ASSESSMENT OF COMPRESSIVE STRENGTH OF CONVENTIONAL CONCRETE BY USING SELF HEALING AGENT

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Abstract: Crack formation is very common phenomenon in concrete structure which allows the water and different type of chemical into the concrete through the cracks and decreases durability and strength. Self-healing mechanism in the concrete which helps to repair the cracks by producing calcium carbonate crystals which block the micro cracks and pores in the concrete. Bacillus pasteurii, Bacillus subtilis and B. sphaericus , Bacillus megaterium which are mainly used for the experiments by different researchers for their study. The selection of the bacteria was according to their survival in the alkaline environment The condition of growth is different for different types of bacteria. For the growth, bacteria were put in a medium containing different chemical at a particular temperature and for a particular time period. In this study Self-Healing agents such as Bacillus Sphaericus used Bacteria is mixed in concrete with calcium lactate. Bacteria used in proportion of 10, 20, 30 ml/liter and calcium lactate 10g/liter water. A Comparison study is made with this concrete subjected to compressive strength of normal concrete and Bacterial concrete.

Index Terms **– Bacillus sphaericus, Bacterial Concrete, Calcium lactate, Self-healing agent**

I. INTRODUCTION

Concrete is the most widely used man made construction material. Some of major forms of environmental attack are chlorides and sulphate that lead to corrosion of reinforcement and subsequent reduction in strength, serviceability and aesthetics of the structure. Crack formation is a typical phenomenon related to durability. Percolation of crack may lead to leakage problems, causing deterioration of the concrete matrix or corrosion of embedded steel reinforcement. [17].So to find solution for this recent years a bacteria-based self-healing concrete is being developed in order to extend the service life this called Self-healing concrete or Bacterial concrete.[11] Bacteria are added to the concrete mix to enhance the strength and also it acts as an excellent self-healing agent. It consists of cement, aggregate, sand, Bacteria, Calcium lactate. Self-healing concrete is a bacterial remediation technique surpasses other techniques it is bio-based, eco-friendly, cost-effective and durable.

II. LITERATURE REVIEW

The research study discusses the plugging of artificial crack in cement concrete using Bacillus Megaterium. The effect on compressive strength, water absorption and water permeability of cement concrete cubes due to due to mixing of bacteria is also discussed in this paper. It was found that the use of Bacillus Megaterium improves the compressive strength stiffness of concrete. It also shows that there is reduction in water absorption and water permeability when compared to conventional concrete.[3]

Bacterial impregnated concrete is crack free & corrosion free by pre-adding the bacteria Bacillus subtilis JC3 into the concrete. Bacteria Bacillus subtilis have the ability to withstand against hostile environment of concrete. B. subtilis have a thick wall membrane which helps to offer resistance against high pH. Hence these bacteria remain hibernated within the concrete for 200 years until gets the suitable environment. Results shows that on durability test of 100 days, 0.1 mm crack width was healed completely concluding that bacterial concrete is denser & durable.[8]

Calcites precipitating Bacterial stains were isolated from alkaline soil samples of a cement factory. Three isolates were selected and identified by 16SrRNA gene sequencing. They were identified as Bacillus megaterium BSKAU, Bacillus licheniformis BSKNAU and Bacillus flexus BSKNAU. Experimental work was carried out to assess the influence of bacteria on the compressive strength and the efficiency of bacteria toward crack healing. The maximum increase in strength was found for bacterial concrete specimens with B. megaterium MTCC 1684, the increase in strength of bacterial concrete specimens with B. megaterium BSKAU and B. licheniformis BSKNAU is equally good. Complete healing of cracks was observed in concrete specimens cast with B.megaterium BSKAU, B. licheniformis BSKNAU and B. megaterium MTCC 1684.[10]

Cement was partially replaced with RHA at 0%, 5%, 10%, 15%, 20%, 25%, and 30% by weight of cement. In addition, micro-silica (MS) was added to all mixes at dosage of 10% by weight of cementitious materials. The mix with the optimum RHA content was supplied with bacterial cells with concentrations of 103, 105, and 107 cells/ml to reduce the formation of microcracks.The RHA concretes showed reduced workability with increasing RHA content. Energy dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM) analyses were performed on the control mix, optimal RHA mix, and bacterial concrete mixes. The best strength properties were achieved for a bacterial concentration of 105 cells/ml, whereas the best durability properties were obtained for a bacterial concentration of 107 cells/ml. The 28-day compressive strength of the optimalmix containing 15% RHA increased by 12% compared to the control mix, and the increase in strength reached 21% with inclusion of bacteria at the optimal concentration. The optimal RHA content with the maximum bacterial concentration led to 415% increase in electrical resistivity and reduced the permeability-related properties up to 80% with respect to the control mix. According to the results, it's possible to produce an SCC with low permeability and high strength and filling ability with inclusion of specific RHA dosage and bacterial cell concentration.[13]

The effect of Bacillus Sphaericus and Sporosarcina Pastuerii bacteria on cement concrete was studied.. After experimental investigation it was found that these bacteria when added at 106 concentration of cells/ml of water to cement composites increased by about 39.8% and 33.07% in paste. The strength increment was found to be 18.3% and 12.2% for Bacillus Sphaericus and Sporosarcina Pastuerii respectively for concrete. It was concluded that Bacillus Sphaericus and Sporosarcina Pastuerii stains can improve the characteristics of cement composites due to calcite precipitation inside the cement composite specimens which are produced microbially.[15]

III. Mechanism Self-healing concrete

Self-healing concrete is a result of biological reaction of non-reacted limestone and a calcium-based nutrient with the help of bacteria to heal the cracks appeared on the building.Special type of bacteria's known as Bacillus is used along with calcium nutrient known as Calcium Lactate[14].When the cracks appear in the concrete, the water seeps in the cracks. The spores of the bacteria germinate and starts feeding on the calcium lactate consuming oxygen. The soluble calcium lactate is converted to insoluble limestone. The insoluble limestone starts to harden. Bacteria are microscopic, single-celled organisms that thrive in diverse environments. These organisms can live in soil, the ocean and inside the human gut.

IV. Bacteria used in Self-healing concrete

From various Researches carried on self-healing concrete researchers concluded that Bacillus family bacteria is used to make self-healing concrete. Following are the Bacteria used in Self healing concrete are Bacillus sphaericus, Bacillus pasteurii, Bacillus megaterium, Bacillus subtilis, Bacillus aerius, Sporosarcina pasteurii, AKKR5, Shewanella Species, Bacillus flexus, etc

V. Preparation of Bacterial Concrete Bacteria

Bacterial concrete can be prepared in two ways-

1. Direct application

Bacterial spores and calcium lactate is added into concrete directly when mixing of concrete is done. When Crack occurred Water comes in contact with this bacterium, they germinate and feed on calcium lactate and produces limestone. Thus sealing the cracks.

2. Encapsulation in lightweight concrete

By encapsulation method the bacteria and its food i.e. calcium lactate, are placed inside treated clay pellets and concrete is prepared. About 6% of the clay pellets are added for making bacterial concrete. [8]

when concrete structures are made with Bacterial concrete, when the crack occurs in the structure and clay pellets are broken and the bacteria germinate and eat down the calcium lactate and produce limestone, which hardens and thus sealing the crack. Minor cracks about 0.5mm width can be treated by using bacterial concrete.

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VI. RESEARCH METHODOLOGY

In this Research paper initial investigation on Self-healing concrete is done on M20 grade of concrete. The main aim in this project is to compare the hardened properties of normal water concrete, Bacterial concrete. The material tests required to obtain the mix design of concrete were carried out in the laboratory. The mix design forM20 concrete is obtained using the IS Standard method of design. The material used are: Cement used is Birla super OPC 53 grade, River Sand and 20mm Coarse aggregates, Bacillus sphaericus Bacteria with 10,20,30 ml/liter(BCNW10, BCNW20, BCNW30), Calcium lactate 10gm/liter. The experimental investigations carried out on normal and bacterial concrete are: Cubic compressive strength. The strengths of Bacterial concrete are compared with the strengths of normal water concrete .The cubic compressive strengths are compared for 7 days, 14 days and 28 days curing period.

VII. Experimental Procedure

To conduct experimental work , material is required to be selected .Also, bacterial culture is also prepared .The detailed procedure of culture preparation is explained .

6.1 Materials

A. Cement: Cement is a binder material, ordinary Portland cement (OPC) of 53 grade (Birla super brand) was used. The physical and chemical properties of cement are as per IS12269:1987[21].

B. Fine aggregate: River sand passing through 4.75mm IS sieve and confirming to zone-2 of IS383:1987[22] was used. The specific gravity was found to be 2.78.

C. Coarse aggregate: The coarse aggregate used in this work was was of 20 mm down nominal size. The crushed angular shaped coarse aggregate was obtained from the local crushing plants. It has specific gravity of 2.94.

D. Water: Potable water is used for conventional and bacterial concrete.[23]

E: Bacillus sphaericus: The Microbial culture of Bacillus sphaericus was obtained in Freeze dried form in ampoules under the code **NCIM 2478 (ATCC14557, DSM28**) from National Collection of Industrial Microorganisms. Prescribed medium by NCIM is Nutrient agar (solid), Nutrient broth (Liquid).

F: Calcium Lactate: Calcium lactate is a white crystalline salt made by the action of lactic acid on calcium carbonate. It is created by the reaction of lactic acid with calcium carbonate or calcium hydroxide. The chemical formula of Calcium lactate is **$C_6H_{10}CaO_6.5H_20$**. Manufactured by Analab fine chemicals, Mumbai. We have used calcium lactate in our research in the Quantity 10 gram/liter.

6.2 Preparation of Bacterial culture

For 1000ml of distilled water 13g of nutrient broth was taken in a conical flask. The conical flask should be cotton plugged. Then the broth is kept in an autoclave for 20 min at 120^0 C . The flask was taken out and it should be cooled to room temperature. Use laminar air flow chamber for inoculating the broth without any contamination. Before using the laminar air flow chamber clean the chamber with ethanol. Then after revived ,culture was taken and it is mixed with the broth. Keep the conical flask in the incubator at 30^0 C for 24 hrs.

6.3 Mix Design

In this research, the concrete M20 Grade for the samples was used. The M20 grade mix design of concrete is taken as per IS10262-2009 [24]. The proportion of mix design is 1:1.64:3.as shown in table 1.

Table 1 Mix Design

Cement(kg)	FA (kg)	Coarse aggregate(kg)	Water (Liter)
426	700	1260	191.58

6.4 Compressive strength test

This test was conducted as per IS 516-1959 [25].The cube mould of size 150mm × 150mm × 150mm, conforming to IS: 10086 – 1982 were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of CTM with the capacity of 200 kN without the eccentricity and a uniform rate on loading is 140 kg/cm2 per minute was applied until the failure of the cube. The maximum load was noted and the compressive strength was calculated. The compression strength in N/mm2=P/A. The tests were performed at a curing age of 7, 14 and 28 days. Total 36 cubes, with three specimens for four different batches were made for testing at each selected age.

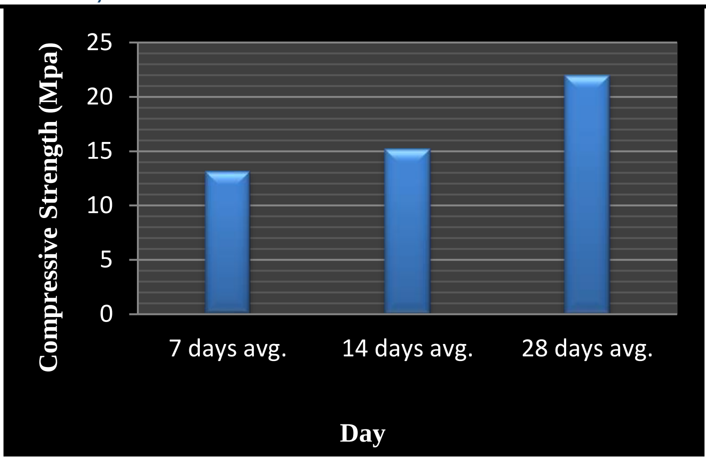
VIII. Result & Discussion

In the compressive strength test, three cubes constituted of one sample. Total 36 cubes were tested the compressive strength test is performed as described in section. The Table show the 7th, 14th and 28th day Compressive strength test results. The test results are shown in table 2.

Table 2 Compressive Strength Results (Mpa)

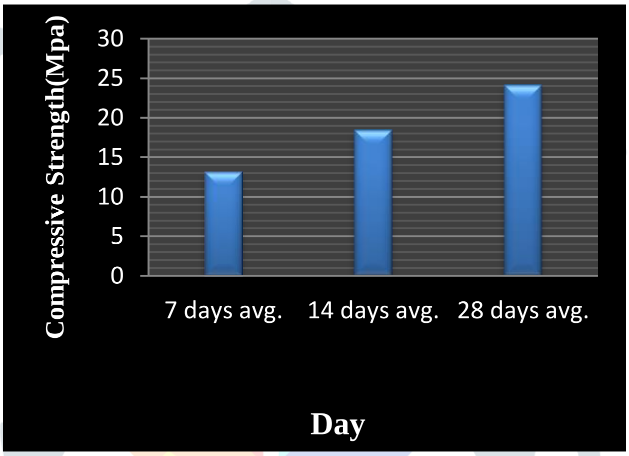
Index	7th Day	14th Day	28th Day
Normal Concrete	13.15	15.2	22
BCNW 10	13.52	18.42	24.12
BCNW 20	18.82	24.12	31.4
BCNW 30	18.36	25.8	32.44

The following Graphs show the Compressive strength results for M20 concrete for 7th, 14th and 28th days.

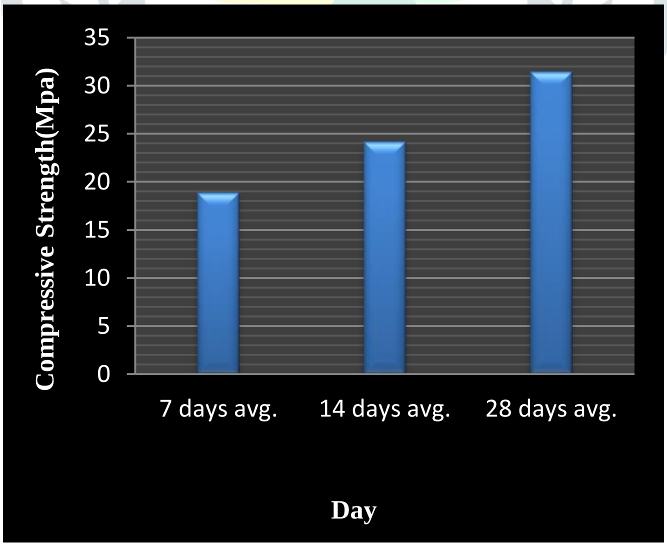


Graph 1-Compressive strength of M20 Normal concrete

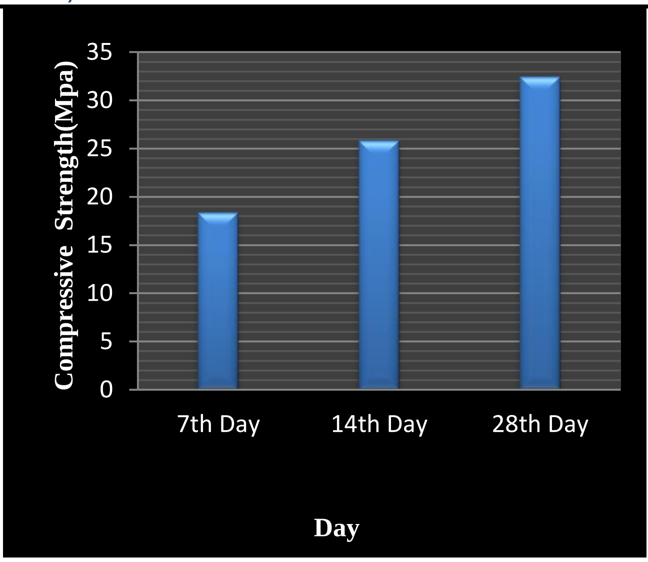
The average test results for concrete with bacterial culture are shown in following graphs.



. Graph 2.Compressive strength of BCNW 10ML



Graph 3.Compressive strength of BCNW 20ML

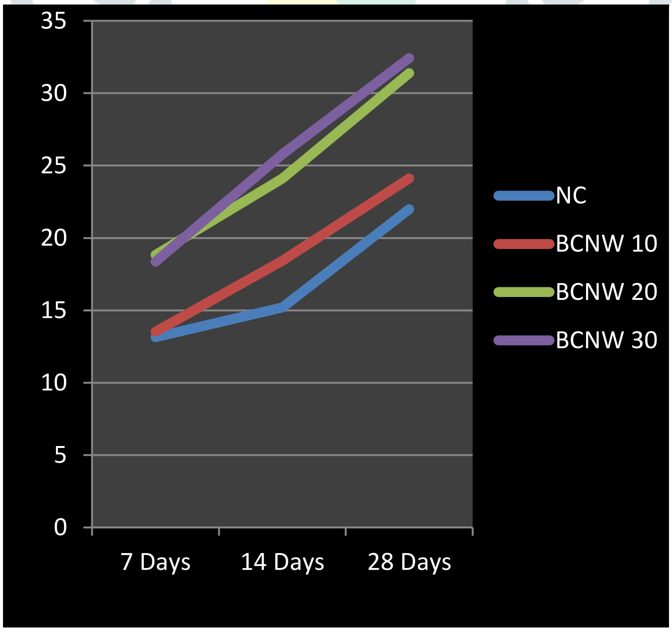


Graph 4.Compressive strength of BCNW 30 ML

The comparison of compressive test result of various concrete mix is shown in table 3

Table 3 Comparison of compressive strength in % normal concrete

INDEX	7th Day	% Increase	14th Day	% Increase	28th Day	% Increase
Normal Concrete	13.15	-	15.2	-	22	-
BCNW 10	13.52	2.81%	18.42	21.1%	24.12	9.6%
BCNW 20	18.82	43.1%	24.12	58.6%	31.4	42.4%
BCNW 30	18.36	39.6%	25.8	69.7%	32.44	47.4%



Graph 5.Comparison of compressive strength w.r.t Normal Concrete

IX. Conclusion

1) The importance of work is to introduce the Bacillus sphaericus bacteria to understand the change in hardened properties of concrete.
2) The bacteria to be proved efficient in enhancing the properties of the concrete strength increase thus we can conclude the

produced calcium carbonate has filled so percentage of void volume thereby making the texture compact and resistive to seepage.

3) The addition of bacteria with tap water is added in the concrete in proportion 10 ml/litre, 20 ml/litre. The result obtained at 7, 14, 28 days the compressive strength increased in the range of 9% to 48% when compared to normal concrete.
4) The Mix with Bacterial concentration of 30 ml/liter attained maximum increase in strength. Bacterial concrete it may become yet another alternative method to replace OPC and hazardous effect on environment pollution

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