

STUDY ON STRUCTURAL BEHAVIOUR OF CONCRETE USING MICROORGANISM

Submitted in partial fulfilment of the requirements for the award of
Master of Engineering Degree in Structural Engineering

By

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**DEPARTMENT OF CIVIL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of T DANIEL RAJ (40380002) who carried out the project entitled "**STUDY ON STRUCTURAL BEHAVIOUR OF CONCRETE USING MICROORGANISM**" under my supervision from November 2021 to May 2022

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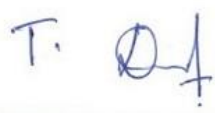
Submitted for Viva voce Examination held on 11/05/2022

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DECLARATION

I **T DANIEL RAJ (40380002)** hereby declare that the Project Report entitled **“STUDY ON STRUCTURAL BEHAVIOUR OF CONCRETE USING MICROORGANISM ”** done by me under the guidance of **Er. J. VANJINATHAN** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfilment of the requirements for the award of Masters of Engineering degree in Structural Engineering.

A handwritten signature in blue ink, appearing to read 'T. Daniel Raj', is written on a light blue rectangular background.

PLACE: Chennai

SIGNATURE OF THE CANDIDATE

DATE: 11-05-2022

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ABSTRACT

"CONCRETE" is the most extensively used "manmade" material for building in many developing countries for all types of civil engineering projects. This study looks at the various types of bacteria that may be discovered in concrete and how they can be used as healing agents. A brief summary of the many properties of concrete that change when microorganisms are added is also included in this study. Microcracks are a natural feature of concrete. This causes concrete degradation, which allows hazardous substances to enter the concrete and cause structural problems. As a result, the concrete will need to be resurfaced. To get out of these situations, self-healing treatments are performed. The inclusion of urease-producing bacteria plus a calcium source causes calcite precipitation in concrete. Bio-mineralization procedures have been demonstrated to be successful in sealing microcracks in concrete. Newly generated micro-cracks in concrete can be sealed by the continuous hydration process. The bacteria and Calcium sulfoaluminate are used in this study work to make an attempt. The compressive strength, split tensile strength, flexural strength, and tensile strength of the specimens, 150x150x150mm cube, 150mmx300mm cylinder, and 100mmx100mmx500mm prism, were all tested throughout the experimental examination. Flexural Behavior (230mmx230mmx1000mm) is also tested using a beam (230mmx230mmx1000mm) with and without bacteria. The strength properties of various Bacteria and CSA mix proportions are investigated, and then compared to standard conventional concrete. For concrete grade M40, an experimental study was conducted employing *Bacillus subtilis* bacteria and calcium sulfoaluminate to cure cracks in the concrete at different percent-ages such as 5%, 10%, and 15% of cement weight. In the current project, M40 grade concrete is used, with bacterial solution at 6 percent, 12 percent, and 18 percent volume fractions, as well as Calcium Sulfoaluminate at a 12 percent cement replacement. The proposed sample will be analysed after 7 days of curing and 28 days. The enhanced tensile strength will be discovered based on the findings. The proposed sample will be analysed after 7 days of curing and 28 days. These findings will reveal whether microorganism-induced concrete is suitable for proper confinement in constructions subjected to excessive loads or not.

TABLE OF CONTENTS

CHAPTER NO.	TABLE OF CONTENTS	PAGE NO.
	ABSTRACT	v
	LIST OF FIGURES	ix-x
	LIST OF TABLES	xi-xii
01	INTRODUCTION	01-06
	1.1. General	01
	1.2 Concrete	02
	1.3 Reinforced Concrete	02
	1.4 Bacterial Concrete	02
	1.4.1 Bacillus Subtilus	03
	1.4.2 Calcium Sulphoaluminate	04
	1.5 Application	05
	1.6 Advantages & Disadvantages	05
	1.6.1 Advantages	05
	1.6.2 Disadvantages	06
	1.7 Need for study	06
02	LITERATURE REVIEW	07-11
	2.1 General	07
	2.2 Literature review	07
	2.3 Summary	11
03	SCOPE AND OBJECTIVE	12-13
	3.1 Aim	12
	3.2 Objective	12
	3.3 Scope	12
04	MATERIALS & METHODOLOGY	14-38
	4.1 Materials	14
	4.1.1 Cement	14
	4.1.2 Aggregates	14
	4.1.2.1 Coarse Aggregate	15

	4.1.2.2 Fine Aggregates	15
	4.1.3 Bacteria	16
	4.1.4 Water	16
	4.2 Methodology Flow Chart	17
	4.3 Concrete mix design	18
	4.3.1 Mixing Procedure	18
	4.3.2 Mix Calculation	20
	4.4 Experimental Investigation	21
	4.4.1 Preparation of Specimen	22
	4.4.1.1 Casting	24
	4.4.1.1.1 Cube	24
	4.4.1.1.2 Cylinder	25
	4.4.1.1.3 Prism	26
	4.4.1.1.4 RC Beam	27
	4.4.2 Demolding and Curing	28
	4.4.2.1 Demolding	28
	4.4.3 Cube Compressive Strength Test	30
	4.4.4 Cylinder Split Tensile Strength Test	30
	4.4.5 Flexural Strength Test	31
	4.4.6 Specimen Designation	32
	4.5.7 RC and B12C12 Beam Test	33
	4.5 Numerical Analysis	34
	4.5.1 General	34
	4.5.2 Ansys workbench	35
	4.5.3 Ansys model	35
	4.5.4 Engineering data	36
	4.5.5 Geometry creation	37
	4.5.6 Setting up the finite model	37
	4.5.7 Providing the support and loading conditions	38
05	RESULT AND DISCUSSION	39
	5.1 Slump Cone Test Result	42
	5.2 Experimental results	43

	5.2.1 Compressive Strength	45
	5.2.2 Split tensile strength	48
	5.2.3 Flexural strength	50
	5.2.4 RC Beam Test results	52
	5.3 Numerical results	57
	5.3.1 Conventional beam	64
	5.3.2 B12C12 MIX	65
	5.4 Comparison of Experimental Results with Analytical Results	67
06	CONCLUSION	68
	REFERENCE	69

LIST OF FIGURES

S.NO	DESCRIPTION	PAGE
1.1	Bacillus Subtilus	04
1.2	Calcium Sulfoaluminate	04
4.1	Bacterial solution	30
4.2	Flow chart	
4.3	Concrete Preparation	31
4.4	Slump cone	31
4.5	Cube casting	32
4.6	Cylinder Casting	
4.7	Prism Casting	33
4.8	Reinforcement details	
4.9	RC Beam Casting	
4.11	Cube Compressive strength test	37
4.12	Split tensile strength test	38
4.13	Flexural strength test	39
4.14	Reinforcement details	40
4.15	Experimental setup for B12C12 Beam	41
4.16	Experimental setup for conventional beam	41
4.17	ANSYS Material Property	42
4.18	Geometry of beam in design modeler	45
4.19	Mesh in mechanical model	46
4.20	Loading condition	47
5.1	Comparison of compressive strength	51
5.2	7 & 28 Day Split Tensile Strength	55
5.3	7 & 28 Day Flexural strength	58

5.4	Load and deflection behavior(experimental)	61
5.5	Stress contour for RC Beam	61
5.6	Deformation for RC Beam	62
5.7	Stress contour for B12C12 Beam	62
5.8	Deformation for B12C12 Beam	62
5.9	Stress vs strain	65
5.10	Load vs deflection curve(analytical)	65
5.11	Comparison of Conventional experimental results with analytical results.	65
5.12	Comparison of B12C12 experimental results with analytical results.	

LIST OF TABLES

S.NO	DESCRIPTION	PAGE
4.1	Test on cement	13
4.2	Test on coarse aggregate	13
4.3	Test on fine aggregate	14
4.4	Fineness Modulus and Gradation	28
4.5	Proportions	40
4.6	Amount of material required	41
4.7	No of Specimen casted	48
4.8	Size of Specimens Casted	
4.9	Specimen Designation	
5.1	Slump Value	50
5.2	7 Day Compressive Strength	50
5.3	28 Day Compressive Strength	51
5.4	7 & 28 Days Compressive Strength	51
5.5	7 Day Split Tensile Strength	53
5.6	28 Day Split Tensile Strength	54
5.7	7 & 28 Days Split Tensile Strength	55
5.10	7 Day Flexural Strength	56
5.11	14 Day Flexural Strength	57
5.12	28Day Flexural Strength	58
5.13	7,14&28 days Flexural Strength	60
5.14	Percentage Increase Strength over conventional mix	63
5.15	Load and deflection value(experimental)	64
5.16	Load and deflection value(analytical)	65

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is weak in tension. At around 10% to 15% of the ultimate load, micro-cracks appear in the matrix of a structural element, which then propagate into macro-cracks at 25% to 30% of the ultimate load. As a result, without continuous bar reinforcing components in the tensile zone of supported parts such as beams or slabs, plain concrete members cannot withstand enormous transverse loads. The development of micro and macro cracks, on the other hand, cannot be stopped or reduced just by the use of continuous reinforcing. The purpose of such reinforcement is to take over the role of a section's tensile zone and assume the tension equilibrium force.

The inclusion of bacterial solution should help to prevent the formation or propagation of micro fractures, which are known to form early in the loading history. Although fibres have been used to strengthen brittle materials like concrete since the dawn of time, newly created fibres have been widely used in the last three decades around the world. *Bacillus Subtilus*, *Brevi Bacillus*, *Bacillus Megaterium*, and *Microvirga* are among the commercially available strains. They've shown that they can improve the concrete's mechanical qualities. *Bacillus subtilus* is the most efficient of the four species of bacterium mentioned above. The introduction of bacteria to concrete in the early 1900s was primarily for the purpose of increasing its strength.

A microorganism-induced bacterial concrete is being developed to raise the concrete's characteristic compressive strength and lengthen its service life. When a crack appears, the steel may be exposed to corrosion; however, when the concrete heals, corrosion is avoided. Because concrete is not flexible, it cannot withstand a lot of strain and wears out over time. This flaw is somewhat remedied by the addition of microorganisms and calcium sulphoaluminate. Bio-associated substances and procedures could be employed for bio aggregation, soil bio grouting and biologging, crack remediation, self-healing, and bio mediated ground improvement, among other applications. Because each species of bacteria has a wide range of properties, they should be guided by the manufacturer's data and expertise with the product before choosing a bacterial solution type.

1.2 CONCRETE

Concrete is a highly adaptable building material. Any structural shape can be cast into it. It is inexpensive and frequently available in metropolitan areas. Concrete is a brittle substance that is strong in compression but weak in tension. As a result, some kind of reinforcement is required. Steel bars are the most popular type of concrete reinforcement.

Concrete has a high compressive strength, is fire resistant, is water resistant, requires little maintenance, and has a long service life. Concrete has several drawbacks, including low tensile strength and the need for form work.

1.3 REINFORCED CONCRETE

Concrete's tensile strength is usually between 8% and 15% of its compressive strength. Over many decades, this flaw has been addressed by utilizing a system of reinforcing bars (rebars) to construct reinforced concrete, which largely resists compressive loads while steel bars resist tensile and shear stresses.

In a beam, longitudinal rebar resists flexural (tensile) stress, whereas stirrups wrapped around the longitudinal bar resist shear pressures. Vertical bars withstand compression and buckling stresses in a column, while ties resist shear and limit vertical bars.

Reinforced concrete is a good composite material with a wide range of applications. Steel bars, on the other hand, simply reinforce concrete against tension locally. Reinforced concrete members have cracks that run freely until they come into contact with rebar. The necessity for concrete reinforcement that is multidirectional and tightly spaced develops.

1.4 BACTERIAL CONCRETE

Bacterial concrete may fill structural gaps without requiring human intervention. To do this, *Bacillus* bacteria, calcium lactate, nitrogen, and phosphorus are combined into concrete and enclosed in clay pellets in a 1:19 bacteria-to-calcium-source ratio. These are small, ranging from 0.1 mm to 0.5 mm, and restrict the germs from being exposed to the outside world.

Bacillus produces spores, which are thick, specialized cell walls that protect germs. This allows the germs to remain latent in the concrete for up to 200 years. Although most organisms cannot survive at pH levels below 10, bacteria are alkaliphilic,

allowing them to thrive in the alkaline (pH 13) environment of concrete [8]. The clay pellets around the crack break when a split in the concrete occurs, allowing the bacteria to assimilate the nourishment and perform their usual metabolic operations. Insoluble calcium carbonate (CaCO_3) is formed as a result, gradually plugging the fractures. Bacterial concrete costs roughly 6846.53 Rupees per m^3 , compared to 5705.44 Rupees for conventional concrete, but it could be a lucrative investment. Although bacterial concrete has a higher initial cost, it is predicted to save money in the long run by lowering the cost of repairs and the resulting disruptions.

The capacity to heal cracks isn't the only benefit of bacterial concrete: its compressive and tensile strengths are raised, and its porosity is reduced, resulting in increased durability. The permeability is lowered, which reduces the infiltration of dangerous substances that could impair the structure of the concrete. If bacterial concrete were more widely used, world cement output and consequently CO_2 emissions would be reduced. As a result, despite increasing costs, despite its high initial costs, bacterial concrete represents a possible advancement in the field of civil engineering.

1.4.1 *Bacillus Subtilis*

Bacillus subtilis (hay/grass bacillus) is a Gram-positive bacterium that can be found in the gastrointestinal tracts of ruminants, humans, and soil. *Bacillus* is a *Bacillus* species. *Bacillus subtilis* is a rod-shaped, robust, protective endospore that can withstand harsh environments. It is a facultative aerobe as well as an obligate aerobe. For research of chromosome replication and cell differentiation, this is the finest gram-positive organism. Enzyme manufacturing is employed on a large scale in biotechnological industries. Christian Gottfried Ehrenberg called *Bacillus subtilis* after *Vibrio subtilis*, and it was eventually renamed *B. subtilis*, which means Fine in Latin. It has a diameter of 0.25-1.0 μm . It has the ability to create endospores and is strongly flagellated, allowing it to travel through fluids. They are particularly receptive to genetic manipulation and have been utilized for a variety of purposes. It is considered as equal to *E. coli*.



Fig 1.1 Bacillus Subtilis

1.4.2 Calcium Sulphoaluminate

China was primarily responsible for the invention of calcium sulphoaluminate (CSA) cement in the 1970s. It's often created from limestone, clay, and bauxite, as well as natural gypsum, at a temperature of 1250–1350°C, which is around 100–200°C lower than traditional Portland cement (OPC). CSA cements (calcium sulphoaluminate cements) are a prospective low-CO₂ alternative to Portland cements. The microstructures in CSA cements are extremely dense. Calcium sulphoaluminate cement is a low-alkali, quick-hardening cementitious compound.



Fig 1.2: Calcium sulfoaluminate

➤ **Concrete Proportion:**

Concrete was chosen in various proportions. B6C12 denotes bacteria that are 6 percent calcium sulphoaluminate and 12 percent calcium sulphoaluminate, B12C12

denotes bacteria that are 12 percent calcium sulphoaluminate and 12 percent calcium sulphoaluminate, and B16C12 denotes bacteria that are 16 percent calcium sulphoaluminate and 12 percent calcium sulphoaluminate. Cement, sand, and aggregate are the three primary components of concrete (Coarse and fine). As the product's qualities vary, so does the ratio. Admixtures are used to change the concrete's performance. With its variable density, strength, heat, and chemical resistance qualities, the final product is customised to its use. The strength of concrete varies depending on the composition of the mixture. We've added bacillus subtilus solution and calcium sulphoaluminate to the concrete, in addition to the general proportion.

1.5 APPLICATION

Compact constructions are commonly found in cities, townships, and municipalities and are usually residential. Because the functions of small housing developments usually change, it's reasonable to want to prolong its lifetime, and self-healing concrete is a great option. As a result, when a building's function is no longer required in a specific location, re-modeling will be used instead of demolition, resulting in a beneficial impact on CO2 emissions reduction by avoiding construction. Self-healing concrete is employed because bridges and all road projects regularly develop microscopic fractures as a result of large loads and require constant maintenance.

This sort of self-healing concrete is highly recommended due to its numerous benefits, as it will considerably reduce maintenance expenses while also boosting safety. This type of concrete can undoubtedly enhance self-healing concrete structures while also enhancing infrastructure and improve safety and longevity.

1.6 Advantages & Disadvantages

1.6.1 Advantage:

Concrete that is self-healing can repair themselves without any need for extra treatment.

Its compressive and flexural strengths are higher than the conventional concrete.

It is extremely resistant to freeze-thaw attacks.

Self-healing concrete has a low permeability.

Reduce corrosion in steel by minimising fissure which is a major source of corrosion.

The microorganisms employed in self-healing concrete, such as Bacillus bacteria, are innocuous to human life and hence can be used efficiently.

1.6.2 Disadvantage:

Cost of self-healing is almost double compared to normal concrete

Growth bacteria can get affected due to various environmental conditions

1.7 NEED FOR STUDY:

Concrete constructions with self-healing concrete will have a longer service life, making the material more robust and sustainable. Bacterial concrete lowers the cost of detecting deterioration and maintaining concrete structures, guaranteeing the long-term stability of the structure. Bacterial concrete can help it last longer. To see how long the concrete will last. Green microbes take carbon dioxide gas to help them grow and generate calcium carbonate, therefore bacterial concrete is also necessary.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

A microorganism-induced bacterial concrete is being developed to raise the concrete's characteristic compressive strength and lengthen its service life. When a crack appears, the steel may be exposed to corrosion; however, when the concrete heals, corrosion is avoided. Because concrete isn't flexible, it can't withstand a lot of pressure and wears down over time. Percolation of fissures can result in leaks, causing concrete deterioration and corrosion of embedded steel reinforcement.

Many complex research are being carried out to control the cracks in structures. Incorporating microorganisms able to precipitate Calcium carbonate (CaCO_3), that can self-heal fractures, is one such experiment. The primary goal of a literature review is to provide an overview of the research that has been done around the world. This serves as the foundation for the work and the strategies that can be used to conduct experiments. The research investigations on fibre addition in concrete are detailed in the following literature review.

2.2 LITERATURE REVIEW:

Partheeban pachaivannan et al. (2020) *Bacillus subtilis* may be created in the laboratory and is safe because its degree of biosafety is just 1 and it is a bacteria found in the soil, according to the results of an experiment. As part of its metabolic activity, it exhibits a phenomena known as biocalcification. It's a technique in which a microbe secretes calcium precipitate from the outside, which fills in the spaces in the concrete texture and makes it more compact.

Shradha Jena et al. (2020). They discovered that the real life span of concrete falls dramatically when fractures occur on its surface, resulting in concrete corrosion. Technological cement production technologies are being applied to address such concerns, and one such high-tech concrete is (MICP)self-healing concrete. This research provides details on an experiment that was carried out to determine the impact of *Bacillus subtilis* bacteria on specific traits. Microorganism calcite precipitation was visualised using scanning electron microscope (SEM), which

demonstrated the formation of additive material, i.e. calcite deposition, inside concrete matrix, leading in denser concrete and greater strength.

C. Manvith Kumar Reddy et al. (2020) They conducted a trial in which mineralizing bacteria were used to improve the structural strength of concrete. By adding laboratory cultivated *Bacillus subtilis* to concrete, they were able to demonstrate the effect on flexural strength (ATCC 9372). For the M20 grade of concrete mix, cultured *Bacillus subtilis* was added to normal water. The flexural strength of concrete was measured in this study by casting rectangular beams with dimensions of 500 mm*100 mm*100 mm and testing them according to Codal requirements.

Miaomiao Gao et al. (2020) used Materials such as alginate-crosslinked hydrogels and chitosan. *Bacillus pseudofirmus* (*Bacillus pseudofirmus*) Medium: Beef and peptone extract This material, combined with 1.0 percent chitosan in hydrogel beads, resulted in a 13.79 percent increase in flexural strength and a 10.28 percent increase in compressive strength.

Sumbly Maqbool et al. (2019) Bacteria were researched to see whether they might be used to effectively mend cracks in concrete. The healing efficiency of cracks is substantially improved when microorganisms are contained inside a carrier, as the carrier shelters the microorganisms from the hostile atmosphere of concrete. This study investigated the use of various media for bacterial encapsulation. The bacteria (Genus *Bacillus*) have been blended into the concrete as a result of mixing, and tests were performed to see how compressive strength affected the age of the cracks at 7, 28, and 56 days. The Microbially Induced Carbonate Precipitation technique greatly increased the compressive strength of the concrete.

Sumit joshiShweta et al. (2019) acted upon After 12 months of exposure to sulphate medium, the compressive strength of specimens with admixed bacteria and surface sprayed bacteria increased by 35% and 16%, respectively, as compared to control specimens. Control specimens showed surface degradation as compared to bacteria-added specimens.

Agarwal et al. (2019) Control concrete and bacteria-induced concrete were compared. Control concrete is a form of concrete prepared by replacing cement with

8% Micronized Biomass Silica (MBS). *Bacillus Sphaericus* was employed in the concrete specimens and was combined at varying levels of 10ml, 20ml, and 30ml. The split tensile strength and compressive strength of high strength concrete grade M60 cast in the form of cylinders and cubes are compared to conventional concrete at the ages of 7 and 28 days. The test findings revealed that specimens containing 20ml bacteria and 8% MBS produced the best outcomes.

Kejun wen et al. (2018) acted upon Microbial induced calcite precipitation (MICP) can improve the mechanical characteristics of sandy soil by bonding sand particles together. This environmentally friendly approach might be used to make bio-bricks and bio-beams, among other building materials. The flexure behaviour of fibre reinforced and bamboo reinforced bio-beams was evaluated using four-point bending tests. The addition of fibre to MICP-treated bio-beams increased ductility, according to the findings. Acid washing was used to quantify the amount of CaCO_3 precipitated in the soil samples. An HCl solution was used to wash the samples.

Jing Xu et al. (2018) According to the manufacturer, bacteria-based healing agents should be incorporated into new state concrete during mixing. Fissures up to 417 m were mended in 28 days just after bacteria-based self-healing solution was embedded in concrete, with a crack closing rate of around 100%. Silica fume (Elkem Materials) was added in percentages of 0%, 20%, and 40% by mass of calcium sulphotoaluminate cement to further lessen the alkalinity of the material. The self-healing performance of microbial CaCO_3 precipitation was evaluated using numerical image analysis and capillary moisture absorption studies. They used calcium sulphotoaluminate cement to create a protective carrier for the microorganisms in their paper.

S.S Lucas et al. (2018) carried out that a biological method is a viable option for achieving tangible healing. Bacteria were immobilised in expanded clay and then added to concrete via aggregate replacement in this study. The findings revealed that a certain kind of bacterium, *Bacillus*, seemed to thrive in unusually harsh conditions. Compression tests as well as XRD analyses were carried out. The samples were investigated using scanning electron microscopy, EDS, and XRD analyses to see if the recovery was caused by the bacteria creating limestone. As a result, replacing particles with expanded clay laced with microorganisms could help

concrete regain its strength.

Armin Saeedi Javadi et al. (2018) In this study, recycled concrete aggregates, The findings were compared to those made using natural aggregates. which are just a common part of c&d waste , have been used to make bio-blocks through the bio-mineralization of CaCO_3 . The durability and mechanical properties of both kind of bio-blocks were also investigated. The difference in compressive strength among bio-blocks made with both aggregate was less than 10%. Bio-mineralization reduced the water absorption of the RCA bio-blocks, which is one of the downsides of recycled aggregate.

M. Roig Flores et al. (2015) The self-healing effect of a crystalline additive was investigated in four types of environmental exposure and compared to a control concrete. Both autogenous and crystalline healing require the presence of water. Water immersion had the best therapeutic results. Healing was investigated using permeability tests on fractured specimens, as well as physical crack closure viewed using an optic microscope and quantified using crack geometrical metrics. The crack holes in the study were less than 300 m long, and the healing duration was set at 42 days.

Mian Luo et al. (2015) In this Bacteria-based self-healing concrete is constructed by integrating a microbial self-healing agent capable of boosting self-healing capability principally through bacteria-induced calcite precipitation, according to the report. A scanning electron microscope (SEM) coupled with an Energy Dispersive X-ray Spectrometer (EDS) and X-ray Diffraction was used to investigate the precipitations formed at the crack surfaces of the cement paste specimens (XRD). Hydro curing was shown to be the best effective method for bacteria-based self-healing concrete.

Mignon et al. (2014) An research was carried out to see if adding a higher amount of Super Absorbent Polymer (SAP) will result in a better self-sealing effect. When 0.5 percent of the cement weight is added to cement mortar, the crack sealing performance is greatly improved over a 28-day period when compared to reference mortar without SAP. When compared to mortar without SAP, a water permeability test revealed that SAP mortar has a higher sealing effect. Stalactites were found on samples, and in-depth examination revealed that the product developing surrounding them was CaCO_3 .

2.3 SUMMARY:

It is clear from the aforementioned article and experimental work that bacterial growth is doing well. When *Bacillus subtilis* is added into concrete, the compressive strength is higher than in normal concrete, and it is known from the study of Parteeban Pachaivannan et al (2020) that biocalcification plays an important role in crack healing. While Bahareh Tayebani et al. (2019) discovered that bacteria other than *Bacillus subtilis* can be employed, According to Kejun Wen et al (2018), CaCO_3 precipitation improves the concrete's durability. Further With advancements in bacterial concrete, it is certain that bacterial concrete will play a role in both rehabilitation and replacement of conventional concrete. It demonstrates that this type of concrete has benefits such as increased concrete strength and fracture healing qualities. When comparing the experimental studies of various authors, it becomes clear that each methodology has its own set of advantages in terms of material attributes. Depending on the resources available, each methodology can be used under various site situations.

CHAPTER 3

SCOPE AND OBJECTIVE

3.1 AIM:

- To determine the flexural behavior of reinforced concrete beam using bacterial and calcium sulfoaluminate.
- To determine optimum mix ratio of bacterial concrete by adding it with suitable concrete ingredients.

3.2 OBJECTIVE:

- The primary objective of this project is to Increase the Characteristic Compression Strength in concrete and to self-repair the cracks with the help of microorganism.
- To check *Flexural Strength* of the concrete as per IS:516-1959 (Methods of tests for strength of concrete)
- To determine the mechanical properties of the concrete. such as compressive strength, flexural strength, split tensile, water absorption, acid attack, alkali attack
- To determine the optimum percentage of addition of bacteria based on compressive strength
- To determine the flexural behavior of RC beam experimentally
- To determine the flexural behavior of RC beam analytically
- Comparison of experimental and analytical results.

3.3 SCOPE:

To achieve our project objective, the scope of our project work is:

- The compressive strength, tensile strength on bacterial concrete is done.
- Loading frame test on beam and split tensile test is determined.

➤ In this present study the bacteria of varying percentage and CSA of constant percentage are incorporated into bacterial concrete.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 MATERIALS

4.1.1 Cement

Portland cement is a mixture of water, alumina, silica, lime, iron, and gypsum that is often used as cement. All mixes were made with Ramco brand cement of Indian Standards (IS) mark 53 grade (IS mark 53 grade means the cement's 28-day compressive strength is 53 MPa). Cement testing was carried out in accordance with IS: 12269-1987.

Cement has a variety of features and characteristics that are determined by its chemical makeup. The oxide compositions of cement have varying qualities and types depending on the fineness of grinding. The use of additives, changes in chemical composition, and the utilisation of various raw materials have resulted in a wide range of cement kinds. The cement used in the experiment was OPC grade 43.

The results of the tests on sample are listed

Table 4.1 Tests on cement

S.No	Parameters	Values
1	specific gravity	3.15
2	standard consistency	32%
3	Setting time	
	(i) Initial setting time	345 minutes
	(ii) Final setting time	510 minutes
4	Fineness	3%

4.1.2 Aggregates

The strength of concrete is determined by the presence of coarse and fine particles in the mix. As fine aggregate, natural sand with a maximum size of 4.75 mm was employed. The dust was removed after the sand was sieved using a 4.75 mm sieve to eliminate any particles larger than 4.75 mm. This project employed

locally accessible coarse aggregates with a size of 12.5 mm. Fine and coarse aggregates were tested according to IS: 383-1970.

Aggregates are an important part of concrete. They add body to concrete, minimise shrinkage, and help you save money. Aggregates account for 70-80% of the volume of concrete, which has an impact on its many qualities and properties. Aggregates were formerly assumed to be chemically stable materials, but it has subsequently been shown that some aggregate are chemically active, with chemical bonding visible at the aggregate-paste interface.

4.1.2.1 Coarse Aggregates

Crushed granite in sizes of 10mm and 20mm is used as coarse aggregate. The aggregate used in this study is crushed blue granite stone aggregate with a size of 20mm or less that is locally available, and the findings of the various tests done on the aggregate are listed below. The tests which follow are conducted in accordance with IS specifications. Investigations on coarse aggregate are shown in Table 4.2.

Table 4.2 Tests on Coarse aggregate

S.No	Parameters	Values
1.	Fineness modulus	7.12
2.	Specific gravity	2.85
3.	Water absorption	0.3%

4.1.2.2 Fine Aggregates

Fine aggregate that meets the requirements for experimental work and complies with the IS: 383-1970 zone definition. It's bought from a local crusher. Fine aggregate is made up of particles that match the specifications' requirements and have a specific gravity of 2.54. The tests that follow are carried out in compliance with IS requirements. Table 1 shows the results of fine aggregate tests.

Table 4.3 Tests on fine aggregate

S.No	Parameters	Values
1.	Specific gravity	2.54
2.	Fineness modulus	2.636
3.	Water absorption	2.62
4.	Bulk density	
	(i) Loose state	1537.96 Kg/m ³
	(ii) Rodded state	1778.609 Kg/m ³

4.1.3 Bacteria

These are gram positive bacteria which has the ability to live in every natural environment. Due to its biosafety level 1 it is not harmful to human beings. The bacteria were bought from Anand Agro Care (Bacterium Bacillus Spp 2.0% A.S)



Fig 4.1 Bacteria

4.1.4 Water

Concrete was mixed and cured with clean drinking water. The water has been tested and meets the criteria. Because its chemical composition is recognised and

highly regulated, potable water is appropriate as a mixing water for cement concrete, plain cement concrete for road building, and other purposes.

4.2 METHODOLOGY

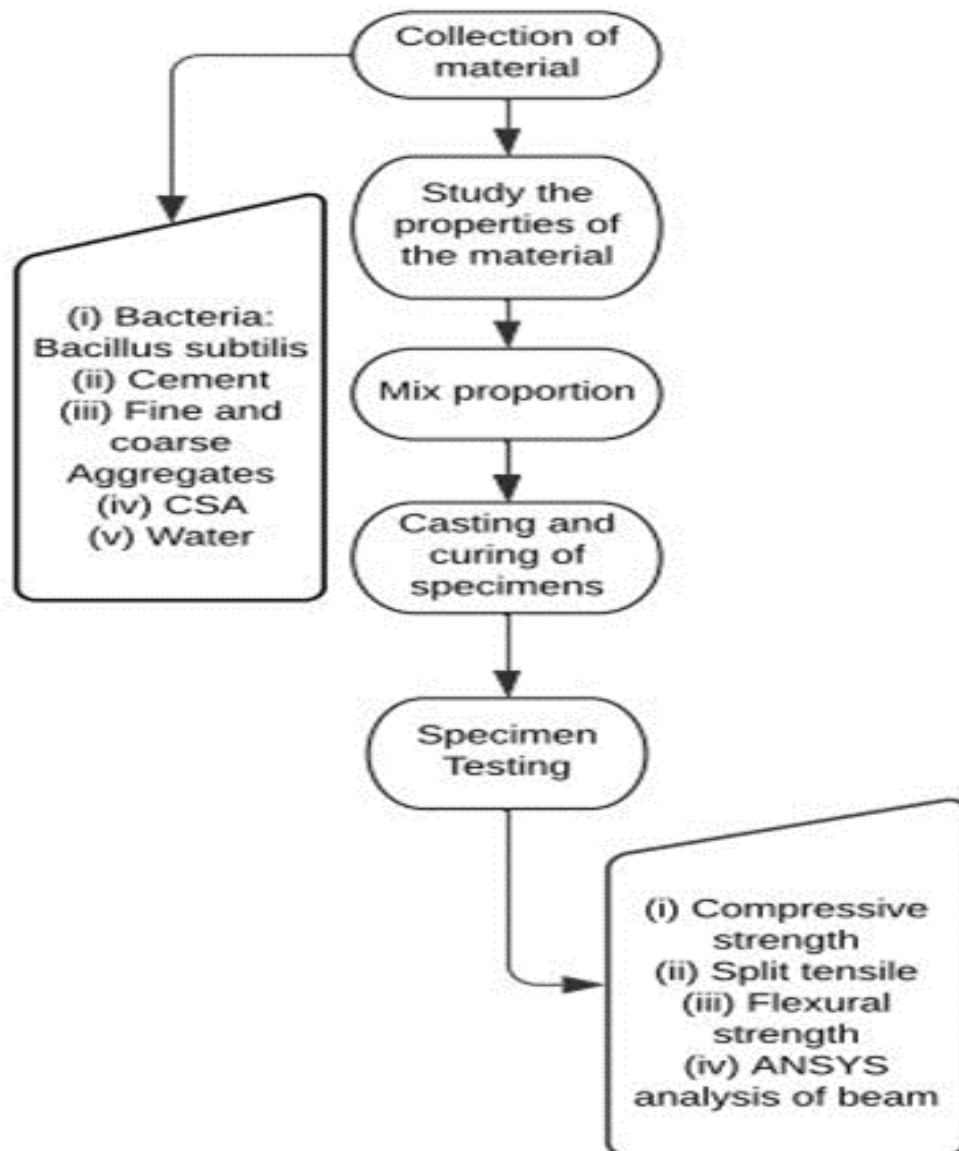


Fig 4.2 Methodology

4.3 CONCRETE MIX DESIGN

4.3.1 *Mixing Procedure*

To obtain accurate specimen test findings, uniform concrete mixing should be guaranteed. In standard concrete, the coarse aggregate is weighed and poured into the mixer in the needed quantity per mix proportioning; then the sand is weighed and poured into the mixer, which is entirely dry.

The cement is weighed and evenly dispersed on the sand surface, ensuring consistent mixing. Dry mixing is done first, then water is added and blended for a minimum of 5 minutes until a uniform colour of concrete is achieved. The concrete is then poured into moulds according to the technique. The above-described technique is followed for bacterial concrete, with the addition of calcium sulfoaluminate and a bacterial solution of different percentages.

➤ STIPULATION FOR PROPORTION:

Grade Designation: M40

Type Of Cement: OPC 53 grade (IS 8112)

Maximum nominal size of aggregates: 20mm

Minimum Cement Content: 320 kg/m³

Maximum water cement ratio: 0.43

Workability: 100mm (slump)

Exposure Condition: Severe (for reinforced concrete)

Method of Concrete Placing: Not Pumping

Degree of Supervision: Good

Types of aggregate: Crushed angular aggregate

Chemical admixture type: 12% CSA

➤ TEST DATA:

- a) Cement-Portland Cement 53grade
- b) Specific Gravity of cement =2.7
- c) Specific Gravity of coarse aggregates=2.7
- d) specific Gravity of fine aggregate =2.6
- e) Sand confirming to zone-III

From Sieve Analysis of 1000g of sand:

Table 4.4: Fineness Modulus and Gradation

Size	Wt. Retained	Percentage Wt. Retained	Cum. Percentage Wt. retained	Percentage Passing
10	0.00	0.00	0.00	100
4.75	0.00	0.00	0.00	100
2.36	110.5	11.05	11.05	88.95
1.18	129.3	12.93	23.98	76.02
0.6	149.4	14.94	38.92	61.08
0.3	411.2	41.12	80.04	19.96
0.15	199.6	19.96	100	0.00

Fineness Modulus = Cumulative % Wt. Retained/100= 253.99/100= 2.53

When FM is compared to FM limitations for Fine Aggregates, we may determine that it is a fine sand. When Percentage Passing is compared to the data in IS: 383 for fine aggregate gradation, we learn that it belongs to Zone III.

Target mean strength for mix proportion is given by

$$f'_{ck}=f_{ck}+1.65s$$

f'_{ck} =Target average compressive strength at 28 days

f_{ck} =Characteristic compressive strength at 28 days

s =Standard deviation (s=5 N/mm²)

Target Strength =48.25 N/mm²

0.43 is the maximum water cement ratio. To estimate the maximum water content, use a w/c ratio of 0.43 (0.400.45) as determined by experience from Table 2 of IS 10262:2009. Because the aggregate's nominal size is 20mm, the water content equivalent to it is 186 litres. For a 100mm slump, the estimated water content is $186+(186*6\%) = 197.16$ litres, or 198L..

Cement content will be $198/0.43= 460$ Kg/m³. From Table 5 of IS 456 minimum cement content for severe exposure condition is 320 Kg/m³. $460\text{Kg/m}^3 > 320 \text{ Kg/m}^3$
Hence Ok.

Volume of coarse aggregate for w/c ratio of 0.43=0.616

Volume of coarse aggregate = $0.616 \times 0.9 = 0.554$

Volume of fine aggregate = $1-0.554 = 0.446$

4.3.2 Mix Calculation

The mix calculations per unit volume of concrete

a) Volume of concrete =1m³

b) Volume Of Cement = $[325/3.15] \times [1/1000]$

=0.103 m³

c) Volume of Water = $[140/1] \times [1/1000]$

=0.140 m³

d) Volume of chemical admixture = $[7/1.145] \times [1/1000]$

=0.006 m³

e) Volume of all in aggregates = $a-(b+c+d)$

= $1-(0.103+0.140+0.006)$

=0.751 m³

f) Mass of coarse aggregate = e x volume of CA x specific gravity of CA

$$=0.751 \times 0.554 \times 2.65 \times 1000$$

$$=1102 \text{ kg/m}^3$$

g) Mass of fine aggregate = e x Volume of FA x specific gravity of FA

$$=0.751 \times 0.446 \times 2.52 \times 1000$$

$$=844 \text{ kg/m}^3 \text{ Volume of concrete} = 1\text{m}^3$$

Table 4.5: Proportions

COMPONENT	PROPORTION
Cement	390 Kg/m ³
Water	198 Litres
Aggregate	844 Kg/m ³
Coarse aggregate	1261
Kg/m ³ W/C Ratio	0.45

Table 4.6: Amount of material required

S.No	Mix No	BC6CSA12	BC12CSA12	BC18CSA12
1	Cement (kg/m ³)	390	390	390
2	M-sand	642	642	642
3	Coarse aggregate	1261	1261	1261
4	w/c ratio	0.45	0.45	0.45
5	% Of bacterial solution	6	12	18
6	% Of CSA	12	12	12

4.4 EXPERIMENTAL INVESTIGATION

Experiments on test specimens were conducted to investigate the strength parameters of Bacterial concrete in various combinations. The experiment uses BC

test specimens to determine the workability and strength-related parameters of various mixes, such as cube compressive strength, cylinder split tensile strength, and prism flexural strength.

For each test, three specimens are tested, and the average is presented for each mix. All of the testing are carried out in accordance with Indian regulations. The ideal percentage is determined based on the results of the cube and cylinder strength tests. The moulds are tested for compressive, tensile, and flexural strength after 7 and 28 days of curing..

4.4.1 PREPARATION OF SPECIMEN

The concrete slump test The Slump Test (ASTM C 143M-00) tests whether fresh concrete is workable. It examines the consistency of the concrete in that batch in greater depth. The consistency of freshly poured concrete is determined using this technique. The phrases "workability" and "consistency" are frequently used interchangeably. It's a word for the condition of freshly placed concrete. It's a word that refers to the ease with which concrete flows. It's a metric for determining how wet something is. The consistency of concrete determines its workability, with wetter combinations being more workable than drier ones. Concrete of the same consistency, on the other hand, might have a wide range of workability. It can also be used to compare the consistency of several batches.

How concrete is made is determined by the mix design. Four levels of newly prepared concrete are poured in a neat slump cone. Before being applied, each layer is tamped a total of 25 times. After the last layer has been tamped, fresh concrete is struck off by a trowel from the top of the mould. The cone is gently raised in the vertical position before being removed. As soon as the sponsored concrete cone comes to a stop, the settlements or subsidence (slump) (i.e., the distance between the height of the slump mould and the highest of the sponsored concrete cone) is measured.



Fig.4.3 Concrete preparation



Fig.4.4 Slump cone test

Table 4.7 No of specimens casted

MIX NAME	CUBES	CYLINDER	PRISM
B6CSA12	2	2	2
B12CSA12	2	2	2
B18CSA12	2	2	2
CONVENTIONAL M40	2	2	2
TOTAL	8	8	8

Table 4.8 Size of specimens casted

NAME OF SPECIMEN	SIZE
CUBE	150*150*150 mm
CYLINDER	150*300 mm
PRISM	100*100*500 mm
BEAM	200*150*1000 mm

4.4.1.1CASTING:

4.4.1.1.1 CUBE:

The concrete cube specimens are casted by the consideration of following steps
Cube Mould:

The cube Moulds are 150 x 150 x 150 metric linear units in dimension, with a nominal aggregate size of 38 mm. Cube Moulds must come with a base plate and must comply with IS:10262-2009..

Rod for Tamping:

According to IS:10262-2009, the tamping rod shall be 160.5 mm in diameter, 600.2 mm long, with a rounded working end, and made of mild steel.

Casting Process:

The cube Mould plates should be removed, cleaned thoroughly, and all bolts should be securely fastened. After that, a thin layer of oil should be spread to all of the Mould's faces. It is required that the cube aspect faces be parallel. The cubes must be solid as soon as possible after taking concrete samples and combining them. In the cube Moulds, the concrete samples should be packed in layers of about 5 cm depth. As the concrete slides from the main edge of the Mould during the insertion of each scoop of concrete, the news will be impacted around it, ensuring a symmetrical distribution of the concrete within the Mould. Each layer must be compressed, either manually or mechanically. As stated below, each layer must be compressed by hand or by vibration.

Compaction by Hand:

Each layer of concrete stuffed into the Mould must be compressed with no more than 35 tool strokes. The strokes must penetrate the underlying layer, and the

bottom layer must be rodded through its entire depth. Wherever the tool leaves spaces, the edges of the Mould should be approached to close the voids.

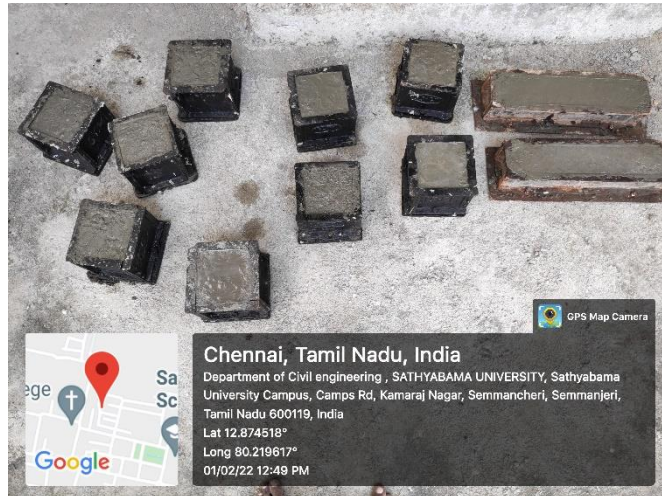


Fig.4.5 Cube Casting

4.4.1.1.2 CYLINDER:

Concrete material qualities can only be accurately assessed if test specimens are prepared and cured according to specifications. Concrete cylinders are commonly used to test the concrete's compressive strength and Split tensile strength.

Cylinder Mould:

Metal cylinder, 150 x 300 mm Moulds are used in the field to cast concrete test specimens. They should be set on a smooth, sturdy, and level surface before filling.

Tamping Rod:

If 150mm diameter Moulds are used, each layer should be stuffed in three equal layers and rodded twenty-five times with a sixteen-millimeter diameter x 450-600mm long hemi spherically pointed steel rod. 28

Casting Process:

The strokes must be evenly spread across the Mould's cross-section. The bottom layer must be rodded all the way to the bottom. The rod should penetrate around 25 mm into the underlying layer for each higher layer. If the rod leaves spaces, tap the edges of the Mould to close the voids before adding the Ext layer of material.



Fig.4.6 Cylinder Casting

4.4.1.1.3 PRISM:

Concrete prisms are cast in accordance with standards to assess the flexural strength of the concrete. As per Indian standard code IS 10262-2009, the casting and testing procedure must be followed..

Prism Mould:

The usual dimensions of the metal mould will be 100 x 100 x 500. The tamping bar must be a steel bar that weighs 2 kg, is 40 cm long, and has a ramming face that is 25 mm square. The test specimen must be made as soon as feasible after trying to mix and in such a way that there is no segregated or excessive laitance in the concrete.

Casting Process:

The compaction must be evenly spread across the Mould's portion. The bottom layer must be rodded all the way to the bottom. The rod should penetrate about 25 mm into the underlying layer for each above layer. If the rod leaves spaces, tap the sides of the Mould to fill the voids before adding the next layer of material.



Fig.4.7 Prism Casting

4.4.1.1.4 RC BEAM:

Concrete beams are casted according to specifications to determine the concrete's flexural strength. As per Indian standard code IS 10262-2009, the casting and testing procedure must be followed.

Beam Mould:

The Mould is made of wood and is 200 x 150 x 1000. The tamping bar must be a steel bar that weighs 2 kg, is 40 cm long, and has a ramming face that is 25 mm square. The test specimen must be made as soon as feasible after trying to mix and in such a way that there is no segregated or excessive laitance in the concrete.

Casting Process:

The compaction must be evenly spread across the Mould's portion. The bottom layer must be rodded all the way to the bottom. The rod should penetrate about 25 mm into the underlying layer for each above layer. If the rod leaves spaces, tap the sides of the Mould to fill the voids before adding the next layer of material.

Reinforcement details:

Main reinforcement = 4 number of 12mm dia bars Stirrups = 8 mm dia bars @ 150mm c/c Specimen dimension: 200mmx150mmx1200

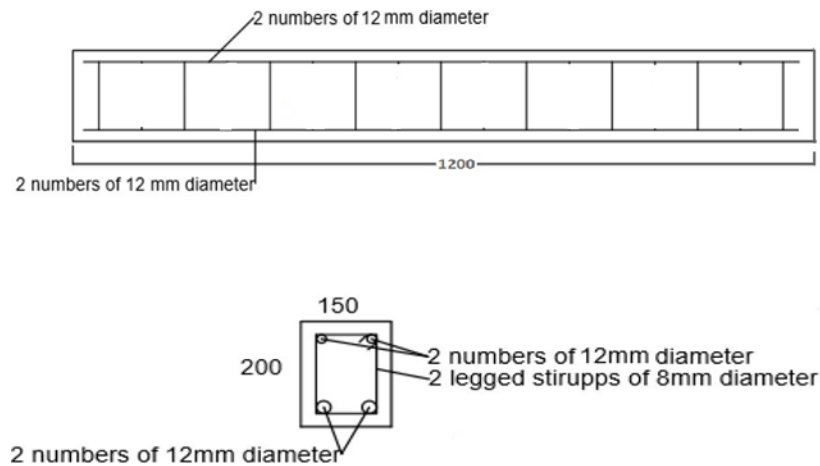


Fig.4.8 Reinforcement Details



Fig.4.9 RC Beam Casting

4.4.2 DEMOULDING AND CURING:

4.4.2.1 DEMOULDING:

When test concrete specimens are made, they should be demoulded between sixteen and twenty-four hours later. Demoulding must be delayed for another twenty-four hours if the concrete has not acquired the strength required to change demoulding without damaging the specimens by this time. Remove the concrete specimens from the Mould and disassemble the Mould completely. Be careful not to damage the specimens since if any cracking occurs, the all-strength parameters may be affected as well. Every examine concrete specimen should be marked with

a clear identifier on the top or bottom with a waterproof crayon or ink when demoulding.

4.4.2.2 CURING:

Curing is crucial for the development of concrete strength and sturdiness. Curing concrete prevents the concrete from losing the moisture essential for bonding and keeps it intact within the proper temperature range. Trying to cure hardened concrete can improve its strength while reducing its permeability. Curing also helps to prevent heat and plastic fractures, which can jeopardize structural integrity.

Curing is the process of keeping the concrete damp or wet until the bonding is complete and strength is achieved. After the initial setting time of concrete, the natural process of concrete should commence immediately. According to IS 456 – 2000, normal Portland Cement concrete should be cured for seven days, while concrete containing mineral admixtures or integrated cement should be cured for a minimum of ten days. Only ten days for OPC and fourteen days for concrete with integrated cement and mineral admixtures should the natural process take place in the case of exceptionally dry weather conditions.



Fig 4.10 Curing

4.4.3 CUBE COMPRESSIVE STRENGTH TEST



Fig. 4.11 Compressive strength test

150mm x 150mm x 150mm cubes was tested, and casting was done according to IS: 516-1959 Codal provision. The concrete's compressive strength was evaluated at 7 and 28 days. All of the elements listed in the mix proportions above are weighted, mixed, and cast in an IS 516 steel cube mould with dimensions of 150X150X150mm. The concrete is shoveled into the cubic mould and manually compacted. Casting is done in a wet atmosphere to reduce moisture loss due to evaporation. Water and cement react chemically, assisting the aggregate in adhering with concrete and causing moisture loss. The cubes were evaluated after 7 days and 28 days of drying. After wiping away the surface moisture, all specimens are evaluated in a saturated surface dry condition. Three identical specimens are evaluated in a compression testing machine at the ages of seven and twenty eight days for each mix combination. The loading was kept going until the specimen failed. The ultimate load is determined by the reading taken at the time of reversal. Figure 4.11 depicts the test setup.

4.4.4 CYLINDER SPLIT TENSILE STRENGTH TEST

A diametric compressive load is delivered along the whole length of the split tensile strength test until failure occurs. Compressive stresses are created in the area surrounding the applied force, while tensile stresses are induced in the plane containing the applied load. The mould has a 150 mm internal dia and a 300 mm height.

This is an indirect test for determining cylindrical specimens' splitting tensile strength. At the age of twenty-eight days, a universal testing machine is used to perform a splitting tensile strength test on a concrete cylinder specimen with a diameter of 150mm and a length of 300mm. The stress is gradually applied until the specimen splits, at which point the readings are taken. Figure 4.12 depicts the test setup. The splitting tensile strength has been estimated using the relationship

$$f = 2P/\pi dl$$

Where, f = Splitting tensile strength of concrete in MPa.

P = Load at failure in Newton

d = Diameter of cylinder = 150mm; l = Length of cylinder = 300mm

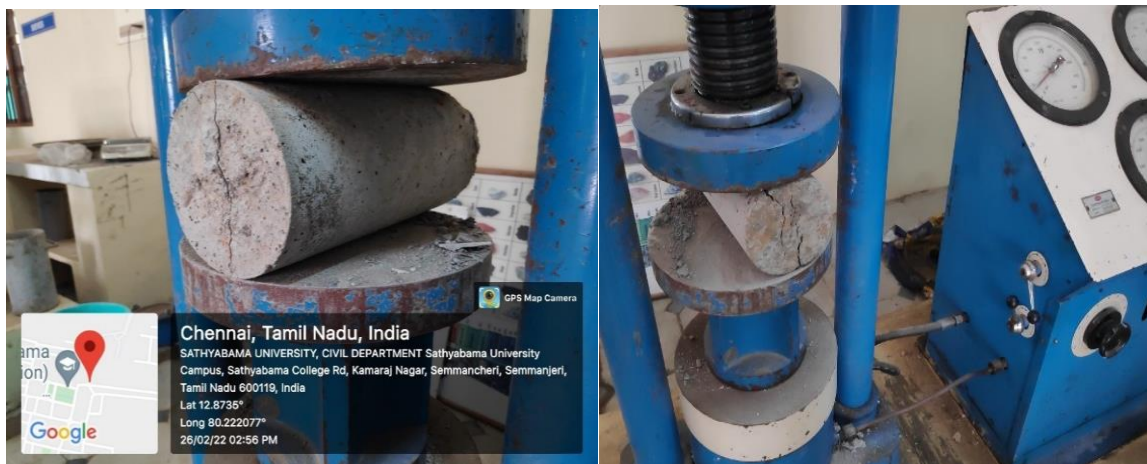


Fig. 4.12 Split tensile strength test

4.4.5 FLEXURAL STRENGTH TEST

Flexural strength is one method for determining the tensile strength of concrete. It is a test that determines the ability of an un-reinforced concrete beams to withstand bending failure. It is calculated by compressing six 6-inch (150-mm) beams with spans at least three times the depth. The flexure of the prisms is evaluated in order to estimate the lateral load resistance. As seen in Figure 4.13. The prism (100mm x 100mm x 500mm) was put horizontally and subjected to third point loading to determine its flexural strength. The initial failure site was observed, and it was discovered that all prisms failed in the center third. The third point loading method was employed to arrive at the final result. The third point loading was used to determine the stress at failure.



Fig.4.13 Flexural Strength Test

➤ **$R = \frac{Pl}{bd^2}$**

Where,

R – Bending stress

P – Maximum applied load in Nl – Span length in mm

b – Average width of the specimen in mm

d – Average thickness of the specimen in mm

4.4.6 SPECIMEN DESIGNATION

Table 4.9. shows the details of the tested specimen designation.

Table 4.9 Specimen Designation

Bacillus subtilis solution by Volume (%)	CSA Content by Volume (%)	Specimen Designation
0%	0%	Conv
6%	12%	B6C12
12%	12%	B12C12
18%	12%	B18C12

4.4.7 RC and B12C12 Beam Test:

A beam with an effective span of 1200 mm is tested under two-point loading by using hydraulic jack with the distance between the loading points as 370 mm after 28 days of curing using wet gunny bags at ambient temperature. LVDT is fixed to measure mid-span deflection.

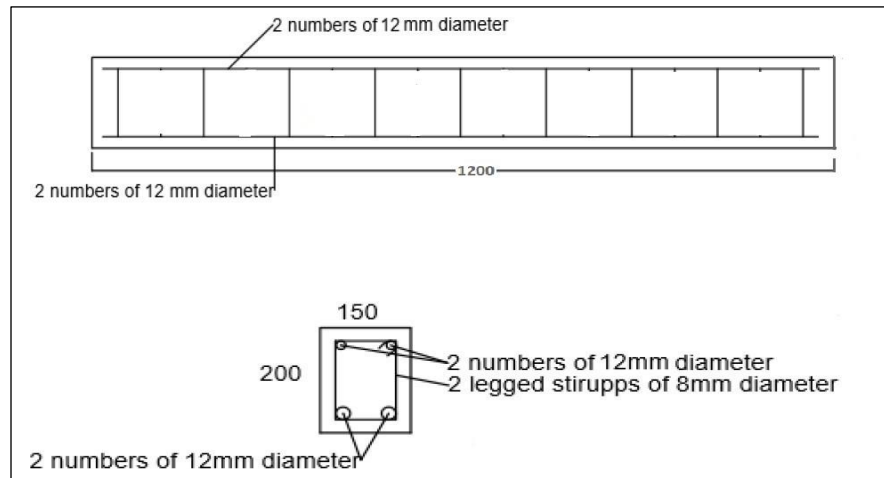


Fig. 4.14 Reinforcement Details



Fig.4.15 Experimental set up for B12C12 beam



Fig.4.16 Experimental set up for conventional beam

4.5 NUMERICAL ANALYSIS

4.5.1 GENERAL

Today, the Finite Element Method (FEM) is viewed as a well-established and useful technique for calculating complex issues in a variety of engineering fields. FEM, on the other hand, may be considered as a valuable tool for solving differential equations that describe diverse physical processes.

In many industrial applications, this advanced design tool has significantly improved both the quality of engineering designs and the design process approach. The FEM's wide range of applications makes it a versatile and powerful instrument for a wide range of problems. As a result, a variety of computer software packages for solving structural and solid mechanics problems have been developed.

4.5.2 ANSYS WORKBENCH

The ANSYS Workbench environment is a user-friendly finite element model tool that may be used with CAD systems and/or Design Modeler. The ANSYS Workbench programmed allows you to do structural, thermal, and electromagnetic analyses. The course focuses on geometry design and optimization, as well as attaching working frameworks, setting up the finite element model, solving, and evaluating the results. The lecture will go through how to use the code, as well as the basics of finite element simulation and how to interpret the results.

For engineers, ANSYS is a general-purpose programmed that allows them to simulate interactions between all disciplines of physics, structural, vibration, fluid dynamics, heat transfer, and electromagnetics. ANSYS can input CAD data and, thanks to its "preprocessing" capabilities, can also generate a geometry. In the same pre-processor, a finite element model (also known as a mesh) is created, which is necessary for calculation. The outcomes of defining loadings and doing analysis can be examined numerically and graphically.

ANSYS can execute sophisticated engineering studies quickly, safely, and realistically because to its wide range of contact techniques, time-based loading features, and nonlinear material models. ANSYS Workbench is a platform that automates and optimizes the integration of simulation technologies with parametric CAD systems. ANSYS Workbench's strength stems from years of expertise using ANSYS solver algorithms. Furthermore, the purpose of ANSYS Workbench is to test and enhance the product in a virtual environment.

4.5.3 ANSYS MODEL

The analysis focuses on

1. Engineering data
2. Fixing up the geometry of beam in design modeler
3. Setting up the finite element model
4. Providing the support and loading conditions
5. Checking for equivalent stress, strain and deformation

4.5.4 ENGINEERING DATA

The materials are to be assigned for the creating model. Here selecting the materials which are used in modeling like steel, concrete. The grade of concrete used in this modeling is Mix-3 Compressive strength value and grade of steel is FE415.

2	Material				
3	Concrete				
4	Structural Steel				Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Properties of Outline Row 4: Structural Steel				
	A	B	C	D E
1	Property	Value	Unit	
2	Material Field Variables	Table		
3	Density	7850	kg m ⁻³	
4	Isotropic Secant Coefficient of Thermal Expansion			
6	Isotropic Elasticity			
7	Derive from	Young's Modulus and Pois...		
8	Young's Modulus	2E+11	Pa	
9	Poisson's Ratio	0.3		
10	Bulk Modulus	1.6667E+11	Pa	
11	Shear Modulus	7.6923E+10	Pa	
12	Alternating Stress Mean Stress	Tabular		
16	Strain-Life Parameters			
24	Tensile Yield Strength	2.5E+08	Pa	
25	Compressive Yield Strength	2.5E+08	Pa	
26	Tensile Ultimate Strength	4.6E+08	Pa	
27	Compressive Ultimate Strength	0	Pa	

1	Contents of Engineering Data	Source	Description
2	Material		
3	Concrete		
4	Structural Steel		Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material		

Properties of Outline Row 3: Concrete				
	A	B	C	D E
1	Property	Value	Unit	
2	Material Field Variables	Table		
3	Density	2390	kg m ⁻³	
4	Isotropic Secant Coefficient of Thermal Expansion			
6	Isotropic Elasticity			
7	Derive from	Young's Modulus and Pois...		
8	Young's Modulus	36800	MPa	
9	Poisson's Ratio	0.18		
10	Bulk Modulus	1.9167E+10	Pa	
11	Shear Modulus	1.5593E+10	Pa	
12	Tensile Yield Strength	0	Pa	
13	Compressive Yield Strength	0	Pa	
14	Tensile Ultimate Strength	5E+06	Pa	
15	Compressive Ultimate Strength	4.1E+07	Pa	

Fig 4.17 ANSYS Material Property

4.5.5 GEOMETRY CREATION

After assigning the material in engineering data, the model is created by providing the proper dimensions of the beam, diameter of bars. Separate model is to be created for all the materials like concrete, steel and it should be assigned for the respective model.

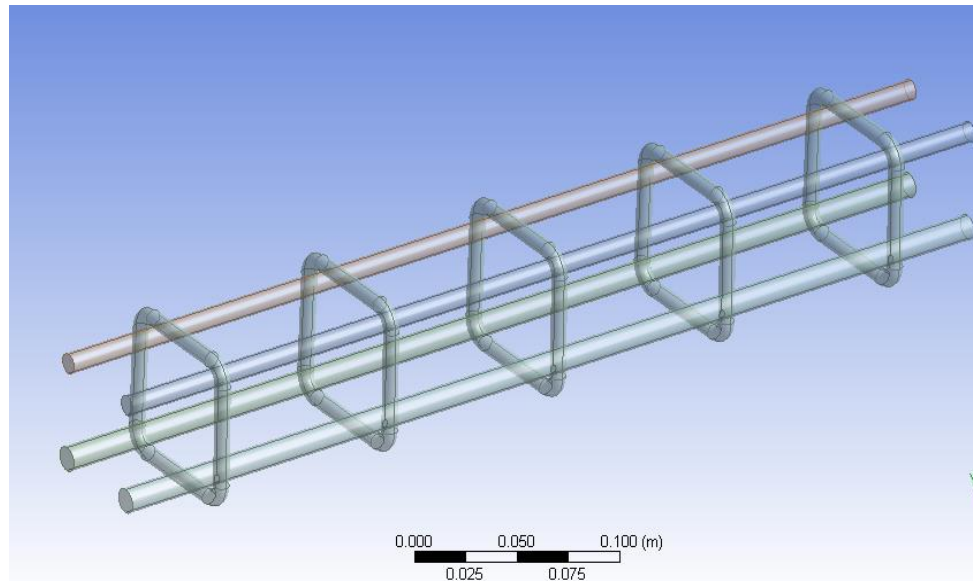


Fig 4.18 geometry of beam in design modeler

4.5.6 SETTING UP THE FINITE ELEMENT MODEL

Go to the modelling step when you've finished the geometry design and assigned all of the material properties. Then we'll create a mesh that will aid us in solving the model using the finite element approach, allowing us to achieve correct results

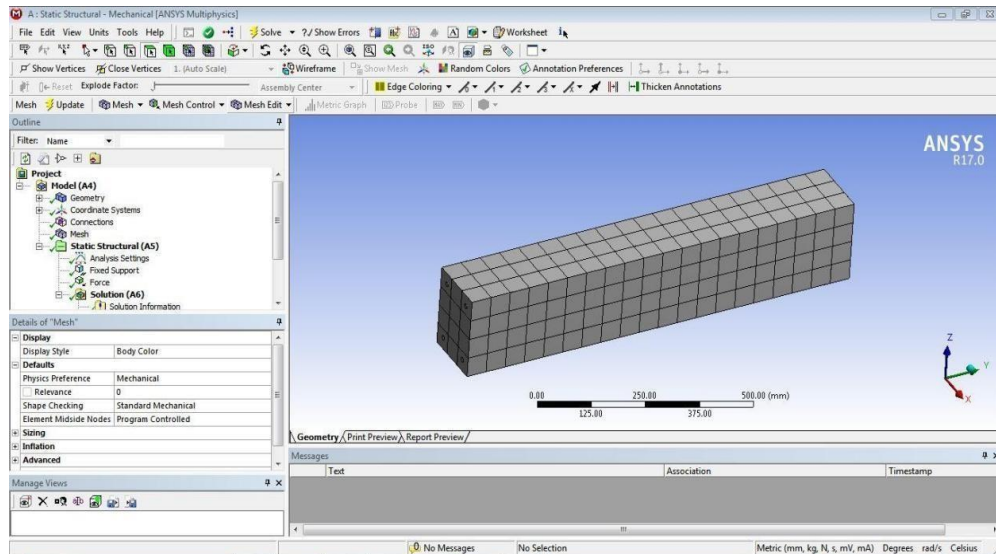


Fig 4.19 mesh in mechanical model

4.5.7 PROVIDING THE SUPPORT AND LOADING CONDITION

The RC beam were applied two-point load After the application of load the model is solved for the required results and the failure mode of the model is obtained.

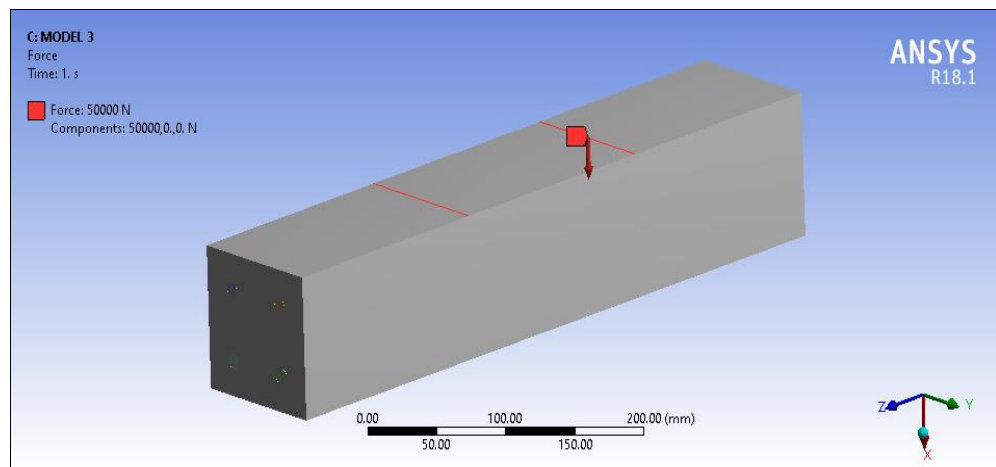


Fig 4.20 Load assign diagram

CHAPTER 5

RESULT AND DISCUSSION

This chapter presents the test results and discusses the development of compressive strength, tensile strength, and flexural strength of Bacterial concrete above regular concrete at various percentages and curing times.

5.1 SLUMP CONE TEST RESULT

Table 5.1 Slump Value

Specimen	Slump Result
Conv	100 mm
B6C12	100 mm
B12C12	100 mm
B18C12	100 mm

The workability of concrete on Conv, B6C12, B12C12 and B18C12 was is lower since carbon fiber has a low moisture absorption.

5.2 EXPERIMENTAL RESULTS

5.2.1 Compressive strength

This procedure may be used to develop a method for measuring the compressive strength of concrete sample. Water-surviving specimens will be analysed as soon as they are retrieved from the water and while they are still wet. The specimens are also kept moist by being covered with wet gunny. The testing machine's bearing surfaces must be cleaned, and loose sand or other similar item must be kept far away from the sample surface that will come into contact with the compression plate. In the case of cubes, the sample is placed in the equipment such that the load is delivered to the opposing sides of the forged cubes, rather than the maximum and minimum sides.

The specimen's axis must be perfectly aligned with the midpoint of thrust of the spherically seated platen. No packing should be utilised between the sides of the check specimens and, as a result, the steel platen of the testing machine. Set the loading rate for a fifteen-centimeter cube to 5.2 KN/sec to load the specimen uniformly.

The load should be applied gradually and steadily till the specimen's tolerance to the increasing load fails and no more load can be sustained. The maximum load applied to the specimen, as well as the look of the concrete and any unexpected failure possibilities within the pattern of failure, will be reported. The most significant metric in structural design is compressive strength. At 7 and 28 days, the strength of fiber reinforced concrete was investigated. Over regular concrete, the variance in compressive strength with different percentages of fiber. The compressive strength of all concrete specimens increased as the cure time increased.

Table 5.2 7 Day Compressive Strength

MIX NAME	Load in KN	COMPRESSIVESTRENGTH in N/mm²
Conv	770.8	34.26
B6C12	925.6	41.14
B12C12	963.4	42.82
B18C12	784.3	34.86

7 Day Compressive Strength = Load/Area

$$= 770.8 \times 1000 / (150 \times 150)$$

$$= 34.257 \text{ N/mm}^2$$

Table 5.3 28 Day Compressive Strength

MIX NAME	Load inKN	COMPRESSIVE STRENGTH in N/mm²
Conv	1082	48.12
B6C12	1156.9	51.42
B12C12	1229.4	54.64
B18C12	1118.9	49.73

Table 5.4 7 and 28-Day Compressive Strength

MIX NAME	7 Days N/mm ²	28 Days N/mm ²
Conv	34.26	48.12
B6C12	41.14	51.42
B12C12	42.82	54.64
B18C12	34.86	49.73

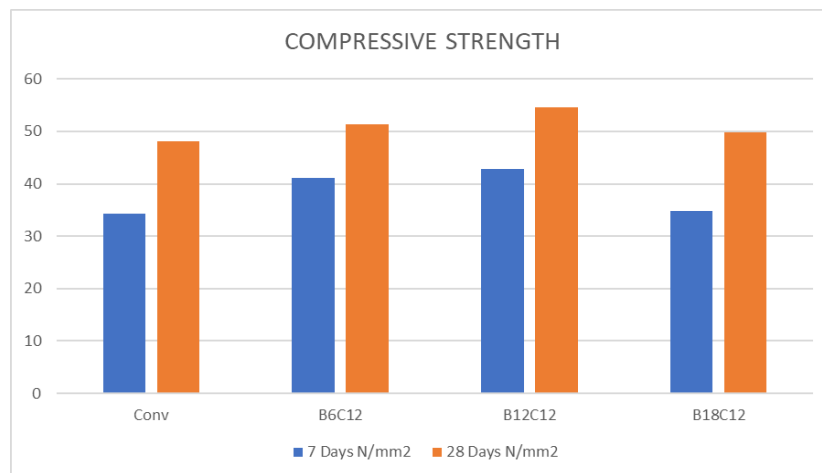


Fig5.1: Comparison of compressive strength

The results for various percentages of bacteria and CSA in M40 grade concrete are shown in Table. The compressive strength of the concrete is boosted when M-sand is combined with bacteria and CSA. It is obvious from the chart that adding bacteria and CSA at the required percentages of 12 percent each increases the concrete's strength. When comparing the 7th and 28th day compressive strength readings, there is an increase in compressive strength. The compressive strength is apparent at the 28th day due to the presence of *Bacillus subtilis* bacteria and Calcium Sulphoaluminate. The compressive strength of the concrete increases as the proportion of bacteria increases, but at 18 percent bacterial addition to the concrete mix, the compressive strength of the concrete tends to decline. This is because the hydration products are saturated at a bacterial solution of 12 percent. The use of M-sand appears to be promising based on the test findings.

5.2.2 Split Tensile Strength

This process can be used to develop testing procedures for the split durability of concrete specimens. Specimens must be kept unbroken in water for twenty-four hours after being received dry before being tested. Unless special circumstances are required for a specific laboratory research, specimens should be analysed immediately after being removed from the water.

Marking - diametric marks should be put on the two ends of the specimen using any suitable procedure and technology to guarantee that they are all in the same plane.

Placing the Sample in the Test Machine- The testing vehicle's bearing surfaces and packing strips must be clean. Placement - one of the laminate strips should be placed in the centre of the lower platen. The specimen should be placed on the laminate strip and orientated such that the lines drawn on the ends of the specimen are vertical and focused from across strip.

The second laminate strip should be applied to the cylinder lengthwise, with its concentration on the dividing lines on the cylinder's ends. To guarantee that the following requirements are satisfied, the component must be portioned. The lines drawn on the specimen's ends are vertical, and the extension of the planes of the two lines drawn on the ends crosses the platens in the centre. When used, the additional bearing bar or plate, as well as the specimen's centre, are just below the spherical bearing block's centre of thrust.

Rate of Loading — The load should be applied without shock and inflated at a rate that provides around a tearing tensile stress of around fourteen to twenty-one kg/cm²/min. This loading rate is 1.62 to 2.43 kN/sec for a cylinder with a diameter of 39 cm and a length of 30 cm. It will be noted which load has been applied to the specimen the most. The appearance of concrete, as well as any unusual options within the type of failure, will be noted.

7 Day Tensile Strength = $2P/\pi DL$

$$= 2 \times 224.5 \times 1000 / \pi \times 150 \times 300 = 3.176 \text{ N/mm}$$

Table 5.5: 7 Day Split Tensile Strength

MIX NAME	Load inKN	TENSILE STRENGTH IN N/mm²
Conv	241.2	3.41
B6C12	248.6	3.52
B12C12	269.5	3.81
B18C12	224.5	3.17

Table 5.6: 28th Day Split Tensile Strength

MIX NAME	Load inKN	TENSILE STRENGTH IN N/mm²
Conv	306.3	4.34
B6C12	313.7	4.44
B12C12	328.6	4.48
B18C12	297.2	4.21

Table 5.7 7 & 28 days Split Tensile Strength

MIX NAME	7 Days N/mm²	28 Days N/mm²
Conv	3.41	4.34
B6C12	3.52	4.44
B12C12	3.81	5.62
B18C12	3.17	4.21

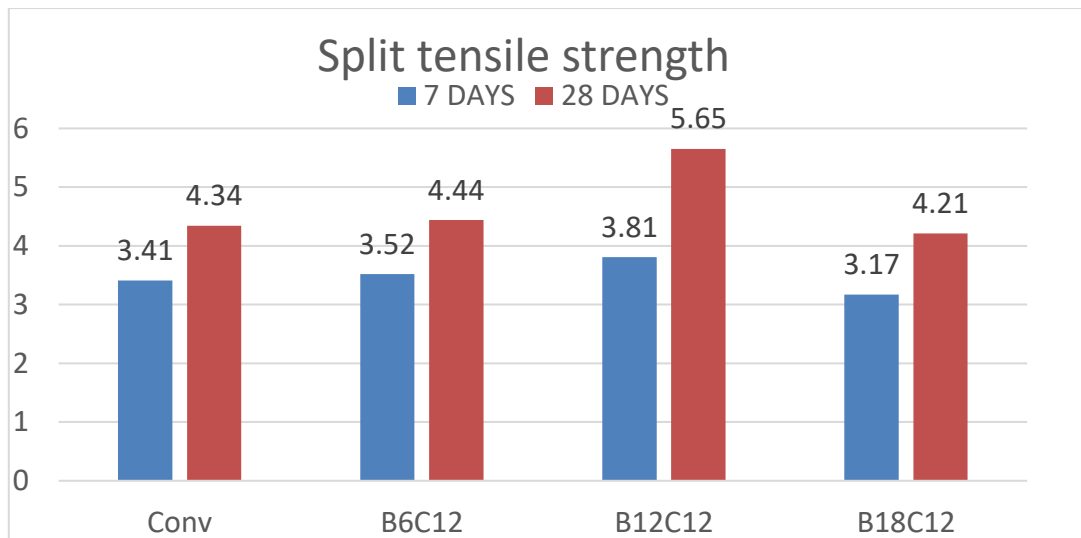


Fig 5.2: 7 & 28 Day Split Tensile Strength

The test is repeated after seven and twenty-eight days. The comparison of conventional and bacterial concrete is shown in Figure. The addition of microorganisms increases the strength, according to the results. Because beyond this percentage, the strength begins to deteriorate, the best result is attained at 12 percent. This rise could be attributed to a significant reduction in the cement matrix's capillary porosity, as well as a good dispersion of the cement grains throughout the mix, boosting bond strength and hence splitting tensile strength. Fibers, like compression, cause significant increases in the composites' post-cracking Behaviour or toughness.

5.2.3 Flexural Strength

The strength in both directions (direct tension and flexural tension) can be demonstrated to be closely connected, but the connection is not proportionate. The ratio of two strengths is determined by the concrete's overall strength. In other words, more compressive strength of concrete equals higher tensile strength, but tensile strength increases at a faster rate.

$$\begin{aligned}
 \text{7 Day Flexural Strength} &= PL/BD^2 \\
 &= 13.5 \cdot 400 \cdot 1000 / 100 \cdot 100^2 \\
 &= 5.38 \text{ N/mm}^2
 \end{aligned}$$

Table 5.8 7 Day Flexural Strength

MIX NAME	Load inKN	TENSILE STRENGTH IN N/mm²
Conv	11.6	4.62
B6C12	13.2	5.26
B12C12	13.5	5.38
B18C12	11.9	4.74

Table 5.9 28th Day Flexural Strength

MIX NAME	Load inKN	TENSILE STRENGTH IN N/mm²
Conv	13.2	5.26
B6C12	13.7	5.46
B12C12	14.1	5.62
B18C12	13.3	5.32

Table 5.10 7 & 28 days Flexural Strength

MIX NAME	7 Days N/mm2	28 Days N/mm2
Conv	4.62	5.26
B6C12	5.26	5.46
B12C12	5.38	5.62
B18C12	4.74	5.32

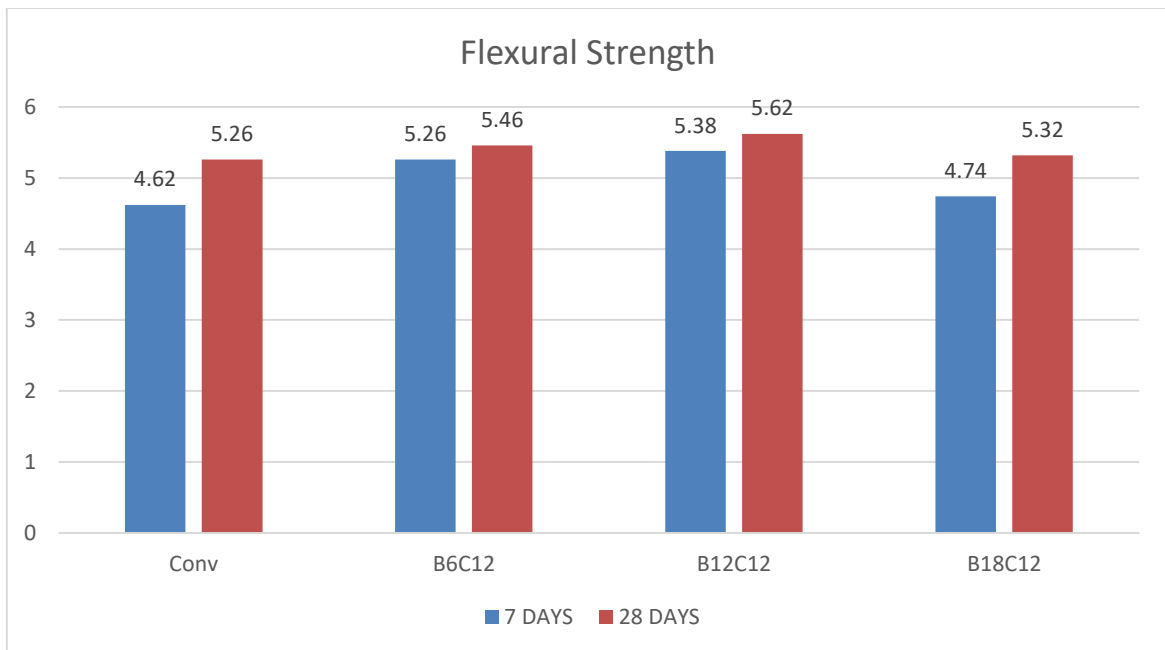


Fig 5.3: 7 & 28 Day Flexural Strength

The difference in flexural strength of bacterial concrete with curing age is existing in for M-sand. A test is carried out to determine the flexural strength of a concrete specimen. The results for 7th day and 28th days is shown in table. As the curing period increases the flexural strength of the concrete also increases.

Table 5.11 Percentage Increase in Strength over conventional mix

Sl.No	Properties	Gain Over NormalConcrete
1.	CompressiveStrength	+13.54%
2.	Split TensileStrength	+30.18%
3.	FlexuralStrength	+6.84%

5.2.4 RC Beam Test Result:

After 28 days of curing, the beam was subjected to two-point loading. Below the two-point loading supports and mid-point, three LVDTs were installed. Three deflection values were recorded for every 10 KN. The B12C12 beam had a first crack load of 90.5 KN, while the Conventional beam had a first crack load of 65.5 KN.

Specimen details:

Main reinforcement = 4 number of 12mm dia bars
Stirrups = 8 mm dia bars @ 150mm c/c
Specimen dimension= 150mmx200mmx1000mm

Table 5.15 load and deflection values (experimental)

Load (KN)	CONV	B12C12
10	56	48
20	73	101
30	113	124
40	147	159
50	170	212.5

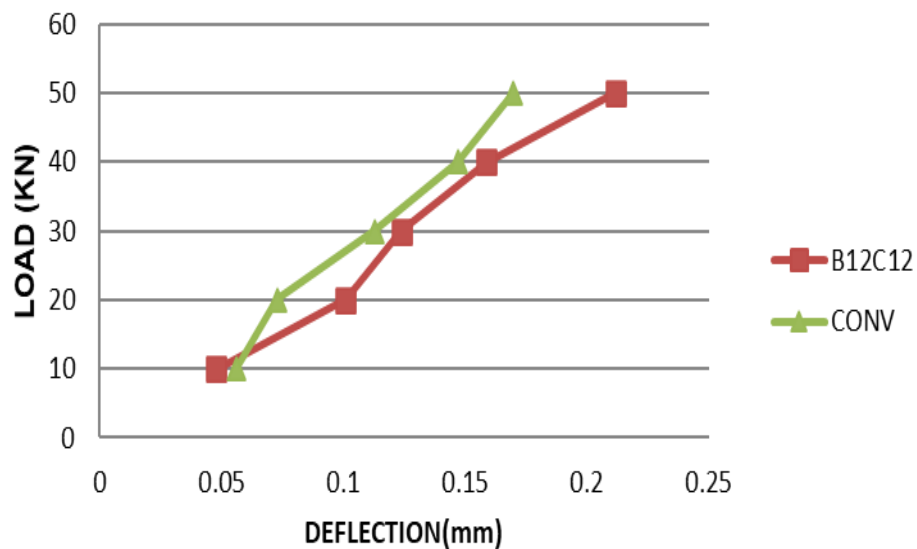


Fig.5.4 Load and Deflection behavior (experimental)

5.3 Numerical Result:

5.3.1 Conventional beam:

The conventional beam is subjected to numerical analysis. Figure 5.5 depicts the stress contour of a standard RC beam. The rays are observed to be.

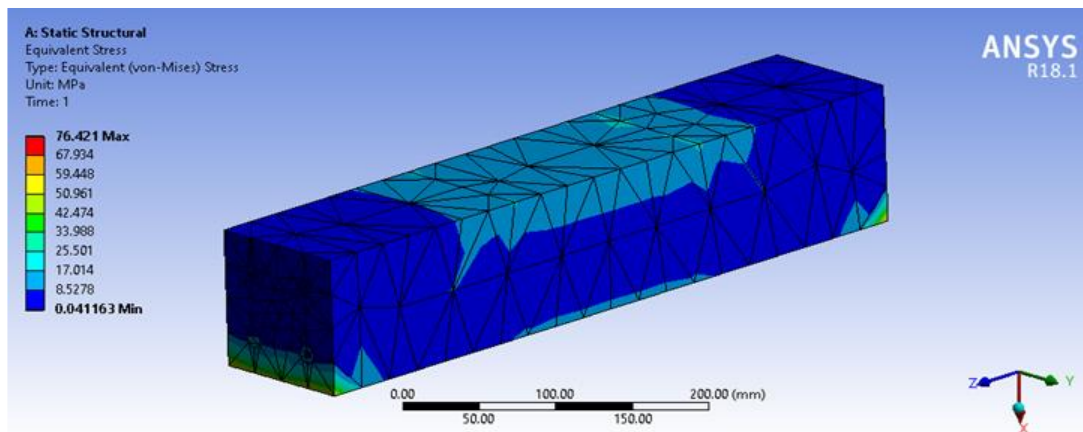


Fig 5.5 Stress Contour for RC Beam

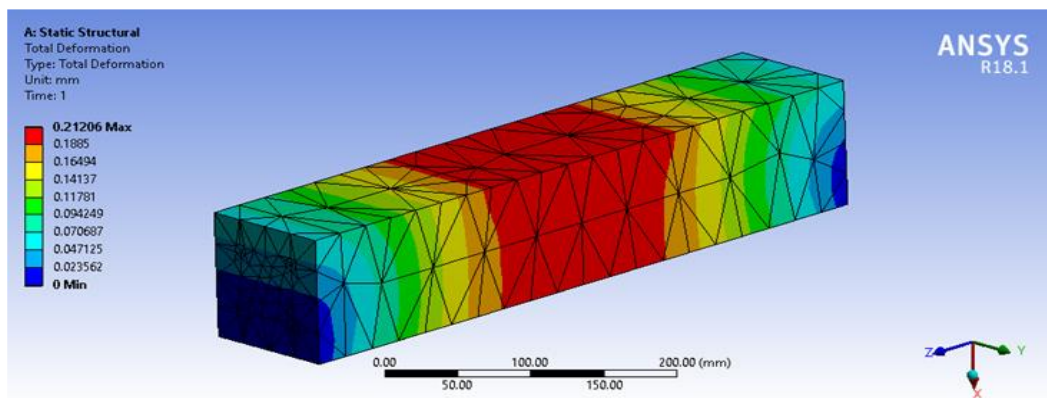


Fig 5.6 Deformation for RC Beam

5.3.2 B12C12 MIX:

For the B12C12, a numerical analysis is carried out. Figure 5.6 depicts the stress curve of a B12C12 RC beam. The rays are observed to be.

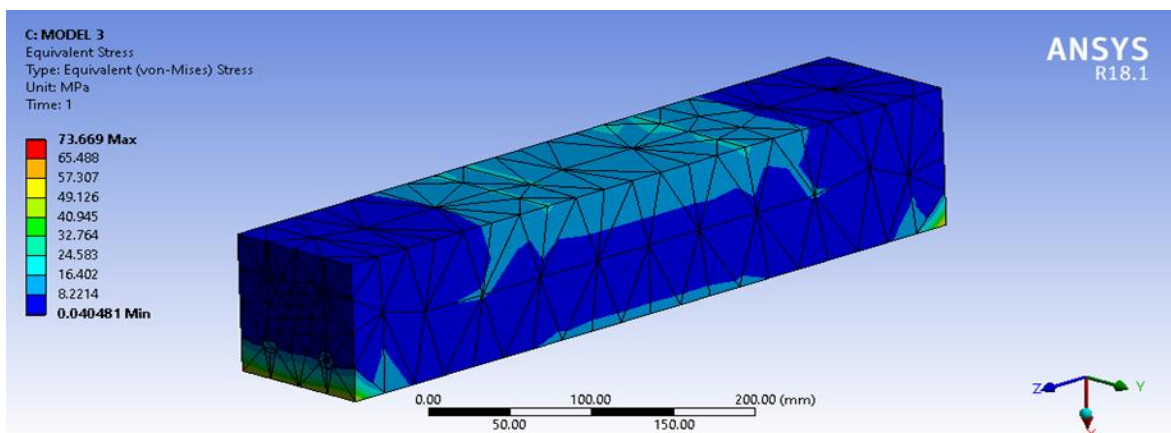


Fig 5.7 Stress Contour for B12C12 Beam

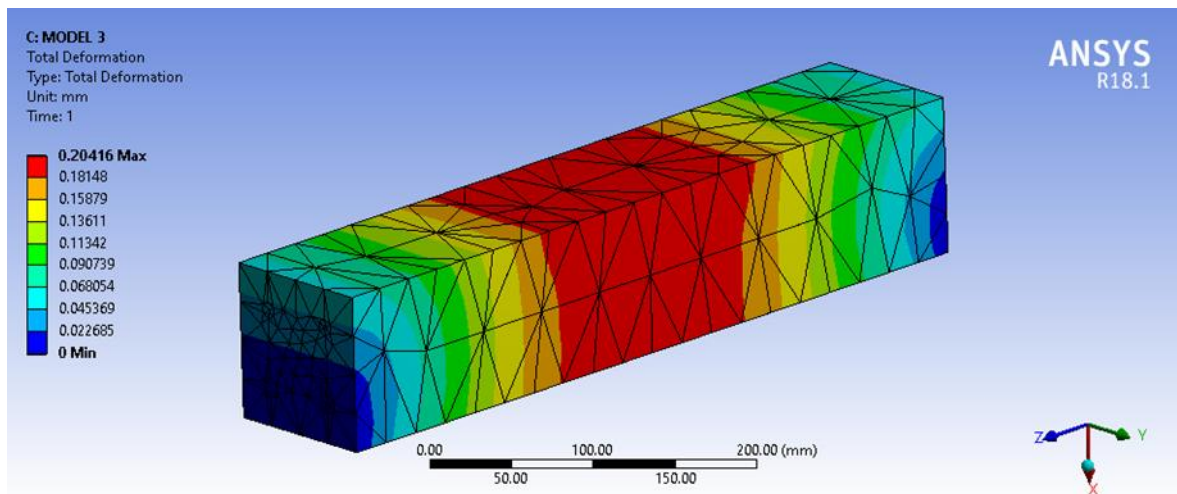


Fig5.8 Deformation for B12C12 Beam

Table 5.16 load and deflection value (analytical)

S. No	Specimen Designation	Load (KN)	Deflection (mm)
1	Conventional Beam	50	2.12
2	B6C12	50	2.04

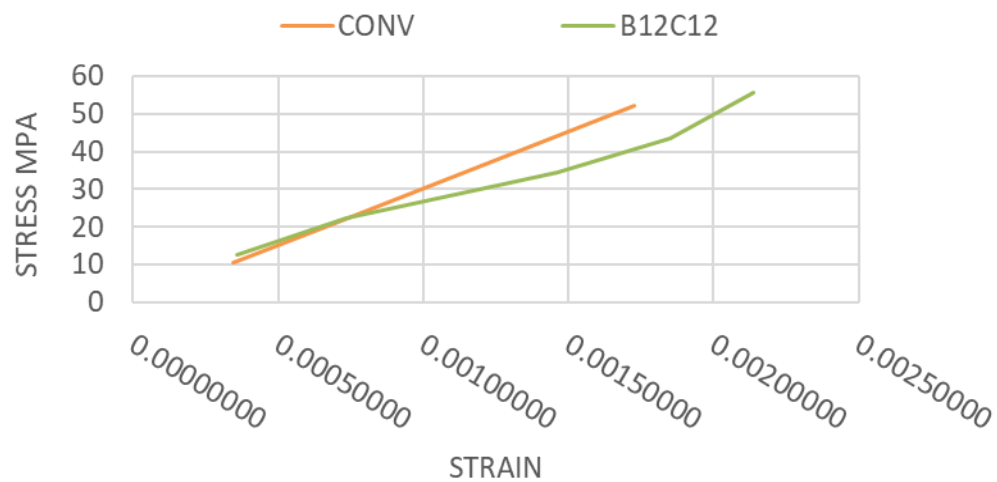


Figure 5.9 stress vs strain curve

The evolved solution will be done using the finite element method and this is the results for maximum deformation is shown in fig 5.10.

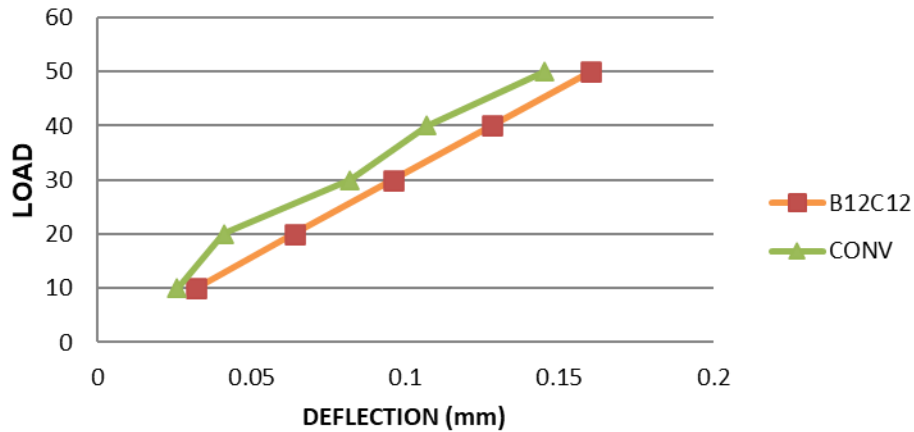


Fig5.10 Load vs Deflection curve (Analytical)

The stress vs strain curve and load vs deflection curve for analytical study is plotted in above fig 5.9 and 5.10. This curve is plotted by the results obtained in Ansys software.

5.4 COMPARISON OF EXPERIMENTAL RESULTS WITH ANALYTICAL RESULTS:

We can see that for both analytical and experimental approaches, the experimental value of conventional beam values is nearly same. However, when we look at the B12C12, we can find that the analytical value varies little. The analytical value is higher than the experiment value. As a result, the experimental approach demonstrates that it may be used to obtain high strength while reducing the total weight of the concrete.

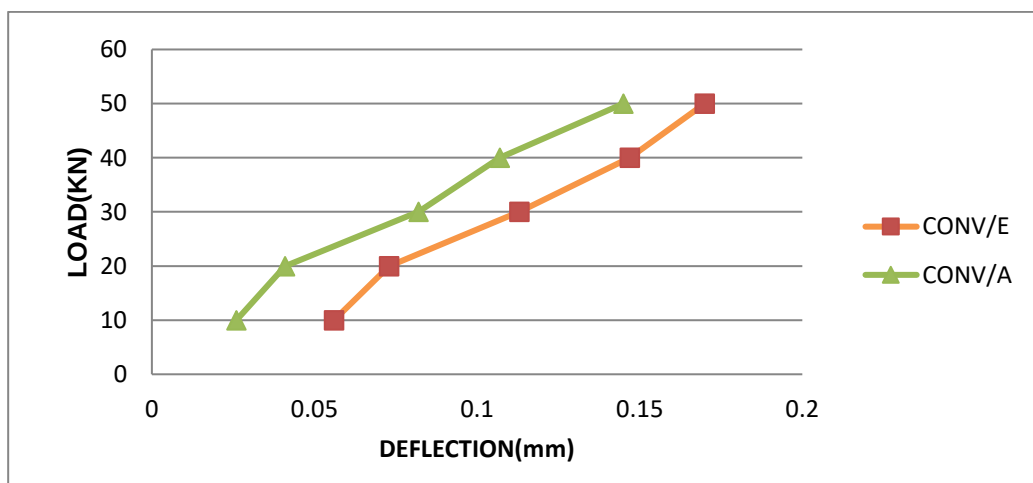


Fig 5.11 Comparison of Conventional Beam Experimental Results with Numerical Results

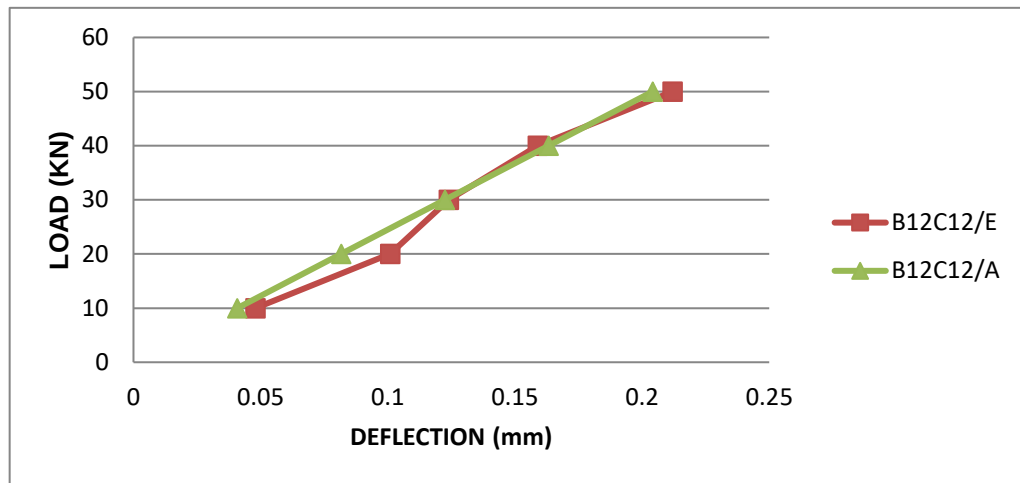


Fig5.12 Comparison of B12C12 Beam Experimental Results with Numerical Results

CHAPTER 6

CONCLUSION

When comparing B12C12 to other mixtures, we may conclude that it is the best blend for achieving ultimate strength. When compared to standard concrete, it consistently outperforms it in all types of tests. The addition of bacterial solution and CSA at a percentage of 12 increases compressive strength by 13.54 percent with B12C12 and subsequently begins to decrease with increasing bacterial solution.

When the Bacterial solution was increased and CSA was added, the compressive strength of the usual mix increased. The findings of the splitting tensile strength tests demonstrate that direct mixing of bacteria increases strength, and the maximum splitting tensile strength was discovered in B12C12 of Mix, which was found to be around 4.48 N/mm² when compared to other mixes.

When compared to the standard specimen, the load carrying ability has increased by 30.18 percent. According to the results of the experimental test, there is an improvement in When compared to the other mixtures, the B12C12 had superior flexural strength at 7 and 28 days. Bacteria in large numbers obstruct the calcium precipitation and biomineralization processes.

The beams were subjected to a two-point load test, and flexural cracks were discovered. According to the results of the investigation, adding bacteria and CSA to the concrete mix improved the flexural capacity of the beam and helped to increase stiffness under service loads. It also aids in the reduction of deflection in both directions.

Resistance to change, no matter how minor, troubles our society; we are constantly hesitant to embrace even the finest. It is past time to conquer the obstacles and aim for the summits. Bacterial concrete provides a new avenue for expanding and globalising the quality of "True Indian Structures," as well as modifying their appearance.

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