EFFECT OF MECHANICAL PROPERTIES IN M25 CONCRETE USING BACILLUS CEREUS IN ORDINARY PORTLAND CEMENT AND PORTLAND POZZALANA CEMENT

MINI PROJECT

FINAL REVIEW

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BONAFIDE CERTIFICATE

This is to certify that the project entitled **EXPERIMENTAL STUDY ON COMPRESSIVE STRENGTH PROPERTIES IN 1:3 BACTERIAL MORTAR** is bonafide work of **VINODHINI.E(U19CE059), PREETHAM KUMAR.K (U19CE701), T.SEETHA (U19CE702), S.GUHAN (U19CE709)**,who carried out this project under my supervision.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

In the current world, concrete is quite possibly the most generally utilized development materials. One successful approach to resolve the issue is to research the chance of progress of the material's self-healing capability. Formation of additional mineral constructions (calcite) can be one of the concepts that might be viewed as while looking for self-healing material which are viable with the primary material. Consequently, they could have the option to seal the cracks without influencing the material properties.

This chapter technique aims to seal of micro-cracks with various “autonomous” self-healing frameworks. By this implies, the inward part of the concrete is secured and the threat of reinforcement corrosion is limited. This research will solely be centered on the examination of this natural way to deal with microbial concrete and separated from exploring the generally directed tests, the author will endeavor to propose, acknowledge and assess new organic agents to the improvement of the organic self-healing concrete dependent on the got data from the past investigations.

1.2 BACTERIAL CONCRETE

The Concept of bacterial concrete was first introduced by V. Ramakrishnan et al. A novel technique is adopted in remediating cracks and fissures in concrete by utilizing calcite ($CaCO3$) precipitation. Microbiologically induced calcite precipitation (MICP) is a technique that comes under a broader category of science called biomineralization. Bacillus Cereus, a common soil bacterium can induce the precipitation of calcite. As a microbial salient, $CaCo3$ exhibited its positive potential in selectivity consolidating simulated fractures and surface fissures in granites and in the consolidation of sand. Microbiologically induced calcite precipitation is highly desirable because the calcite precipitation induced as result of microbial activities, is pollution free and natural. The technique can be used to improve the compressive strength and stiffness of cracked concrete specimens.

The bacterial concrete makes use of calcite precipitation by bacteria. The phenomenon is called microbiologically induced calcite precipitation (MICP). The pioneering work on repairing concrete with MICP is reported by the research group of Ramakrishnan V and others at the South Dakota School of Mines & Technology, U.S.A. The MICP is a technique that comes under a broader category of science called Bio-Mineralization. It is the process by which living organisms or bacteria from inorganic solids. Bacillus Cereus, a common soil bacterium, can induce the precipitation of calcite. Under favourable conditions Bacillus cereus, when used in concrete, can continuously precipitate a new highly impermeable calcite layer over the surface of the already existing concrete layer. The precipitated calcite has a coarse crystalline structure that readily adheres to the concrete surface in the form of scales.

In addition to the ability to continuously grow upon itself, it is highly insoluble in water. It resists the penetration of harmful agents (chlorides, sulphates, carbon dioxide) into the concrete thereby decreasing the deleterious effects they cause. Due to its inherent ability to precipitate calcite continuously, bacterial concrete can be called a ―Smart Bio Material for repairing concrete. The MICP comprises a series of complex biochemical reactions. It is selective and its efficiency is affected by the porosity of the medium, the number of cells present and the total volume of nutrient added. The optimum pH for growth of B.pasteurii is around 9. The alkaline environment of concrete with pH around 12 is the major hindering factor for the growth of bacteria.

However, B.pasteurii has the ability to produce endospores to endure an extreme environment, as observed by V Ramakrishnan and the research team. The microbial modified mortar or concrete has become an important area of research for high-performance construction materials. Ghosh et al. investigated the effects of incorporating a facultative anaerobic hot spring bacterium on the microstructure of a cement–sand mortar. Environmental scanning electron microscopic (ESEM) views and image analysis (IA) of the bacteria modified mortar (thin-section) showed significant textural differences with respect to the control (without bacteria) samples.

1.3 CLASSIFICATION OF BACTERIA

A. Classification on the Basis of Shapes

Bacteria are usually classified on the basis of their shapes. Broadly, they can be divided into Rod-shaped bacteria (Bacilli), Sphere-shaped bacteria (Cocci) and Spiral-shaped bacteria (Spirilla).

B. Classification on the Basis of Gram Strain

This classification is based on the results of Gram Staining Method, in which an agent is used to bind to the cell wall of the bacteria, they are Gram-positive and Gram-negative.

C. Classification on the Basis of Oxygen Requirement

This classification is based on the requirement of oxygen for the survival of the bacterium. They are Aerobic (Use molecular oxygen as terminal electron acceptor) and Anaerobic (Do not use molecular oxygen as terminal electron acceptor).

Various bacteria used in the concrete are:

- Bacillus pasteurii
- Bacillus sphaericus
- Escherichia coli
- Bacillus subtilis
- Bacillus Cereus (used in the present study).

1.4 BACILLUS CEREUS

Researchers with different bacteria proposed different bacterial concretes. The various bacteria used in the concrete are Bacillus pasteurii, Bacillus sphaericus, E.coli etc. In the present study an attempt was made by using the bacteria Bacillus Cereus. The main advantage of embedding bacteria in the concrete is that it can constantly precipitate calcite. This phenomenon is called microbiologically induced calcite precipitation (MICP). Calcium carbonate precipitation, a widespread phenomenon among bacteria, has been investigated due to its wide range of scientific and technological implications. Bacillus Cereus is a laboratory cultured soil bacterium and its effect on the strength and durability is studied here. Bacillus cereus is gram-positive rod-shaped bacilli with square ends.They are single rod-shaped or appear in short chains. Clear cut junctions between the members of chains are easily visible. It is $1x3^{-4}$µm in size. Endospores are able to survive long periods of exposure to air and other adverse environmental conditions. Most Bacillus species grow readily on nutrient agar or peptone media. The optimum temperature for growth varies from 20°C to 4° The optimum temperature for growth varies from 20°C to 40°C, mostly 37°C.

On Nutrient Agar at 37°C, it forms large (2-5mm) grey-white granular colonies with a less wavy edge and less membranous consistency.

Fig. No.1.1: Bacillus cereus

1.5 OBJECTIVES

- To study the mechanical Properties in M_{25} Concrete using Bacillus Cereus.
- To carry out the workability test on Control and Bacterial Specimens.
- To compare the mechanical properties between OPC and PPC in control and Bacterial Specimens.
- To compare the test result for the Conventional and Bacterial Specimen at different curing periods.

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL

A Literature Review is an overview of the previously published works on a topic. A good literature review can ensure that a proper research question has been asked and a proper theoretical framework and research methodology have been chosen.

2.2 LITERATURE REVIEW

Priyom.S.N., et.al., (2022) in their research paper "Microbial Technology-A Sustainable Alternative To Improve Concrete Quality" in the journal "advances in civil engineering" has investigated concrete has become the world's most broadly utilized building material due to its adaptability, solidness, sustainability, and economy. Traditional concrete generally refers to the mixture of aggregates, i.e., sand and stone chips, and held firmly by a binder of cementitious paste. Different supplementary cementitious materials have already been developed by researchers to improve quality of concrete. However, the present study is only centered with traditional cement-based concrete with a biogenic self-healing system. Generally, a biological agent with culture media is consolidated in concrete which gives rise to a modified concrete termed as "microbial concrete." Microbial concrete technology can improve concrete quality effectively through bio-mineralization process. The aim of the present work is to promote eco-friendly biological agents to enhance concrete quality. A pre-fixed culture density (0.5 ± 0.1) was maintained for preparing three different grades of concrete (20, 30 and 40mpa). The effects of two bacterial strains, i.e., *bacillus cereus* and *Escherichia coli*, were studied on mechanical properties of concrete. Five different ratios of plain water to microbial culture were added to concrete matrix to investigate the effect of microbial percentage. The study result reveals that the uses of *bacillus* strain are more effective than *Escherichia* strain regarding concrete strength development. Out of the five ratios, 25:75 (plain water to microbial culture) is found maximum effects on concrete consolidation.

Jena S., et.al., (2021) in their research paper "Effect Of Bacillus Cohnii Bacteria On The Properties Of Concrete" in the journal "Recent developments in sustainable infrastructure" has investigated concrete plays an important role in this era of rapid urbanization. but concrete is quite prone to crack formation, which affects its durability. if immediate precaution is not taken then cracks tend to expand further and require costly repair. due to the cracks, an easy path is developed in the structure, through which water, oxygen and carbon dioxide, etc. from air penetrates into the concrete which leads to the decrement in durability of concrete. To overcome this disadvantage, various crack healing techniques have come into limelight; one of them is self-healing bacterial concrete. This paper is aimed at finding out the influence of bacillus cohnii bacterium on the properties of concrete. bacterial cell count, i.e., colony-forming unit (CFU) of 10^5 and 10^{10} cells/ml were selected for the present work. then 10^3 and 10^8 cells/cm^3 bacterial concentrations have been added to concrete for 10^5 and 10^{10} cells/ml, respectively. Specimens were tested after different intervals of curing period. When compared to control mix (without the addition of bacteria), it is noticed that concrete with bacillus cohnii bacteria shows increment in compressive, flexural and split tensile strength in all curing periods for both cell concentrations 10^3 and 10^8 cells/cm^3. The highest strength is achieved when 10^3 cells/cm^3 bacterial concentration have been added to concrete for 10^5 cells/ml.

Karimi N And Mostofinejad D (2020) in their research paper "Bacillus Subtilis Bacteria Used In Fiber Reinforced Concrete And Their Effects On Concrete Penetrability" has investigated in the present study, bacteria is used as sediment producing agents in concrete specimens strengthened with different types of fiber. For this purpose, a strain of bacillus subtilis was employed in its culture medium. These were found capable of filling concrete pores to reduce porosity in fiber-reinforced specimens.

Agarwal et.al., (2020) in their research paper "Experimental Investigation on Bacterial Concrete With Micronized Biomass Silica" in the journal "materials today: proceedings" has investigated the use of concrete in the construction industry is never ending and so are their complementary ill effects. Thus, they should be handled within the stipulated time and in a sustainable manner. The major idea of the present research work is to assess the strength parameters of the concrete specimens made by inducing bacteria along with a suitable cement replacing substance. Therefore, the use of sustainable strategies like inducing bacterial culture into the concrete mix can act as an active support for both nature as well as the economy of construction industries. There are many substitutes which are used for replacing cement. In this paper, control concrete, concrete made by replacing cement with 8% of micronized biomass silica (MBS) and bacteria induced concrete are compared. The bacteria used is bacillus sphaericus and is mixed in the concrete specimens at different levels of 10ml, 20ml, 30ml. M60 grade high strength concrete is casted in the form of cubes and cylinders and their compressive strength and split tensile strength at the age of 7 and 28 days are compared with that of conventional concrete. From the test results, it was concluded that, specimens with 20ml bacteria and 8% MBS showed optimum results.

Ishalif.A., et.al., (2019) in their research paper "Improvement of Mechanical Properties of Bio-Concrete Using Enterococcus Faecalis And Bacillus Cereus" in the journal "environmental engineering research" has investigated the present study aimed to investigate the potential of enterococcus faecalis (e. Faecalis) and Bacillus cereus (B. cereus) in improving the properties of bio-concrete. E. faecalis and B. cereus strains were obtained from fresh urine and an acid mire water at cell concentration of 1.16×10^{12} and 1.3×10^{12} cells ml^{-1}, respectively. The bacterial strains were inoculated in a liquid medium into the concrete with 1, 3 and 5% as replacement of water cement ratio (w/c). The ability of E. faecalis and B. cereus cells to accumulate the calcite and the decrement of pores size within bio-concrete was confirmed by SEM and EDX analysis. The results revealed that E. faecalis exhibited high efficiency for increasing of compressive and splitting tensile strength than B. cereus (23 vs. 14.2%, and 13 vs. 8.5%, respectively). These findings indicated that E. faecalis is more applicable in the bio-concrete due to its ability to enhance strength development and reduce water penetration. It can be concluded that E. faecalis and B. cereus has the potential to be used in the bio-concrete in order to improve the concrete properties such as compressive strength, tensile strength and water penetration. The incorporation of both bacteria into concrete produces a higher amount of calcite in the samples of all curing periods and resulted self-healing of concrete pores up to 28 d. Moreover, E. faecalis was more efficient than B. cereus. The characteristics of Bio-concrete have improved with 3% of E. faecalis and 5% of B. cereus. Microstructure analysis using SEM and EDX confirmed that E. faecalis and B. cereus are capable precipitating calcium, which leads to increase in $Caco_3$.

Tiwari S (2019) in their research paper "Mechanical And Microstruct Ure Study Of The Self Healing Bacterial Concrete" in the journal "mater sci forum" has investigated concrete largely used for construction material, degrades with the development of cracks that becomes easy passage for entry of chemicals and harmful compounds. Self healing capability is helpful to mitigate the deterioration of the concrete structures. This research work focuses on the self healing behaviour and mechanical properties of the bio-concrete supplemented with three different bacteria namely bacillus sphaericus, bacillus cohnii and bacillus megaterium. Concrete supplemented with bacillus cohnii exhibited 35.31% increase in compressive strength compared to control mix after 28 days. Concrete supplemented with other bacteria Bacillus sphaericus and Bacillus megaterium also showed enhanced compressive strength. Interestingly, addition of bacteria aided in healing of artificially generated cracks by formation of $caco_3$ minerals. Maximum amount of healing (bacterial precipitation) which could be quantified as calcite minerals present in the bacterial concrete was 11.44% with B. cohnii confirmed by the Scanning Electron Microscope (SEM) with Energy Dispersive Spectroscopy (EDS).

Krishnapriya.S et.al., (2015) in their research paper "Isolation And Identification Of Bacteria To Improve The Strength Of Concrete" in the journal "Microbiol res" has investigated the objective of this research work is to isolate and identify calcite precipitating bacteria and to check the suitability of these bacteria for use in concrete to improve its strength. Bacteria to be incorporated in concrete should be alkali resistant to endure the high pH of concrete and endospore forming to withstand the mechanical stresses induced in concrete during mixing. They must exhibit high urease activity to precipitate calcium carbonate in the form of calcite. Bacterial strains were isolated from alkaline soil samples of a cement factory and were tested for urease activity, potential to form endospores and precipitation of calcium carbonate. Based on these results, three isolates were selected and identified by 16s rRNA gene sequencing. They were identified as Bacillus megaterium BSKAU, Bacillus licheniformis BSKNAU and Bacillus flexus BSKNAU. The results were compared with Bacillus megaterium MTCC 1684 obtained from microbial type culture collection and gene bank, Chandigarh, India. Experimental work was carried out to assess the influence of bacteria on the compressive strength and tests revealed that bacterial concrete specimens showed enhancement in compressive strength. The efficiency of bacteria toward crack healing was also tested. Substantial increase in strength and complete healing of cracks was observed in concrete specimens cast with B. megaterium BSKAU, B. licheniformis BSKNAU and B. megaterium MTCC 1684. This indicates the suitability of these bacterial strains for use in concrete. The enhancement of strength and healing of cracks can be attributed to the filling of cracks in concrete by calcite which was visualized by scanning electron microscope.

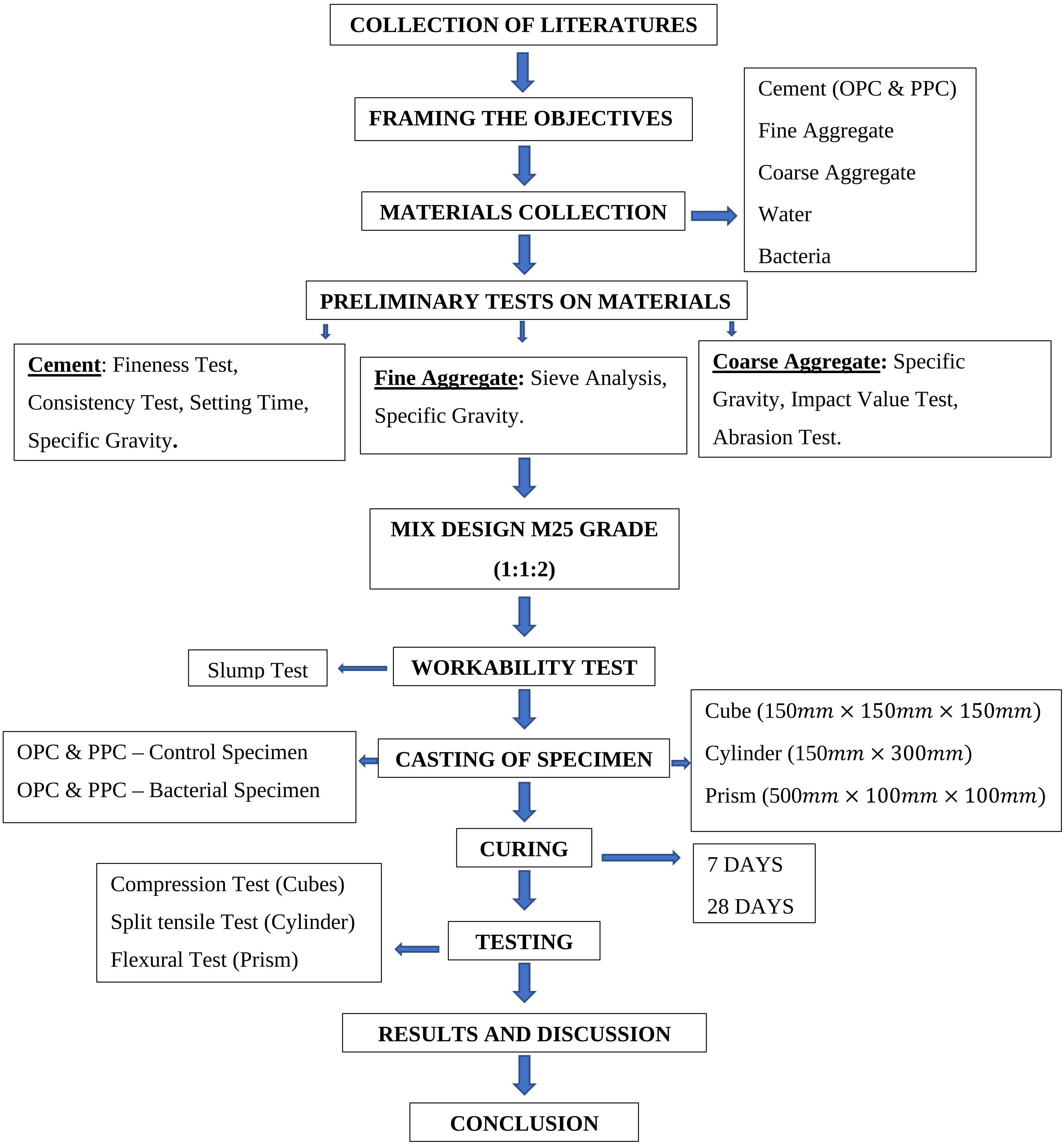
Jonkers, et. Al., (2010) in their research paper "Application Of Bacteria As Self-Healing Agent For The Development Of Sustainable Concrete" in the journal "ecological engineering" has investigated the application of concrete is rapidly increasing worldwide and therefore the development of sustainable concrete is urgently needed for environmental reasons. As presently about 7% of the total anthropogenic atmospheric co_2 emission is due to cement production, mechanisms that would contribute to a longer service life of concrete structures would make the material not only more durable but also more sustainable. One such mechanism that receives increasing attention in recent years is the ability for self-repair, i.e., the autonomous healing of cracks in concrete. In this study we investigated the potential of bacteria to act as self-healing agent in concrete, i.e., their ability to repair occurring cracks. A specific group of alkali-resistant spore-forming bacteria related to the genus bacillus was selected for this purpose. Bacterial spores directly added to the cement paste mixture remained viable for a period up to 4 months. A continuous decrease in pore size diameter during cement stone setting probably limited life span of spores as pore widths decreased below 1μm, the typical size of bacillus spores. However, as bacterial cement stone specimens appeared to produce substantially more crack-plugging minerals than control specimens, the potential application of bacterial spores as self-healing agent appears promising.

Yang, Y., et.al., (2009) In Their Research Paper "Autogenous Healing Of Engineered Cementitious Composites Under Wet-Dry Cycles" in the journal "cement and concrete research" has investigated the self-healing of engineered cementitious composites (ECC) subjected to two different cyclic wetting and drying regimes was investigated in this paper. To quantify self-healing, resonant frequency measurements were conducted throughout wetting–drying cycles followed by uniaxial tensile testing of self-healing ECC specimens. Through self-healing, crack-damaged ECC recovered 76% to 100% of its initial resonant frequency value and attained a distinct rebound in stiffness. Even for specimens deliberately pre-damaged with the tensile strain capacity after self-healing recovered close to 100% that of virgin specimens without any preloading. Also, the effects of temperature during wetting–drying cycles led to an increase in the ultimate strength but a slight decrease in the tensile strain capacity of rehealed pre-damaged specimens. This paper describes the experimental investigations and presents the data that confirm reasonably robust autogenous healing of ECC in commonly encountered environments for many types of infrastructure.

Li. V. C., Lim, et.al., (1998) In Their Research Paper "Feasibility Study Of A Passive Smart Self-Healing Cementitious Composite" in the journal "composites part b: engineering" has investigated the basic concept of a passive smart healing cementitious composite has been demonstrated, in the laboratory, to be feasible. The basic elements of this smart material include the sensors and actuators in the form of controlled microcracks and hollow glass fibers carrying air-curing chemicals. Controlled microcracking is offered by a strain-hardening engineered cementitious composite developed previously. The mechanisms of sensing and actuation are revealed through in situ environmental scanning electron microscopy observations. The self-healing effectiveness is confirmed by measurement of the elastic modulus of the composite. The elastic modulus is found to regain its original value in a repeat loading subsequent to damage in a first load cycle. The feasibility of a PSS-ECC has been investigated via conceptual design, preliminary embodiment and experimental tests. The sensing action of overloading by ECC matrix cracking, and actuation of chemical release from hollow glass fibers embedded in an ECC by glass fiber breakage, were confirmed by direct observation of the sensing and actuation mechanisms in small specimens of a model PSS-ECC system tested in situ in an ESEM.

CHAPTER 3

METHODOLOGY



3.1 GENERAL

The Methodology refers to a discussion of the Bacterial concrete. Methodology is the procedure or techniques used to identify, select, process and analyze information about a Bio-Concrete. Self-healing concrete is a product that will biologically produce limestone to Heal cracks that appear on the surface of concrete structures. In bio-concrete if water is the contact with the concrete with the concrete the cracks the bacteria get activated from its stage of dormance formed which further in calcium carbonate which act as a healing material.

CHAPTER-4

MATERIALS TESTING

4.1 GENERAL

Concrete is one of the most widely used construction material throughout the world. It is obtained by mixing together cement, aggregates, water and sometimes admixtures. The mixture when placed in forms and allowed to cure, it hardens into a rock like mass. The quality of concrete is exclusively dependent on the quality of its ingredients and the workmanship for concrete making and placing.

4.2 MATERIAL SPECIFICATION

Specifications for raw materials and ingredients should contain the following information: Name of the material. A description of the material, including biological, chemical and physical characteristics. Composition of the material, including additives and processing aids.

4.2.1 Cement

The cement chosen is OPC and PPC cement as per IS standard code. This standard covers the manufacture and chemical and physical requirements of 53 grade ordinary Portland cement and Portland Pozzolana Cement. Ordinary Portland cement 53 grade shall be manufactured by intimately mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resultant clinker so as to produce a cement capable of complying with this standard.

Fig. No.4.1: Cement

No material shall be added after burning, other than gypsum water, performance improver(s), and not more than a total of 1.0 percent of air- entraining agents or other agents including colouring agents, which have proved not to be harmful. Portland Pozzolana Cement 53 grade shall be manufactured by mixing and fine-grinding silicate cement clinker, pozzolanic material, and gypsum. Pozzolanic materials contain active silica and aluminum and usually do not have any cementitious properties. But when they are mixed with water and lime at ambient temperatures, they will react with calcium hydroxide to form compounds possessing cementitious properties. No material shall be added after burning, other than gypsum water, performance improver(s), and not more than a total of 1.0 percent of air- entraining agents or other agents including colouring agents, which have proved not to be harmful.

4.2.2 Fine Aggregate

Fine Aggregate collected here is river Sand.

Fig. No.4.2: Fine Aggregate

4.2.3 Coarse Aggregate

Aggregate most of which is retained on 4.75 mm IS Sieve and containing only so much finer material as is permitted for the various types described in this standard. Coarse aggregates have been supplied in the nominal sizes given for any one of the nominal sizes, the proportion of other sizes, as determined by the method described in as below 20mm for testing of 150mm cube.

Fig. No. 4.3: Coarse Aggregate.

4.2.4 Bacteria

The bacteria used here is Bacillus cereus. It is a gram positive bacterium. Bacillus Cereus are rod-shaped bacteria. The cell wall is a rigid structure outside the cell. It is composed of peptidoglycan, which is a polymer of sugars and amino acids. The peptidoglycan that is found in bacteria is known as murein. Other constituents that extend from the murein are teichoic acids, lipoteichoic acids, and proteins. The cell wall forms the barrier between the environment and the bacterial cell. It is also responsible for maintaining the shape of the cell and withstanding the cell's high internal turgor pressure. A mature endospore has no metabolic activity; it is inert. The interior of the endospore, the core, is very dry and resistant to moisture.

4.2.5 Potable Water

Potable water comes from surface and ground sources. Potable water is not pure water because it almost always contains dissolved impurities. Water used for curing is free from impurities and salt. The water used for culturing the bacteria is similar to water used for curing.

4.3 MATERIAL TESTING

Materials testing, measurement of the characteristics and behavior of such substances as metals, ceramics, or plastics under various conditions. The data thus obtained can be used in specifying the suitability of materials for various applications—e.g., building or aircraft construction, machinery, or packaging.

4.3.1 Cement Test

The Physical properties of Cement are,

A. Fineness test
B. Normal Consistency Test
C. Initial and Final setting time
D. Specific Gravity

A. Fineness Test; IS 4031 (Part-1):1988

Cement is obtained by grinding various raw materials after calculation. The degree to which cement is ground to smaller and smaller particles is called fineness of cement. The fineness of cement has an important role on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence the faster development of strength although the ultimate strength is not affected. Fineness also provides more cohesiveness to concrete and avoid separation of water at the top of concrete (called bleeding). However, increase in fineness of cement increases the drying shrinkage and cracking of the concrete.

Fineness of cement is tested either by sieving or by determination of specific surface using air-permeability apparatus. The specific surface is defined as the total surface area of all the particles in cm^2 per one gram of cement. Although determination of specific surface is more accurate to judge fineness of cement, it is rarely used except for specific purpose. In contrast sieving is most commonly used method to determine fineness of cement and is quite good for field works.

Determination of fineness of cement by dry sieving.IS-90micron sieve conforming to 15: 460 (Part 1-3)-1985; Weighing balance, Gauging trowel: Brush. Ordinary Portland cement and Portland Pozzolana Cement. Weigh accurately 100 g of cement to the nearest 0.01 g and place it on a standard 90 micron IS sieve. Break down any air-set lumps in the cement sample with fingers. Agitate the sieve by giving swirlin g, planetary and linear movements for a period of 10 minutes or until no more fine material passes through it. Collect the residue left on the sieve, using brush if necessary, and weigh the residue. Express the residue as a percentage of the quantity first placed on the sieve to the nearest 0.1 percent. Repeat the whole procedures two more times each using fresh 100 g sample.

Fig. No.4.4: Sieve Shaker (Fineness Test) **Fig. No.4.5: Fineness Test on Cement**

OPC:-

W1 = 100g

W2 = 96g

- $\frac{W2}{W1} \times 100 = \frac{96}{100} \times 100 = 96$ % (OPC)

PPC:-

W1 = 100g

W2 = 97g

- $\frac{W2}{W1} \times 100 = \frac{97}{100} \times 100 = 97$ % (PPC).

B. Normal Consistency Test; IS 4031 (Part-4):1988.

This test is conducted to calculate the amount of water to be added to the cement to get a paste of standard consistency which is defined as that consistency which will permit the Vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the Vicat mould. This experiment is done with the help of Vicat apparatus (Figure 1). The time taken between adding of water to the cement and filling of mould of Vicat apparatus is called as gauging time which should be between 3 to 5 minutes.

For finding out initial setting time, final setting time, it is necessary to fix the quantity of water to be mixed in cement in each case. Since different batches of cement differ in fineness, pastes with some water content may differ in consistency when first mixed. For this reason the consistency of the paste is standardized by varying the water content until the paste has a given resistance to penetration. Determination of percentage of water by weight of cement required to prepare a standard acceptable (consistent) cement Vicat apparatus conforming to IS: 5513-1998; Weighing balance; Gauging trowel: measuring cylinder. Ordinary Portland cement; Water. Take 400 g of cement sieved through 90 micron IS sieve and keep it on a non- porous, non-absorbent plate. Add 120 ml of water (.e. 30% by weight of cement) to the cement and mix thoroughly with two trowels for 3 to 5 minutes till a uniform cement paste is achieved. Fill the past in mould and level with trowel. Shake or tap to remove air bubbles. Place the nonporous plate and the mould under the plunger. 5. Release the plunger gently to touch the surface of paste. Record the initial reading. Release the plunger quickly and allow penetrating into the paste. When the plunger comes to rest, note the final reading. Repeat the procedure with fresh paste varying the water percentage until the plunger penetrates to a depth 5 to 7 mm from the bottom of the Vicat mould.

Fig. No. 4.6: Normal Consistency Test using Vicat Apparatus.

Table. No.4.1: Normal Consistency Test Result

SI. N O.	Normal consistency Test	OPC	PPC
1	Trial 1	29	37
2	Trial 2	15	32
3	Trial 3	2	14.5

C. Setting Time of Cement; IS 4031 (Part-5):1988

Cement when mixed with water forms slurry which gradually becomes lesser and lesser plastic, and finally forms a hard mass. In this process a stage is obtained when the cement paste is sufficiently rigid to with stand a definite amount of pressure. The time to reach this stage is called setting time. The setting time is divided into two parts: the initial setting time and the final setting time. Vicat apparatus conforming to IS: 5513-1998; Weighing balance; Gauging trowel; measuring cylinder, stop watch. Ordinary Portland cement; Water. Prepare a uniform cement paste by gauging 400 g of cement with 0.85 times the water required to give a paste of standard consistency. The procedure of mixing and filling the mould is same as standard consistency. Start the stopwatch or note down the time when water is added to the cement. Determination of initial setting time. Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the initial setting needle (with cross section 1 mm): lower the needle gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block. Repeat this procedure until the needle, when brought in contact with the test block and released as described above, fails to pierce the block beyond 5.0+ 0.5 mm measured from the bottom of the mould. Note the time. The difference of time between operations (2) and (4) provides the initial setting time of cement. Determination of final setting time: Replace the initial setting needle of the Vicat apparatus by the needle with an annular attachment. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment fails to do so. The interval of time between operation (2) and (7) provides the final setting time of cement.

Table No. 4.2: Setting Time of Cement.

Setting Time of Cement	OPC	PPC
Initial	30 min.	30 min.
Final	600 min.	600 min.

Fig. No. 4.7: Vicat Apparatus

Fig. No.4.8: Setting Time of Cement

Specific Gravity Test; IS 4031 (Part-11):1988

Specific gravity is defined as the ratio between weight of a given volume of material and weight of an equal volume of water. In case of cement, specific gravity is determined by use of a Le Chatelier's flask (Figure 3). Sometimes, a specific gravity bottle may be employed to a standard Le Chatelier's flask. To determine the specific gravity of cement, kerosene is used which does not react with cement. The specific gravity of OPC is generally around 3.15. Apparatus used for the test are Le Chatelier's flask, weighing balance, kerosene (free from water). Materials are Ordinary Portland cement; Portland Pozzolana Cement; Water; Grease. Dry the flask carefully and fill with kerosene or naphtha to a point on the stem between zero and 1ml. Record the level of the liquid in the flask as initial reading. Put a weighted quantity of cement (about 60 g) into the flask so that level of kerosene rise to about 22 ml mark, care being taken to avoid splashing and to see that cement does not adhere to the sides of the above the liquid. After putting all the cement to the flask, roll the flask gently in an inclined position to expel air until no further air bubble rise3s to the surface of the liquid. Note down the new liquid level as final reading

4.3.2 Fine Aggregate Test

The physical properties of Fine Aggregate are,

- Specific Gravity
- Sieve Analysis Test

Specific Gravity of Fine Aggregate; 2386 (Part-3)-1963

Specific gravity of an aggregate is defined as the ratio of the mass of solid in a given volume of sample to the mass of equal volume of water at 4oo CC. However, all rocks contain some small amount of void and the apparent specific gravity includes this voids. The specific gravity of aggregates is an indirect measure of material's density and its quality. A low specific gravity may indicate high porosity and therefore poor durability and low strength.

Place 500 g of fine aggregate in a tray and cover it with distilled water at a temperature of 22 to 32°C. Remove air entrapped in or bubbles on the surface of the aggregate by gentle agitation with a rod. Keep the sample immersed under water for 24 Hrs. Carefully drain the water from the sample, by decantation through a filter paper. Air dry the aggregate and solid matter retained on the filter paper, to remove the surface moisture. When the material just attains a "free-running" condition, weight the saturated and surface-dry sample (A). Place the aggregate in the pycnometer and fill the remaining space by distilled water. Eliminate entrapped air by rotating the pycnometer on its side, covering the hole in the apex of the cone with a finger.

Weight the pycnometer with this condition (B). Empty the contents of the pycnometer into a tray. Ensure that all the aggregate is transferred. Refill the pycnometer with distilled water to the same level as before and measure the weight at this condition (C). Carefully drain the water from the sample, by decantation through a filter paper. Oven-dry the aggregate in the tray at a temperature of 100 to 110o C for 24 hrs. During this period, stir the specimen occasionally to facilitate proper drying. Cool the aggregates calculate its weight (D).Calculate the specific gravity, apparent specific gravity and the water absorption as follows:

Where,

W_1 = Weight of Pycnometer = 594.2gm

W2 = Weight of pycnometer with sand = 794.2gm

W3 = Weight of pycnometer with sand and water = 1780.7gm

W4 = Weight of pycnometer filled with water = 1658gm

➢ $\frac{W2-W1}{(W4-W1)-(W3-W2)} = \frac{794.2-594.2}{(1658-594.2)-(1780.7-794.2)} = 2.587.$

Sieve analysis; IS: 2386 (Part I) – 1963

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through different sieve. Balance or scale with an accuracy to measure 0.1 per cent of the weight of the test sample. The test sample is dried to a constant weight at a temperature of 110+5℃ and weight. The sample is sieved by using a set of IS Sieves. On completion of sieving, the material on each sieve is weighed. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100. According to the IS 2386-1963, the sand used here is Zone II.

Table No. 4.3, Sieve analysis

IS SIEVE	WEIGHT OF RETAINED AGGREGATE	% RETAINED	CUMULATIVE PERCENTAGE RETAINED	% PASSING
10mm	2	0.2	0.2	99.8
4.75mm	12	1.2	1.4	98.6
2.36mm	30	3	4.4	95.6
1.18mm	322	32.2	36.6	63.4
600mic	208	20.8	57.4	42.6
300mic	276	27.6	85	15
150mic	107	10.7	95.7	4.3
75mic	21	2.1	97.8	2.2
Pan	22	2.2	100	0

Fig.4.9. Sieve Analysis Test.

4.3.3 Coarse Aggregate Test:

The Physical Properties of Coarse Aggregate are,

- Specific Gravity
- Impact Value Test
- Abrasion Test

Specific Gravity of Coarse Aggregate; IS: 2386 (Part-3)-1963

For design of concrete mix, information about the specific gravity and water absorption of the coarse aggregates are required. Specific gravity of aggregate provides valuable information on its quality and properties. If the specific gravity is above or below than the value normally assigned to a particular type of aggregate; it may indicate that shape and grading of aggregate has altered. It is also important in determination of moisture contact and in many concrete mix design calculations. It is also required for the calculation of volume yield of concrete.A sample of not less than 2 Kg of the aggregate shall be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C to 32°C with a cover of at least 5 cm of water above the top of the basket. Immediately after immersion the entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and aggregate shall remain completely immersed during the operation and for a period of 24 ± l/2 hours afterwards. The basket and the sample shall then be jolted and weighed in water at a temperature of 22°C to 32°C. The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the, aggregate shall be gently emptied from the basket on to one of the dry clothes, and the empty basket shall be returned to the water and weighed in water. The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. The aggregate shall then be weighed aggregate shall then be placed in the oven in the shallow tray, at a temperature of 100 to 110°C and maintained at this temperature for 24 ± l/2 hours. It shall then be removed from the oven, cooled in the airtight container and weighed.

Where,

W1 = Empty weight of pycnometer = 597gm

W2 = Weight of pycnometer with aggregate = 1036gm

W3 = Weight of pycnometer with aggregate and full of water = 1769gm

W4 = Weight of pycnometer with full of water = 1439gm

- $\frac{W2-W1}{(W4-W1)-(W3-W2)} = \frac{1036-597}{(1439-597)-(1769-1036)} = 2.6.$

Impact Test Value on Coarse Aggregate; IS: 2386 (PART IV)-1963

The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load. Aggregates for the test sample can be decided by passing it through 12.5mm sieve and retained on 10mm sieve. The sieved aggregates should be dried in an oven and then filled in a cylindrical steel cup and tampered with 25 strokes by tamping rod.

The test sample is filled in 3 layers and each layer is tampered for 25 numbers of blows. Metal hammer (weighing approx. 14 kg) is pre-arranged to drop with a free fall of 380mm. The test specimen is subjected to 15 numbers of blows each at not less than 1 second. The crushes aggregate is removed from the test specimen and sieve it through the 2.36mm IS sieve. An impact value is measured as % of aggregates passed through the 2.36mm sieve (W2) to the total weight of the sample (W1).

W1 = 336gm; W2 = 80gm.

Aggregate impact value = $\frac{W2}{W1} \times 100 = \frac{80}{336} \times 100$ = 23.80%.

Abrasion Test of Coarse Aggregate; IS:2386 (Part IV)-1963

The Measurement of toughness and resistance like degradation, crushing and disintegration. The abrasion test on aggregate in Los Angeles is carried out with the following objectives:

- To discover the value of Abrasion in Los Angeles aggregate.
- Find the suitability of aggregates for use in road construction projects.

Select the grading to be utilized in the test such that it conforms to the grading to be utilized in construction, to the maximum extent possible. Require 5 kg of sample for gradings A, B, C and; D, and 10 kg for gradings E, F & amp; G. Pick the abrasive charge depending on the grading of aggregates. Place the aggregates and abrasive charge to the cylinder and fix the cover. Rotate the machine at a speed of 30 to 33 revolutions per minute. The number of revolutions is 500 to get gradings A, B, C and D, and 1000 for gradings E, F and G. The machine ought to be balanced and driven such that there is uniform peripheral speed. The machine is stopped after the desired number of revolutions and material is discharged to a tray. The entire stone dust is sieved on 1.70mm IS sieve. The material coarser than 1.7mm size is weighed correct.

Weight of sample = 5000gm,

Weight after test (Wash & Oven Dry) = 4087gm.

Los Angeles abrasion value = $\frac{Different\ in\ weight}{Weight\ of\ sample} \times 100$

$$= \frac{5000-4087}{5000} \times 100 = 18.26\%$$

Table No. 4.4. Physical properties of cement

PHYSICAL PROPERTIES OF CEMENT			
SI. NO.	Physical Properties	Test Result	
		OPC	PPC
1	Fineness Test	96%	97%
2	Normal consistency Test	30%	30%
3	Initial Setting Time	30 min.	30 min.
4	Final Setting Time	10 hr.	10 hr.
5	Specific Gravity	3.15	3.15

Table No.4.5. Physical properties of Fine Aggregate

PHYSICAL PROPERTIES OF FINE AGGREGATE		
SI. NO.	Properties	Test Result
1	Sand Zone	Zone-II
2	Specific Gravity	2.58

Table No.4.6. Physical Properties of Coarse Aggregates

SI. NO.	Physical Properties	Test Result
1	Specific Gravity	2.6
2	Impact Test	23.80%
3	Abrasion Test	18.26%

CHAPTER 5

MIX DESIGN

5.1 GENERAL

The objective of proportioning concrete mixes is to arrive at the most economical and practical combinations of different ingredients to produce concrete that will satisfy the performance requirements under specified conditions of use. An integral part of concrete mix proportioning is the preparation of trial mixes and effect adjustments to such trials to strike a balance between the requirements of placements, that is, workability and strength, economically satisfying durability requirements. Concrete has to be of satisfactory quality bot in its fresh and hardened states. Mix proportioning is generally carried out for a particular compressive strength requirements ensuring that fresh concrete of the mix proportioned to possess adequate workability for placement without segregation and bleeding while attaining a dense state. In addition, the method has scope to consider the combination of wider spectrum of cement and mineral admixtures proposed to be used to meet the requirements of durability for the type of exposure conditions anticipated in service.

5.2 MIX PROPORTIONING FOR A M25 GRADE CONCRETE ; IS 10262 : 2009

The Mix Proportioning for a concrete of M25 Grade.

5.2.1 STIPULATIONS FOR PROPORTIONING

a) Grade designation : M 25
b) Type of cement : OPC & PPC 53 grade
c) Maximum nominal size of aggregate : 20mm
d) Minimum cement content : 320 kg/m^3
e) Maximum water-cement ratio : 0.5
f) Workability : 100 mm (slump)
g) Exposure condition : severe
h) Method of concrete placing : Plumbing
i) Degree of supervision : Good
j) Type of aggregate : Crushed angular aggregate
k) Maximum cement content : 450 kg/m

5.2.2 TEST DATA FOR MATERIALS

a) Cement used : OPC & PPCS 53 grade conforming to IS 8112
b) Specific gravity of cement : 3.15

c) Specific gravity of:

1. Coarse aggregate : 2.6
2. Fine aggregate : 2.5

d) Water absorption:

1. Coarse aggregate : 0.5 percent
2. Fine aggregate : 0.5 percent

e) Free (Surface) moisture:

1. Coarse aggregate : Nil (absorbed moisture also nil)
2. Fine aggregate : Nil.

5.2.3 TARGET STRENGTH FOR MIX PROPORTIONING

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

where,

- f'_{ck} = target average compressive strength at 28 days,
- f_{ck} = characteristic compressive strength at 28 days, and
- s = standard deviation.

From Table 1, standard deviation, s = 4 N/mm^2.

Therefore, target strength = $25+1.65\times4 = 31.6\ N/mm^2$.

5.2.4 SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 456, maximum water-cement ratio = 0.5.

Based on experience, adopt water-cement ratio as 0.40.

0.5 < 0.55, hence O.K.

5.2.5 SELECTION OF WATER CONTENT

From Table 2, maximum water content =186litre (for 25 to 50 mm slump range) for 20 mm aggregate.

Estimated water content for 100 mm slump = $186 + \frac{6}{100} \times 186 = 197$ litre.

5.2.6 CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.5

Cement $= \frac{197}{0.5} = 394\ Kg/m^3$.

5.2.7 PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3. volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I)

for water-cement ratio of 0.50 = 0.60.

Therefore, volume of coarse aggregate = 0.60.

Volume of fine aggregate content = 1 - 0.60 = 0.40.

5.2.8 MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = $1m^3$

b) Volume of cement = $\frac{Mass\ of\ cement}{Specific\ gravity\ of\ cement} \times \frac{1}{1000}$

$= \frac{394}{3.15} \times \frac{1}{1000} = 0.125\ m^3$

c) Volume of water = $\frac{Mass\ of\ water}{Specific\ gravity\ of\ water} \times \frac{1}{1000}$

$= \frac{197}{1} \times \frac{1}{1000} = 0.197m^3$

d) Volume of all in aggregate = [a- (b + c)]

= 1-(0.125 + 0.197)

= $0.678\ m^3$.

e) Mass of coarse aggregate = e x Volume of coarse aggregate x Specific gravity of coarse aggregate × 1000

$= 0.678 \times 0.60 \times 2.6 \times 1000$

= 1057.68 Kg

f) Mass of Fine aggregate = e x Volume of coarse aggregate x Specific gravity of fine aggregate × 1000

$= 0.678 \times 0.40 \times 2.5 \times 1000$ = 678 Kg.

5.2.9 MIX PROPORTIONS:

Cement : 394 Kg/m^3

Coarse aggregate : 1057.68 Kg/m^3

Fine aggregate : 678 Kg/m^3

Water-Cement ratio : 197 Kg/m^3.

Coarse aggregate : 1057.68 Kg/m^3

Table No.5.1. Mix Proportion Ratio

	CEMENT	**FINE AGGREGATE**	**COARSE AGGREGATE**	**WATER**
	(Kg/m^3)	**(Kg/m^3)**	**(Kg/m^3)**	**(L)**
Quantity	394	678	1057.68	197
Ratio	1	1.72	2.7	0.5

CHAPTER 6

EXPERIMENTAL INVESTIGATIONS

6.1 GENERAL

The experimental investigations carried out on the test specimens to study the strength-related properties of concrete. The experimental test were conducted to examine the effect of using different sources of water for mixing and curing purposes on the mechanical properties of fresh and hardened concrete. Finally experiments were carried out on the properties of concrete with various mixing and curing water were variable in the concrete mixes. A total of 108 concrete samples will be casted and tested on the 7th, 14th and 28th days of curing age for compressive strength, splitting tensile strength and flexural strength. A slump test was adopted to determine the workability of fresh concrete.

6.2 MATERIAL CALCULATION

The amount of materials required for+ the concrete specimens of cubes, cylinder and prism are calculated.

a) MATERIAL CALCULATON FOR CUBES

The size of cube is $150\times 150 \times 150$mm. Materials are calculated for the mass of 9 cubes.
The total mass of concrete = 83.83 Kg.
The amount of materials required for the concrete cubes are,

$$\text{Cement} = \frac{1\times Total\ Mass\ of\ concrete}{Sum\ of\ ratio} = \frac{1\times 83.83}{5.92} = 14.16\text{Kg.}$$

$$\text{Fine Aggregate} = \frac{1.72\times 83.83}{5.92} = 24.35\text{Kg.}$$

$$\text{Coarse Aggregate} = \frac{2.7\times 83.83}{5.92} = 38.23\text{Kg.}$$

$$\text{Water} = \frac{0.5\times 83.83}{5.92} = 7.08\text{L}$$

b) MATERIAL CALCULATIONS FOR CYLINDERS

The size of cylinder is 150×300mm. Materials are calculated for the mass of 9 cylinders. The total mass of concrete for the cylinders are 131.61Kg. The amount of materials required for the cylinders are cement, fine aggregate, coarse aggregate and water respectively are 22.23kg, 38.22kg, 60.024kg and 11.11 L.

c) MATERIAL CALCULATIONS FOR PRISM

The size of prism is $500\times 100 \times 100$mm. The total mass of concrete for 9 prisms are 124.2kg. The quantity of materials required for the prism of cement, fine aggregate, coarse aggregate and water respectively are 20.97kg, 36.08kg, 56.64kg and 10.4L.

6.3 CULTURE OF BACILLUS CEREUS

Most Bacillus spp. grow readily on nutrient agar or peptone media. Liquid media are sometimes referred as "broths" (e.g. nutrient broth). Nutrient Broth is used for the cultivation and maintenance of a bacteria and various micro-organisms. In liquid medium, broth grow uniformly producing general turbidity.

Composition:

Peptone	:	5 gm/lit.
Sodium chloride	:	5 gm/lit.
Yeast extract	:	2 gm/lit.
Beef extract (ex. Buffalo)	:	1 gm/lit.

BROTH PREPARATION:

Add 6gm nutrient powder to distilled water. Bring volume to 400ml and mix thoroughly. Gently heat and bring to boiling. Autoclave at 15psi pressure at 121℃ for 15 minutes. After 30 minutes of heating process, cool down the broth in the Laminar Air Flow Machine with the effect of UV rays. Inaugurate the bacteria by using the loop in the Laminar air flow machine. Keep the closed flask in the shaker for 24 hours.

Mix Proportion of Bacteria:

No of Specimen =13x30ml(Bateria Solution) =390ml

Total amount of water =12.97 lit

Bacteria Solution = 0.39 lit

Total amount of Water with bacteria solution = 12.58 lit

Fig. No.6.1 Nutrient Broth

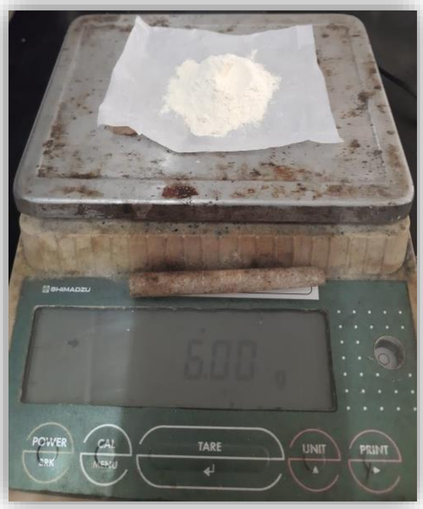


Fig. No. 6.2 Weighing Machine

Fig. No. 6.3 Laminar Air Flow Machine

Fig. No. 6.4 Sieve Shaker

Fig. No. 6.5 Cultured Bacteria

6.4 WORKABILITY OF CONCRETE BY SLUMP CONE TEST : IS 7320-1974, IS 1199-1959.

The slump cone experiment is conducted in an apparatus called slump cone. This apparatus essentially consist of a metallic mould in the form of a frustum of a cone having the internal dimension as under: Bottom 20 cm, Top dimension 10cm, height 30cm and the thickness of the metallic sheet for the mould should not more than thinner than 1.6mm. To determines the workability of freshly mixed concrete by the use of slump test. Apparatus used for this slump test is Slump cone, tamping rod, metallic sheet, weighting machine and scale. Material required the test are Cement, sand, aggregate and water. Prepare a concrete mix for testing workability. Consider a W/C ratio of 0.5 to 0.6 and design mix of proportion about 1:2:4 (it is presumed that a mix is designed already for the test). Weigh the quantity of cement, sand, aggregate and water correctly. Mix thoroughly. Use this freshly prepared concrete for the test. Place the concrete into the upper hopper up to its brim. Open the trapdoor of the upper hopper. The concrete will fall into the lower hopper. Open the trapdoor of the lower hopper, so thus concrete falls into the cylinder below. Remove the excess concrete above the level of the top of the cylinder, clean the outside of the cylinder. Weigh the concrete in the cylinder. This weight of concrete is the "weight of partially compacted concrete". (W_1). Empty the cylinder and refill with concrete in layers, compacting each layer well (or the same may be vibrated for full compaction). Top surface may be struck off level.

6.5 CASTING OF SPECIMENS

For concrete experimental tests, the samples are based on the types of test requirements available and standards. A total number of 24 concrete cubic specimens of standard size 150mm using sources of water will be cast, cured and tested for the compressive strength at the period of 7 and 28 days. The split tensile strength test used for the water curing to Casting, curing and testing of 24 concrete cylindrical specimens of standard size 150mm diameter and 300mm length for at the period of 7 and 28 days. The 24 concrete flexural specimens of standards size ($100\times 100 \times 500$mm) will be tested at 7 and 28 days of curing period.

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Fig 6.6 Cube Specimens ($150mm \times 150mm \times 150mm$)

Fig. 6.7 Cylinder Specimens ($150mm \times 300mm$)

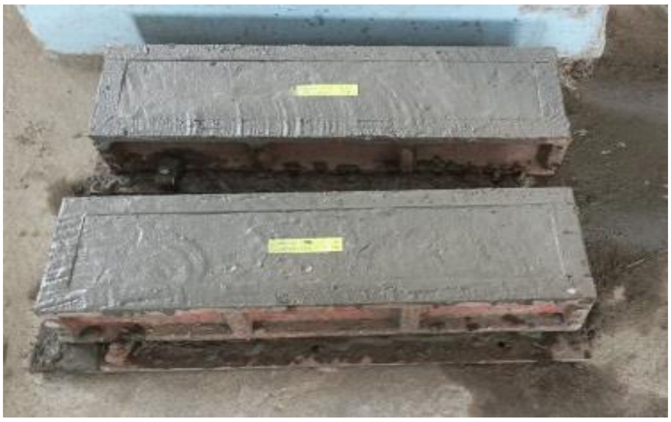

Fig.6.8 Prism Specimens ($500mm \times 100mm \times 100mm$)

6.6 COMPRESSION STRENGTH TEST FOR CONTROL SPECIMEN; IS:5816-1959

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. Calculate the material required for preparing the concrete of given proportions. Mix them thoroughly in mechanical mixer until uniform colour of concrete is obtained. Pour concrete in the lightly greased cube molds. Fill concrete in two layers each of approximately 75 mm and ramming each layer with 35 blows evenly distributed over the surface of layer. Struck off concrete flush with the top of the moulds. Level the concrete at the top of the mould by means of trowel and give proper identification mark of the specimen. Immediately after being made, they should be covered with wet mats. Specimens are removed from the moulds after 24hrs and cured in water. Take the cube out of water at the end of three days with dry cloth. Measure the dimensions of the surface in which the load is to be applied. Let be 'L' and 'B respectively. Place the cube in compressive testing machine and apply the load uniformly at the rate of 35N/mm2. Where A is the area of loaded surface (i.e., LxB). Repeat the same procedure (steps 9 to 12) for other two cubes. Repeat the whole procedure (Step 9 to 13) to find the compressive strength of the cube at the end of 7 days and 28 days.

Load(P) = 725.5 KN

Compression Test = $\frac{Load}{Cross\ section\ area}$ N/mm $= \frac{725500}{22500}$ N/mm2

Compression Strength = 32.24 N/mm^2

Compression strength of the cube (OPC) at the end of 28 days curing is 32.24 N/mm^2.

Fig 6.4 Compression Test

6.7 SPLIT TENSILE STRENGTH TEST FOR CONTROL SPECIMENS; IS:5816-1999

Splitting tensile test is generally carried out to obtain the tensile strength of concrete and the stress field in the tests is actually a biaxial stress field with the compressive stress three times greater than the tensile stress. A method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. Sampling of Materials: Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material. Proportioning: The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Weighing The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch. Mixing of concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a sir is to leave about 10 percent excess after moulding the desired number of test specimens. The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS: 10086-1982.

$$\text{Split tensile strength} = \frac{2P}{\pi d l}\ \text{N/mm}^2$$

$$= 6.50\ \text{N/mm}^2$$

The split tensile strength of the cylinder at end of 28 days curing period is 6.50 N/mm^2.

Fig 6.5 Split Tensile Test

6.8 FLEXURAL STRENGTH TEST FOR CONTROL SPECIMEN; IS:516-1959

The flexural strength of a material is defined as the maximum bending stress that can be applied to that material before it yields. The most common way of obtaining the flexural strength of a material is by employing a transverse bending test using a three-point flexural test technique. Sampling of Materials: Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material. Proportioning: The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Weighing: The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

Mixing of Concrete: The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. The standard size shall be 500 x 100 x 100 mm.

Load (P) = 9.59KN

Flexural strength = $\frac{pl}{bd^2}$ N/mm^2 = $\frac{9590 \times 500}{1000000}$ = 4.795 N/mm^2

Flexural strength of the Cylinder(OPC) at the end of 28 days curing is 4.795 N/mm^2.

Fig.6.6 Flexural Test

6.9 RESULTS & DISCUSSION

The tests results for compression strength test, split tensile strength test and flexure strength test are tabulated in table 6.4,6.5 and 6.6 respectively. In all the test performed on 7 days curing period, it is observed that the specimens with Bacillus cereus bacteria in M25 concrete containing PPC shows increase in strength.

Table No: 6.1 Compression Strength Test

Compression Test Result				
	Bacterial Concrete		Conventional Concrete	
	7 Days	28 Days	7 Days	28 Days
OPC	28.14	32.5	26.72	30.10
PPC	29.57	34.10	27.31	31.30

Table No: 6.2 Split Tensile Strength Test

Split tensile Test				
	Bacterial Concrete		Conventional Concrete	
	7 Days	28 Days	7 Days	28 Days
OPC	4.31	8.20	3.46	6.50
PPC	5.11	9.83	4.11	8.22

Table No: 6.3 Flexure Strength Test

Flexure Test				
	Bacterial Concrete		Conventional Concrete	
	7 Days	28 Days	7 Days	28 Days
OPC	3.41	5.98	2.68	5.60
PPC	4.22	7.15	3.21	6.10

CHAPTER 7

CONCLUSIONS

The following points were concluded based on results and discussions;

1. Based on compressive strength test results it is observed that the specimens with Bacillus cereus bacteria in M25 concrete containing OPC and PPC shows increase in strength about 5.05% and 7.64 % respectively at 7 days curing period.
2. Based on split tensile strength test results it is observed that the specimens with Bacillus cereus bacteria in M25 concrete containing OPC and PPC shows increase in strength about 19.72% and 21.26 % respectively 7 days curing period.

3. Based on flexural strength test results it is observed that the specimens with Bacillus cereus bacteria in M25 concrete containing OPC and PPC shows increase in strength about 22.87% and 23.93 % respectively 7 days curing period.
4. Bacterial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and increase in durability of various building materials.

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