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COLLAPSE AND SERVICEABLITY ANALYSIS OF SELF HEALING CONCRETE

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Abstract - *Infrastructures will continue to rely on concrete because of its excellent characteristics, such as easy availability, low cost, long life, and strength, as well as the ease with which it can be used in structural construction via casting. Although it can resist compressive loads, it is vulnerable to cracking under tensile loads. As time goes on, the structure hardens and becomes more brittle, while the moisture content drops as a result of the heat generated during hydration. The consequence of this is that concrete begins to react with water, resulting in corrosion and cracking.''*

This phenomenon occurs on a regular basis, and it has the potential to lead to structural collapse and an increase in maintenance work that is unmanageable. To avoid this, we created a new kind of concrete called Self Healing Concrete to help prevent structural and concrete cracking. We use self-sealing ingredients in this concrete to improve the connection between the concrete molecules and the reinforcing steel. Concrete structures are more serviceable because of the decrease in chemical treatment that results from the self-healing fracture mechanism. This study makes an effort to fill in the gaps. Innovative bacteria-based crack healing concrete has a self healing ingredient that gives it improved crack healing capability. Through microbiological fracture healing activities, this technique improves the structure's strength and longevity while also being environmentally benign. The newest method uses self-healing concrete.

KEY WORDS- *Concrete, Self healing, Compressive Strength, Tensile Strength, Non Destructive Test, Flexural Strength Test. Etc*

1 INTRODUCTION

1.1 GENERAL

In construction, concrete is by far the most often used building material. Despite its adaptability in design, there are a number of drawbacks. ''It's brittle under stress, ductile, and crack-resistant. Various changes have been made from time to time to address the shortcomings of cement concrete as a result of ongoing research conducted throughout the world. The continuing study in concrete technology has led to the creation of special concrete using industrial materials such as fly ash, blast furnace slag, silica fume, metakeolin, etc. considering construction speed, concrete strength, concrete durability, and environmental friendliness.

Microorganism metabolic activities in concrete result in microbial mineral precipitation that improves overall behavior of concrete, according to recent findings. If it happens within or outside of the microbial cell, or even in the concrete, that's possible. Over saturation and mineral precipitation are often the result of bacteria simply changing the chemical composition of a solution. A novel material, bacterial concrete, may be created by incorporating these bio ogical ideas with concrete.

1.2 HISTORY OF MICROBIOLOGY

Bacteria are single-celled prokaryotic organisms that are tiny in size. Bacteria are available in a variety of forms and sizes. "They exist in many kinds of places, from dirt and acidic springs to radioactive waste and the deepest parts of Earth's crust, as well as organic matter and the living bodies of plants and animals.'' Bacteria are a fact of life wherever you look. Most of the world's biomass is formed by bacteria, which may be found in 40 million cells per gram of soil and a million cells per millilitre of fresh water.

Antoine van Leeuwenhoek used a custom-built single-lens microscope in 1676 to discover bacteria for the first time. He dubbed them animalcules and wrote about them in a series of letters to the Royal Society. Christian Gottfried Ehrenberg, a German biologist, coined the term bacteria considerably later, in 1838.

Bacterial cell walls may be classified as either Gram-positive or Gram-negative. Gram stain response names derive from the long-used technique for classifying bacterial species, which uses cells' reaction to the stain. Bacteria are often cultivated on solid or liquid medium in the laboratory. Pure cultures of a bacterial strain are isolated using solid growth medium such as agar plates. Liquid growth medium, on the other hand, are utilized when cell volumes are high or growth has to be measured. It is possible to isolate single bacterium from liquid media when growth occurs as an even cell suspension in stirred medium. This makes dividing and transferring cultures simple. It is possible to detect particular microorganisms by using selective media (medium enriched or lacking in certain nutrients, or media containing antibiotics).

There are three stages of bacterial development. It takes time for bacteria to get acclimated to their new surroundings when they initially enter a high-nutrient environment.

1.3 CLASSIFICATION OF BACTERIA

1.3.1 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).

1.3.2 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.

1.3.3 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).

1.4 VARIOUS BACTERIA USED IN THE CONCRETE

They are broadly classified as follow—

Bacillus pasteurii

Bacillue sphaericus

Escherichia coli

Bacillus subtilis (used in the present study)

1.5 BACTERIAL CONCRETE

V.Ramakrishnan was the first to propose the idea of bacterial concrete. Microbiologically generated calcite (CaCO3) precipitation is used in a new way to repair concrete fractures and fissures. It is a method in the field of science known as biomineralization to use microbiologically induced calcite precipitation (MICP). Calcite precipitation may be induced by a common soil bacteria. Using CaCO3 as a sealer for simulated granite cracks and surface fissures, as well as in the consolidation of sand, showed promising results. Because the calcite precipitation produced by microbial activity is pollution-free and natural, microbiologically induced calcite precipitation is very desired Using this method, fractured concrete specimens may have their compressive strength and stiffness increased.

2 LITERATURE REVIEW

2.1 ADMIXTURES FOR ENHANCING MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE

To improve the dispersion of silica fume, Erich et al. (2012) utilized high-intensity power ultrasound. The result was enhanced compressive strength and improved pore refinement in mortars. Increased particle dispersion caused by sonication increases pozzolanic reactivity. Increasing compressive strength and decreasing permeability were found in the tests. To make CSH gel last longer, the pozzolanic reaction aided in its production.

The mechanical characteristics of high-performance mortar reinforced with steel microfibers were studied by Pierre et al. (1999). Microfiber content ranges from 0% to 5% of the paste volume, while sand to binder ratios range from 0% to 2%. Flexural strength was improved by 2.5 percent with the addition of microfibers. There was an increase in the amount of air trapped in the mortar as the fiber content rose.

There has been research on the use of sludge filler in concrete, and the effects of sludge on the fresh and hardened characteristics of concrete, by Tay (1987). Sludge ash was found to be chemically inert, and workability improved somewhat as a consequence of the experiment. As sludge ash replacement % rose, compressive strength dropped by 28 days. However, the compressive strength was reduced by 10% when sludge ash was replaced with the same amount of ash.

Mineral admixtures such as silica fume, slag, fly ash, and metakaolin were tested on the mechanical properties of young concrete under uniaxial compression and tension stress by Jin and Li (2003). The stress-strain curve of young ductile concrete differed from that of mature concrete. However, when subjected to a uniaxial tensile stress, ductility was significantly reduced. Fly ash concrete with silica fume and calcium nitrate solution was investigated by Li et al. (2000) and found to have an alkali silica reaction. Corrosion was slowed down by the use of a calcium nitrate solution. Cascade correlation method, a neural network idea, was used to make future predictions about this kind of response. Fly ash and silica fume consumed more calcium hydroxide when calcium nitrate solution was added. Porousness was reduced and microstructure was improved in the silica fume/CN solution combination.

3 EXPERIMENTAL TESTES AND THEIR RESPECTIVE RESULT

The tests and methods for evaluating concrete's self-healing mechanism were established based on the literature review. Cement, fine aggregates, coarse aggregates, and admixtures including silica fume and fly ash are standard research materials. The following characteristics are analyzed in order to investigate the mechanical qualities of conventional and admixed concrete:

a) Compressive Strength Test

b) Split Tensile Test

c) Flexural Test , and

d) Non Destructive Test like

I. Schmidth Rebound Hammer Test

II. Ultrasonic Pulse Velocity test

III. Rapid Chloride Permeability Test

IV. Water Absorption Test

V. Cracks width and depth measurement

VI. Chemical Test

3.1 COMPRESSIVE STRENGTH TEST

For concrete compressive strength testing, concrete cubes 150 mm 150 mm 150 mm in size were produced. Cubical, cylindrical, or prismoidal molds may all be used to find this test! The test was performed in accordance with the guidelines in International Standard ISO 516 – 1959. (Reaffirmed 2004). Compressive strength tests were performed using standard M30 concrete cubes with 10 numbers cast at 7, 14 and 28 days. The test results yielded average values, which were then calculated. Three more concrete examples were made to further understand the self-healing process. The first specimen's compressive strength was tested for 28 days. To create a concrete cube with micro fractures, a compressive strength of 80% was computed using that value and then applied to a second specimen using a compression testing equipment. The micro-cracked cube was submerged for a further 28 days to give the specimen time to self-heal . When evaluated for compressive strength 56 days later, the specimen almost equaled the unhealed original specimens' values, which were determined by comparing them to 28-day compressive strength values.

Compressive strength data were initially used to admixture-incorporated specimens to determine the optimal admixture replacement %. 3 cubes of silica fume with replacement percentages of 0%, 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%, 3 cubes of fly ash with replacement percentages of 0%, 5 percent, 10%, 15%, 20 percent, 25 percent, and 30%, 10 cubes with 50% recycled aggregate replacement, and 3 cubes of rice husk ash with replacement percentages of 0%, 5%, 10%, 15%, and 20% After that, ten specimens were cast and tested for compressive strength after seven, fourteen, and 28 days to determine the optimal percentage. A standard method was then used to finish the specimens.

3.2 SPLIT TENSILE STRENGTH TEST

Also known as the Brazilin Test, this is a blood test. Using a universal testing machine (UTM) with steel plates, a compressive load of 2N/mm2/min is given to a cylindrical specimen with a diameter and height of 300 mm and 150 mm till failure. When compressive loads are applied to specimens, only a specific depth (d/6) below the site of application of load develops compressive strains, yet a significant part causes the specimen to split. The biggest benefit of this test is that the concrete's compressive and tensile strengths may be determined using the same specimen and equipment. This test is simple to carry out, and the results are superior because more or less homogeneous tensile stresses occur on the failure plane. According to IS 5816 – 1999, this test was performed (Reaffirmed 2004). At 28 days, a split tensile test was performed on both the standard mix and the optimal replacement mix. When compared to a direct tensile strength test, the results produced from this one are higher, but the flexural tensile strength test shows lower results.

3.3 FLEXURAL STRENGTH TEST

To be able to carry out this investigation If the maximum nominal aggregate size is more than 20mm, a concrete mould with dimensions of (500 mm 100 mm 100 mm) was used; however, if the aggregate size is less than 20mm, a mould with dimensions of (100 mm 100 50 mm) was used. In order to conduct this test, a 5cm mold is placed on top of the material, and each layer is compressed using vibration. When the mold is filled to the brim, it is submerged in water heated to (272)C for 48 hours. A 30cm-diameter roller support is used to hold the sample, which is then withdrawn from the water and put over the roller supports, which are 60 or 40cm apart center to center. As a next step, the sample will be loaded in two places with rollers that have a diameter of 30mm and are spaced 20/13.3 cm apart in the middle, applying a force of 0.7N/mm2/min until failure is achieved. The tension side of the fracture line is then measured along the center line to determine the concrete's bending tensile strength. This was put through its paces according to the protocol outlined in International Standard ISO 516 – 1959. (Reaffirmed 2004). For conventional mix and optimal % replacement mix, a flexural strength test was performed after 28 days Fig. 3. To test the load deflection characteristics and determine the usage of additives to enable self-healing for real-time practical applications, three reinforced beams with dimensions of 1000mm150mm150mm were also cast. There was a flexure test carried out in accordance with IS: 516 – 1959 on the beam and it was developed and manufactured in accordance with IS: 456 – 2000 (Reaffirmed 2004).

3.4 NON DESTRUCTIVE TEST

However, the strength of concrete used in real construction components cannot be determined from the testing that has been done on a representative sample. For this reason, non-destructive tests are used to determine the concrete's strength in real construction components. These tests also provide information about the concrete's properties, such as the presence of voids, fractures, or other defects. Any of the following non-destructive test techniques may be used.

3.4.1 Schmidth Rebound hammer test

There will be an impact test that involves moving a spring-controlled plurger within a tubular casting casing over a rebound-hammer with a mass that can rebound. A hammer is used to hit a concrete surface to be tested, and a release button is pushed to induce the rebound mass to contact the concrete surface. The displacement of the rider is then measured across a scale to determine how much concrete is there based on the parameter rebound number.. There are many variables that may affect the test's outcome.

- smoothness of the surface under consideration
- internal and external moisture condition
- age of the concrete
- shape, size and rigidity of the member
- type of cement and coarse aggregate used

3.4.2 Ultrasonic Pulse Velocity Test

Because sound velocity in materials relies on both modulus of elasticity and density, this test's concept is based on that fact. A transmitter and a reclever are used in this experiment. ''To determine the quality of the concrete, the time it takes for a pulse to travel a certain distance in a concrete sample is measured and utilized as follows." First, a 28-day curing period was followed by an 80 percent preloading period, and finally, a healing period. The results of the ultrasonic pulse velocity test are shown in Figure 3.6 To ensure accuracy, the test was conducted in accordance with IS 13311 (Part 1) – 1992. (Reaffirmed 2004). Also, the test's outcome is influenced by many variables.

- percentage of reinforcement in concrete
- temperature during the test
- internal and external moisture condition
- smoothness of the surface under the test

Table 1 Standard value of UPVT for different quality of concrete

Velocity of pulse (km/sec)	Quality of Concrete
< 4.5	Excellent
3.5 - 4.5	Good
3 - 3.5	Moderate
< 3	Doubtfull

3.4.3 RAPID CHLORIDE PERMEABILITY TEST

Rapid Chloride Permeability Test and water absorption test were used to evaluate the long-term durability of

concrete specimens with respect to the self-healing mechanism.

To begin, RCPT was performed after 28 days, then after 80 percent preloading, and finally after 56 days (i.e. after healing) in accordance with ASTM C 1202 – 12's standard protocol.

3.4.4 WATER ABSORPTION TEST

For a high grade of concrete with low permeability, especially one that is resistant to freezing and thawing, this is an essential property. a low-strength concrete. When water is allowed to pass through, the permeability of the material prevents it from freezing and spilling. The cement paste and aggregate both have pores through which water may get in. This was done in accordance with ASTM C 642 – 97, which calls for a 28-day water absorption test, followed by an 80-percent preloading test and another 56-day test after healing.

3.4.5 CRACK WIDTH AND DEPTH MEASUREMENT

Based on a review of the literature, tests were performed only to determine the healing capability. Two 500 mm 100 mm 100 mm Prisms were cast for each mixture, and one was examined for flexure after 28 days. The second specimen had fractures generated based on the flexural strength test results. With the aid of a UPVT and a microscope, researchers assessed the crack's breadth and the crack's depth. "The fracture was kept to a maximum of 3 mm in width Fig.." They were then submerged in water for a period of time to allow the body's own healing mechanisms to kick in. The specimens were retested for UPVT 56 days later to determine the crack's breadth Fig. The fracture depth was also examined using a microscope to assess the internal self-healing mechanism's capacity to close the crack. Each admixture's healing time for three millimeter fractures was also recorded.

4 RESULTS AND EXPERIMENTS

Test were performed in accordance with IS: 4031-1988 (Reaffirmed 2005) and IS: 1199-1959 to determine the physical properties of binders (ordinary portland cement, silica fume, fly ash, and Rice Husk Ash), such as colour, specific gravity, soundness, fineness, consistency, and initial and final setting times, water absorption and slump values (Reaffirmed 2004). Fine aggregate, coarse aggregates and admixture, and admixture specific gravities and water absorption are all analysied.

OPC mix tested to have a compressive strength of 41 MPa, whereas other mixes tested to have compressive strength values of 42 MPa, 49 MPa, 41 MPa and 45 MPa had different findings. Excellent particle packing effect provided good compressive strength values as nominal mix for the additive that replaced previous mixes. Replaced mixtures that included fly ash and rice husk ash had greater compressive strengths than mixes that had the nominal amount of each. To ensure sustainable building methods, admixtures such as silica fume and fly ash may be utilized successfully in practice. Recycled aggregates and rice husk ash can also be used in place of silica fume.

5. CONCLUSIONS

OPC mix had the highest split tensile strength of 2.38 MPa, whereas silica fume, fly ash, recycled aggregates, and rice husk ash mixes all yielded values of 2.02, 2.02, 2.04, and 2.08, respectively (see split tensile strength data). As a nominal mix, the admixture that replaced the original mixtures had excellent split tensile strength ratings. The split tensile value of the new mix, which included 25% fly ash instead of the usual 50%, was almost identical to the old mix's. As a result, admixtures such as silica fume, fly ash, recycled aggregates, and rice husk ash may be utilized effectively to provide excellent tensile strength characteristics to concrete without sacrificing tensile strength features.

The standard M30 mix's 28-day flexural strength test resulted with a value of flexure values of 4.54 MPa, 4.88 MPa, 4.41 MPa, and 4.56 MPa were obtained by substituting 12.5% silica fume, 25.5% fly ash, 50 percent recycled aggregate, and 15 percent rice husk ash for the original mix. Results showed that as a nominal mix, the admixture-replaced mixes had excellent flexural strength characteristics.

Based on standard OPC mix UPVT findings, a mix comprising silica fume, fly ash, recycled aggregates, and rice husk ash, it was apparent that the specimens were able to recover their original UPVT values owing to the process of self healing. After healing, the UPVT value of the silica fume mixture increased from 5.0 km/sec to 5.4 km/sec. Like fly ash mix, the starting value of rice husk ash mix was set at 4.7 km/sec and the UPVT value was set at 5.2 km/sec after the mixture was healed. However, in comparison to their initial values, the silica fume and fly ash blends had greater UPVT values, whereas the latter two blends, because to the strong internal self-healing effect, were able to return to their original UPVT values as well.

According to compressive strength findings after healing, the strength of the standard OPC mix was 41 MPa, whereas the strength after healing was 47 MPa for silica fume, 52 MPa for fly ash, and 49 MPa for rice husk ash mixes. When tested, it was shown that silica fume and fly ash mixtures had the capacity to restore their original compressive strength values after micro-cracks had been internally healed. To see whether silica fume, fly ash, and rice husk ash mixtures had greater compressive strength after healing, the original uncracked specimens were compared.

According to OPC, silica fume, fly ash, recycled aggregates, and rice husk ash mix water absorption test findings, the water absorption values reduced owing to the healing response in the specimens and matched the original specimens' values. Uncracked initial specimens had much lower water absorption when rice husk ash replaced the mix. Even after the wound had healed, the rice husk ash mixture still had a lower water absorption value than the control group had. Due to its fine particle composition, rice husk ash may successfully be used as an additive in concrete, resulting in denser concrete due to the particle packing effect.

If you compare all of the 56-day RCPT values of un-cracked and healed specimens of all of the mixtures, the initial RCPT values of OPC and silica fume mixtures to fly-ash, recycled aggregate, and rice-husk-ash mixtures, you'll find that they were 3329, 416, 782, 3104, and 617 coulombs, respectively. Healed specimens' RCPT readings came back at 3350 coulombs.

As the chloride penetration value decreased significantly, other mixtures had lower RCPT values. Because the particles were so tiny, the mixtures packed well, resulting in denser concrete. In comparison to conventional mix and recycled aggregate mix, the initial chloride permeability of admixture-added specimens was significantly lower due to denser concrete. RCPT values of healed specimens showed lower values after healing owing to excellent hydration response and healing product production, and the values were in line with the original ones. The crack width and depth measurements of all mixes after healing revealed that the un-hydrated binder particles present in the concrete mix reacted further to produce CSH gel or portlandite depending on the activity of silica, thus closing the fissures. Internal healing action allowed all the mixtures to close the 3 mm crack breadth and depth in the same amount of time. For OPC mix and recycled aggregate mix, the number of days required for full crack healing was much longer due to the active involvement of silica contained in additives such silica fume, fly ash, and rice husk ash.

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