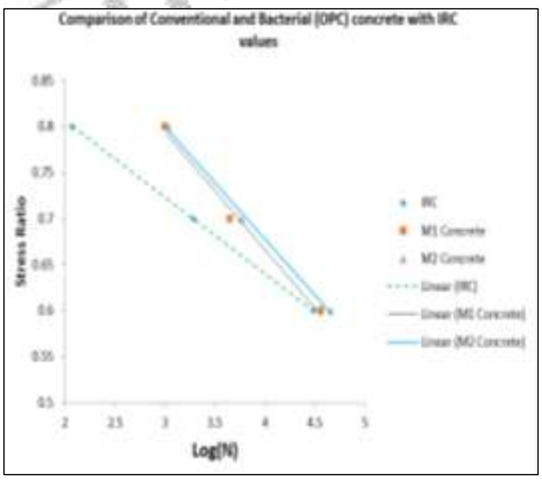

Figure (9)

From Table 3 and Figure 5.7 it is observed that the number of repetitions to failure at all stresses ratio for both mixes is more than that of IRC values.

3.5 Finite Element Analysis

The experimental results are validated using Ansyss software. The dimension of beam considered is 100x100x500 mm. Density of concrete is 2389 Kg/m$^{3.}$ Poisson ratio assumed that 0.15.Youngs modulus of concrete is 35266MPa.

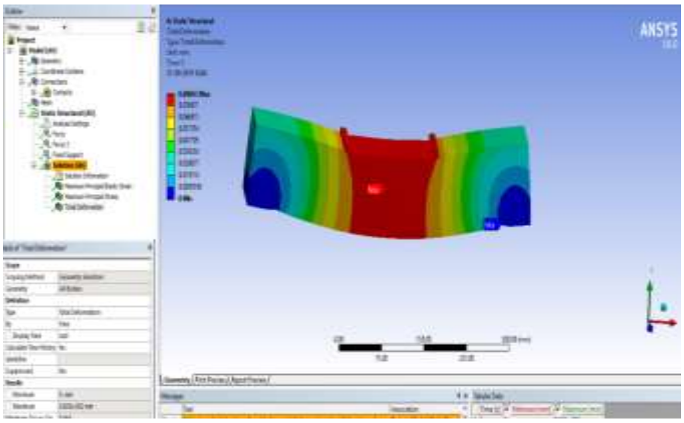

Figure (10) Deformation of beam

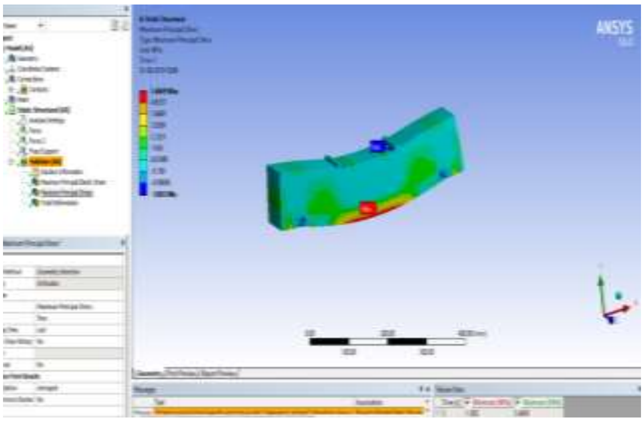

Figure (11) Failure model of a beam By ANSYS analysis

Table 4 Comparison of experimental and Ansyss result

Element type	**Stress in Normal concrete (Mpa)**		**Stress in Bacterial concrete (Mpa)**	
	Experimental data	ANSYS	Experimental data	ANSYS
Beams	**5.2**	**5.46**	**5.92**	**6.32**

It is noticed that from above Table 4: ANSYS results were 4% to 10% more than the Experimental value. Because of no uniformity in mixing, uniformity in material which have casted will not be same and dimensions may change slightly hence the experimental results are less when compared to ANSYS

4. CONCLUSION

1. There is an increase of 13.84 % in Flexural Strength of bacterial OPC concrete when compared to controlled concrete beams.
2. There is an increase of 12.25 % in Flexural Strength of bacterial PPC concrete when compared to controlled concrete beams.
3. The model developed in this study can be used for fatigue analysis and estimating the cumulative fatigue life while designing bacterial pavement.
4. Due to the higher flexural strength there will be reduction in thickness of pavement hence bacterial concrete pavements are economical.

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