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Experimental Survey on Self-Sensing Concrete

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ABSTRACT
Traditional concrete is strong in compression but not so much in tension. When exposed to external conditions, typical concrete is readily broken. Self-healing microorganisms are put to the concrete to undertake biological restoration. Bacillus Subtilis, a self-healing microbe, was employed in this study. They are calcite-forming bacteria that produce precipitates in fractures when they come into contact with water. To make the structure more cost-effective, waste materials are also utilised in this project. Concrete is made by replacing cement with fly ash and sand with brick powder. The materials employed in this study are M30 concrete and Fe415 steel. In this study, 0 percent, 15%, and 30% replacement materials will be used, as well as the inclusion of self-healing bacteria as an admixture. The examples of these varied proportions will be cast, and the outcomes will be compared to standard concrete. The goal of this study is to develop a crack-resistant concrete that is also cost-effective. The usage of waste material reduces both the cost and the amount of garbage produced. The use of self-healing microorganisms in this study results in physiologically crack-proof concrete.
Key words: Biologically crack proof concrete,calcite,and self-healing bacteria.

I.INTRODUCTION

1.1 GENERAL

Because of its great compressive strength, low cost, and other advantages, concrete is the most extensively used construction material. Concrete's vulnerability to fracture development as a result of its low tensile strength is one of its disadvantages. As a result, to handle tensile stresses, concrete is frequently coupled with steel reinforcing. Although these rebars limit crack width, they are rarely designed to prevent crack development entirely. Cracks put the longevity of concrete buildings at jeopardy because hostile liquids and gases can seep into the matrix and cause damage. As a result, fractures may widen and reinforcement may get exposed to the elements. If the

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reinforcement begins to deteriorate, the building may collapse completely. As a result, it appears self-evident that concrete crack inspection, maintenance, and repair are all required. When cracks aren't visible or accessible, however, crack restoration becomes more challenging. Furthermore, repair expenditures account for half of the yearly building budget in Europe. In addition to the direct expenditures, secondary costs such as lost productivity and traffic bottlenecks have a significant economic impact. As a result, self-healing of broken concrete would be extremely advantageous. Concrete's innate autogenous healing qualities cause it to self-heal, which is an old and well-known phenomena. Autogenous healing, on the other hand, is restricted to small fractures, only works when water is present, and is difficult to manage.

Concrete is a building material that is utilised all over the world due to its superior qualities. However, because of its poor tensile strength, this material is susceptible to cracking. Concrete buildings are well-known for cracking, which allows chemicals and water to enter and damage the concrete, lowering the structure's functionality and necessitating expensive maintenance in the form of repairs. In this paper, the following noteworthy points about bacteria are observed and identified from other research works: classification of bacteria, self-healing of cracks in concrete, chemical process for crack remediation, self-healing mechanism of bacteria, application of bacteria in construction field, advantages and disadvantages of bacterial concrete, and so on. Because cracks are responsible for the transportation of liquids and gases that might potentially contain harmful chemicals, cracking in the surface layer of concrete affects its durability. The concrete constructions, on the other hand, exhibit some self-healing potential, i.e. the ability to mend or seal newly generated micro-cracks.

When exposed to strain, traditional concrete has a flaw: it cracks. Civil Engineering has been working on a healing agent that works when bacteria implanted in concrete transform nutrients into limestone. Concrete structures are currently constructed according to specified standards that allow for cracks up to 0.2 mm in width. Micro fractures of this nature are normally seen as acceptable because they do not immediately compromise a structure's safety and strength. Furthermore, because many varieties of concrete have a crack-healing potential, tiny fissures can occasionally mend on their own. Ingress water interacts with these particles during crack development, causing tiny fissures to close. Water leakage as a result of micro crack development in tunnel and subterranean structures might occur, however, due to the diversity of autonomous crack healing of concrete constructions. While self-healing of 0.2 mm wide fissures occurred in 30% of the control samples, all bacteria-based samples had full closure of all cracks. Furthermore, the latter group's fracture sealing ability was found to be enhanced to 0.5 mm cracks.

II.METHODOLOGY

The various supplies required were gathered and kept on hand. To avoid water absorption by the concrete mix, all ingredients, excluding cement, must be used in a Saturated Surface Dry state based on a 24-hour submersion in potable water.

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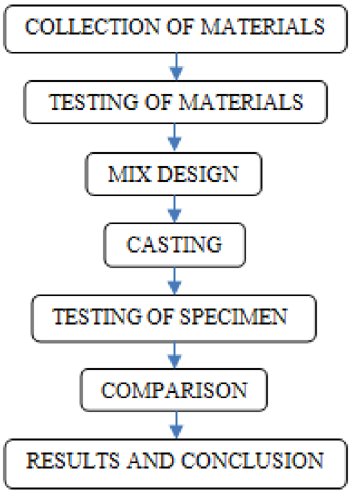

Fig 2.1 Flow Chart for Methodology

With a water cement ratio of 0.38, the requisite water for mixing was obtained. By weight, cement, sand, and aggregates are proportioned 1:1:2.43.

III.CONCRETE INGREDIENTS

Concrete is a very durable and moldable building material. Concrete has the ability to harden and increase strength over time. The various components of smart concrete are listed and explored in the following sections.

3.1 CEMENT

OPC is divided into three classes by the Bureau of Indian Standards (BIS). The categorization is primarily based on the compressive strength of cement-sand mortar cubes with a face area of 50 cm2 that are made up of 1 part cement to 3 parts standard sand by weight, with a water-cement ratio determined according to a formula. The grades are as follows: I 33, (ii) 43, and (iii) 53. The grade number is the minimum compressive strength of cement sand mortar in N/mm2 after 28 days, as determined by the technique described above. Ordinary Portland Cement is the binding element in concrete. Calcium silicate sand, aluminates sand, and alumina ferrite make up ordinary Portland cement. It is made by pulverising and heating preset proportions of lime stone clay and other ingredients in limited quantities at high temperatures – approximately 1500°C – to make clinker. The clinker is subsequently pulverised with modest amounts of gypsum to form Ordinary Portland Cement [OPC], a fine powder. When combined with water, sand, and stone, it creates a unique texture. It slowly reacts with water to make concrete, a hard substance. Cement is a hygroscopic substance, which means it absorbs moisture and performs a chemical process known as hydration when exposed to moisture. As a result, as long as cement does not come into touch with moisture, it will remain in good shape. If the cement is older than three months, it should be tested for strength before being used. For experimental purposes, this cement comes in 53 grades that comply with IS 456-2000. Cement was tested in the lab for specific gravity, consistency, beginning and final setting times, and fineness. Cement's compressive strength is tested using a casting cube and a compressive testing equipment. This cement should be kept cold and dry in a cool location.

3.2 FINE AGGREGATE

Fine aggregate is defined as material that passes through a 4.75 IS sieve. River sand was employed as the fine aggregate throughout the experiment, adhering to IS 383(part 3):1970 grading zone II. Fine aggregate should have a specific gravity of 2.7 or less. It has been discovered that sand with a fineness modulus of less than 2.5 provides the greatest workability and compressive strength in concrete, whereas sand with a fineness

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modulus of around 3.0 provides the best workability and compressive strength.

3.3 COARSE AGGREGATE

River gravel or crushed stone should be used as the coarse material for the project. Aggregate with an angular form and a diameter of 20mm or less. Coarse aggregate is defined as material that passes through a 75mm screen and retains a size of 4.75mm or less. It should be firm, powerful, thick, long-lasting, devoid of clay or loamy admixtures, and clean. Before usage, aggregates should be thoroughly screened and, if necessary, cleaned clean. The grading of coarse aggregates should follow IS 383-1970 requirements. A previously dried sample of coarse aggregate should not grow more than 5% in weight after being immersed in water for 24 hours.

3.4 WATER

Concrete may be made from water that is safe to drink. For mixing concrete and curing the test specimen, the college provided potable, clean drinking water. The hydration of cement and the shaping of concrete to the appropriate shape both require water. Compressive strength and water cement ratio have a well-established connection. The compressive strength increases as the water cement ratio decreases.

3.5 FLY ASH

Fly ash is the byproduct from the burning of pulverised coal that is collected from the flue gases of thermal power plants using mechanical or electrostatic separators. The spherical shape of the particles in fly ash is one of its most distinguishing features. This particle form enhances flowability while lowering water consumption. Low calcium class F. Ash is characterised by a low specific gravity, homogeneous gradation, and lack of flexibility in this study. The specific gravity of ash particles varies depending on chemical composition, although it typically ranges from 2 to 2.6, with an average of around 2.2. Fly ash has a pH range of 8 to 12 when it comes into contact with water. On a global scale, coal-fired power plants produce millions of tonnes of trash each year, including fly ash, bottom ash, boiler slag, and flue gas desulphurization sludge. ASTMC618 defines two types of fly ash for use as a mineral filler in asphalt: Class F and Class C fly ash. The quantity of calcium, silica, alumina, and iron in the ash is the main distinction between these classes. The chemical composition of the coal burnt has a significant impact on the chemical characteristics of the fly ash.

3.5.1 CLASS F – FLY ASH

Class F fly ash is produced by burning tougher, older anthracite and bituminous coal. This fly ash is pozzolanic, which means it contains less than 20% lime (Cao). Because Class F fly ash has pozzolanic qualities, it requires the addition of a cementing agent, such as Portland cement, quicklime, or hydrated lime, together with the presence of water, in order to react and generate cementitious compounds.

3.5.2 CLASS C- FLY ASH

In addition to pozzolanic qualities, fly ash formed from the combustion of younger lignite or subbituminous coal contains some self-cementing capabilities. Class C fly ash will harden and develop strength over time if exposed to water. In most cases, Class C fly ash includes more than 20% lime (Cao). Self-cementing Class C fly ash does not require an

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activator, unlike Class F. Class C fly ashes include greater levels of alkali and sulphate (SO4).

3.6 BRICK POWDER

The debris produced by the burning of clay bricks in brick kilns is known as brick powder. It has an excellent pozzolanic quality. Brick bats were crushed into a coarse powder and used as fine material in concrete. Waste bricks from a demolished structure were gathered and crushed to obtain particles that passed a 4.75 mm screen and were kept on a 0.075 mm sieve to get fine aggregate grading. In the trials, 10%, 20%, and 30% brick powder were utilised to substitute sand.

3.7 MICRO-ORGANISMS

For concrete crack restoration, Bacillus subtilis, a model laboratory bacterium, is employed. Bacillus Subtilis, popularly known as the hay bacillus or grass bacillus, is a bacteria found in soil and the human gastrointestinal tract. Bacillus subtilis is a rod-shaped Bacillus species that produces a strong, prolific endospore that allows it to withstand harsh environmental conditions. It is the most well-studied gram-positive bacterium and a model organism for bacterial chromosomal replication and cell differentiation research. Self-healing concrete fractures would extend the service life of concrete structures, making the material not only more durable but also more sustainable.

IV. CASTING AND CURING OF CUBES

4.1 CASTING

Casting is a manufacturing method in which a liquid substance is poured into a mould with a hollow hole of the required shape and solidified. To finish the process, the solidified portion, also known as a casting, is expelled or broken out of the mould. Epoxy, concrete, plaster, and clay are examples of casting materials that cure after combining two or more components together.

4.1.1 MOULDS:

It is necessary to use metal moulds, ideally steel or cast iron, that are thick enough to avoid deformation. The height of the mould and the distance between the opposing faces are both +0.2mm. The angle between adjacent internal faces, as well as between internal faces and the mold's top and bottom planes, must be 90o +0.5o. The mould's internal faces are planar surfaces with a maximum vibration of 0.03mm. A metal base plate with a flat surface is included with each mould. The base plate should be large enough to hold the mould without leaking during the filling process, and it should be attached to the mould via springs or screws.

Fig.4.1Cube Mould

To guarantee that no water escapes during the filing, the joints between the parts of the mould are thinly coated with mould oil, and a similar coating of mould oil is put between the contact surface of the bottom of the mould and the base plate. To avoid concrete adhesion, the

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inside surfaces of the constructed mould must also be lightly coated with mould oil. A tamping bar is a steel bar with a 16mm diameter, 0.6m length, and a bullet pointer on the bottom end.

4.2 COMPACTING

The cube specimens are constructed as soon as possible after mixing and in such a way that the concrete is fully compacted with no segregation or excessive laitance. The concrete is poured into the mould in five-centimeter-deep layers. Each layer is either crushed by hand or vibrated. The surface of the concrete is made to be completed level with the top of the mould using a trowel after the top layer has been compacted. Solids, water, and air are all present in green concrete. It is necessary to remove the entrapped air from the concrete mass while it is still in a plastic stage in order to make it impermeable and achieve its optimum strength. If the air isn't totally evacuated, the concrete loses a lot of strength. It has been shown that 5% vacancies diminish strength by roughly 30%, while 10% voids lower strength by more than 50%. Compaction removes air bubbles and forces fine material to the surface and against the forms, resulting in the desired polish. Steel rods, paddle sticks, and tampers can be used as hand tools, although mechanical vibrators are the best. Any compacting device must be tiny enough to pass between reinforcing bars and reach the bottom of the form. Because the strength of the concrete component is dependent on adequate reinforcement placement, avoid dislodging the reinforcing steel. Iron rods are used to compact reinforced concrete construction, which is highly crucial. The thickness of the concrete layers should be greater than 15 cm in this scenario. The most effective approach for effectively compacting concrete is to consolidate each layer individually so that its top surface is level and fairly smooth before adding the next. When tamping, take care to ensure that the rod penetrates the whole layer of the last layer put, as well as some of the laying, to create a proper link between the bonds. Second, the reinforcement and formwork must not be moved from their original placements. When compacting concrete, it's important to keep the phenomena in mind. Whether compaction is accomplished by ramming or vibration, the goal is to remove entrapped air from the concrete until it has reached the closest configuration feasible for a given mix.

4.2.1. COMPACTING BY HAND:

When compacting by hand, the normal tamping bar is utilised, and the bar's strokes are evenly dispersed over the cross section of the mould. Depending on the kind of concrete, the number of strokes per layer necessary to achieve the specimen conditions varies. In the case of cubical specimens, no fewer than 35 strokes per layer for 15cm cubes and beams, or 25 strokes per layer for 10cm cubes and beams should be used.

Fig. 4.2.1 Compaction bar

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4.3 CURING

Curing is defined as the preservation of a suitable environment for the continuation of chemical processes, such as the retention of moisture inside the concrete or the provision of moisture to the concrete from an external source, as well as protection from temperature extremes.

Fig.4.3 Curing Of Cubes

V. EXPERIMENTAL ANALYSIS

5.1 SLUMP TEST

The slump test is used to assess whether or not new concrete is workable. The Slump Test, as defined by IS: 1199 - 1959, is used. Slump cone and tamping rod are the tools used in slump testing. The slump test is the most extensively used, owing to the ease of the needed apparatus and the test technique. The slump test shows how a compacted concrete cone behaves when subjected to gravity forces. The test is performed using a slump cone mould that is filled with three equal layers of new concrete and tamped 25 times using a normal tamping rod. The top layer is levelled, and the mould is lifted vertically without causing any damage to the concrete cone.

Fig 5.1 Slump Cone Apparatus

During the test, the slump should be quantified in millimetres of sinking of the specimen. Any slump specimen that collapses or shears off laterally yields an inaccurate result, and the test should be redone with a new sample if this happens. If the specimen shears again in the repeat test, the slump should be measured and the fact that the specimen sheared documented. This is a site test that is always performed by the supervisor on site to verify the workability of the ready mixed concrete immediately before it is placed in its final location inside the formwork. However, if the site supervisor notices that the green concrete has dried out or that the concrete placement has been halted during the concreting process, a re-test on the remaining concrete, particularly the pour for the crowded reinforcing region, should be undertaken. The slump test equipment mainly consists of a metallic mould in the shape of a frustum of a cone with the inside dimensions as follows: The bottom diameter is 20 cm, the top diameter is 10 cm, and the height is 30 cm. The copper sheet used in the mould should not be less than 1.6 cm thick. Suitable guides for

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raising vertically up are sometimes included with the mould. A steel tamping rod with a bullet end and a diameter of 16 mm is used to tamp the concrete. Before starting the test, the inside surface of the mould is completely cleaned and free of excess moisture and adhesion of any old set concrete. The mould is then filled in four layers, each one a quarter of the height of the mould, with each layer tamped 25 times using a conventional tamping rod, taking care to equally distribute the strokes over the cross section. The concrete is knocked off level using a trowel and tamping rod after the top layer has been rodded. The mould is immediately removed from the concrete by gently and carefully elevating it vertically. Concrete was able to settle as a result of this. Concrete slump is the term for this type of sinking. The level difference between the mold's height and the highest point of the subsiding concrete is measured. This difference in height is measured in millimetres and is referred to as concrete slump.

Table 5.1 Slump value

% of Fly	ml of bacteria	Slump Value
0%	30 ml	87 mm
15%	30 ml	78 mm
30%	30 ml	74 mm

5.2 COMPRESSION STRENGTH TEST

The strength of hardened concrete, which symbolises the capacity of concrete to withstand pressures, is one of its most essential qualities. Compressive strength is defined as the ability of a force to compress another object. The compressive strength of hardened concrete is often regarded as the most essential feature, and it is frequently used as a barometer of the material's overall quality. Most of the other qualities of concrete that are directly connected to the structure of hardened cement paste may be inferred from strength. A stronger concrete is thick, compact, impermeable, and weather and chemical resistant. A stronger concrete, on the other hand, may have greater drying shrinkage and cracking as a result of the larger cement concentration. Compressive strength is also linked to other desired features like as shear and tensile strengths, modulus of elasticity, bond, impact, and durability. Because compressive strength can be easily evaluated on standard sized cubical or cylindrical specimens, it may be used as a criteria for determining the impact of any variable on concrete quality.

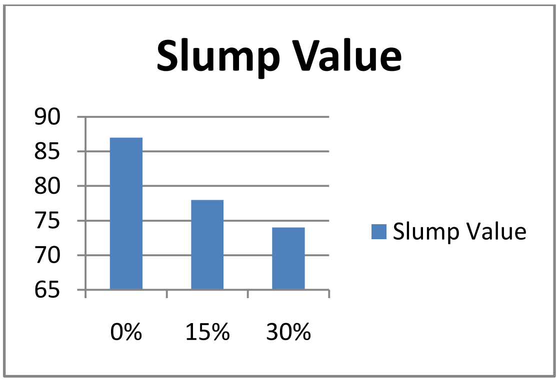

Fig 5.2 Slump Value of tested specimen

Under various testing settings, however, the concrete offers varied values for every attribute. To minimise variances in test results, the technique of testing, the size of the specimen, and the rate of loading are all specified while testing the concrete. For describing the quantitative value of any given attribute of hardened concrete, statistical approaches are typically applied. The cube specimen is 150 x 150 x 150 mm in dimension. 10 mm size cubes can also be used as an option if the maximum nominal size does not exceed 20 mm.

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5.2.1 COMPRESSIVE STRENGTH OF CONCRETE

The capacity of a material to endure axially directed pressing pressures is described as compressive strength. The compressive test creates a more complicated stress system. Because of the poisson's ratio effect, the cube expands laterally under compression force.

- The tests are carried out in a compression testing machine for 7, 14, and 28 days, and the load bearing capability is recorded.
- Using the formula, the compression strength is determined and tabulated.
- Compression strength = $\frac{load}{crosssectionalarea}$

Fig 5.3 Cube placed on the CTM

% of Fly ash	7 days curing		14 days curing		28 days curing	
	Load (KN)	**Compressive Strength (Mpa)**	**Load (KN)**	**Compressive Strength (Mpa)**	**Load (KN)**	**Compressive Strength (Mpa)**
0%	13.6	40.2	13.7	40.6	16.2	48
15%	65	19.2	68	20.2	83	24.6
30%	23	6.6	29	8.6	38.8	11.5

Table 6.1 Compressive strength analysis

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VI.RESULT AND DISCUSSION

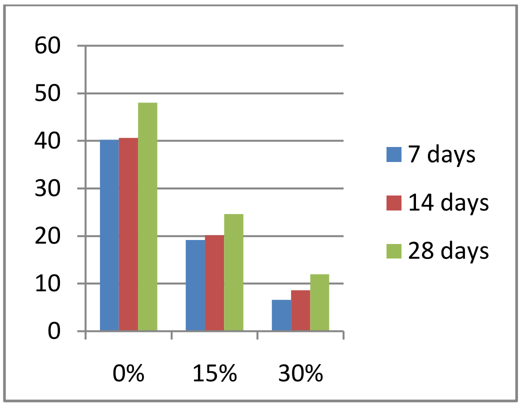

Fig 6.1

We can see from the graph above that our M30 grade smart concrete has a better compressive strength when 30ml of bacillus subtilis is added to the mix instead of Fly ash.

VII. CONCLUSION

The following conclusion is reached based on the current experimental investigation:

- Bacillus subtilis can be safely and cost-effectively generated in the laboratory.
- When 30 ml of bacillus subtilis bacteria is added, no cement is replaced by flyash, and fine aggregate is partially replaced by brick powder, the compressive strength reaches 48 MPa.
- Because of its eco-friendly nature and ease of use, Smart concrete technology has shown to be superior to many conventional technologies.
- This cutting-edge concrete technology will soon serve as the foundation for a new generation of high-quality structures that are both cost-effective and ecologically friendly.

The use of microbial concrete in building might ease certain present construction processes while potentially revolutionizing new construction methods.

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