An Experimental Investigation on Self-Healing Concrete Incorporating Marble Dust as Fine Aggregate Replacement

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ABSTRACT:

Concrete plays a vital role as a construction material in the world. New technologies have helped to develop new types of construction and alternative materials in the concrete area. As society makes determined moves towards sustainability, construction has a very important role to play within this new agenda, not only because of its economic and social contribution, but also because of its impact on the quality of our lives, our comfort and safety. This project presents the results of an experimental investigation carried out to evaluate the influence of Bacillus Subtilis and Bacillus Licheniformis on the compressive strength, water absorption and its self-healing properties. An attempt is made to heal these cracks by the addition of the bacteria in the concrete and also to increase of the strength of the concrete. Each bacteria of concentration are added. Tests were performed at the ages of 7, 28 and 56 days. The applicability of specifically calcite mineral precipitating bacteria to fill the cracks in concrete and the bacteria chosen must have the self-healing capacity and the bacteria used must be nonpathogenic and sustainable. It is found that the cracks in the concrete have been healed and the formation of calcite precipitation is observed using Scanning Electron Microscopy (SEM). In thepresent project here is an attempt made to fill the cracks with the help of bacteria which has a self- healing property along with fine aggregate as marble dust. The potential bacteria are isolated and cultured. The optimum parameter will be considered and the bacterial liquid is being coated on cracked surface of concrete and the variation in the strength and the durability characteristics willbe studied. Calcite formation of isolated bacteria which can produce calcite precipitates on suitable media supplemented with a calcium source. Usage of bacteria like Bacillus Subtilis, Bacillus Licheniformis improves the strength and durability of concrete through self-healing effect.

I. INTRODUCTION

The worldwide utilization of cement is second just to water. As the interest for concrete as a development material increments, so additionally the interest for Portland bond. Concrete is a sturdy development material delivered by blending Portland bond, water, totals and added substances with uncommon extent. Updating the fixings and creation technique for ordinary cement is vital as for high utilization of concrete as a development material. Concrete as a champion among the most ordinarily used improvement materials, expect akey part in numerous fields. It has been extensivelyused as a piece of the improvement of structures, dams, storing tanks, sea ports, lanes, ranges, tunnels, cable cars and distinctive systems. Concrete is for the most part a mix of water, absolute (coarse and fine), and bond. Bond is the most basic bit of the strong material. It ties the sums and fills the voids among coarse and fine particles. High compressive quality, availability, sturdiness, and furthermore great lead with fortress bars, low esteem, clear arranging and believability of tossing in needed shapes and sizes settle on cement the material of choice for a few applications. Despite strong's ideal conditions it hasa high penchant to outline parts empowering compelling synthetic substances to go into the structure.

PROBLEM STATEMENT

Cracking

Definition: an entire or inadequate partition of either concrete or brick works into at least twosections delivered by breaking or fracturing. Cracksare sorted as happening either in plastic concrete or solidified cement. The reasons for each kind of breaking rely upon a wide range of variables, and may influence appearance just, or they may show noteworthy basic pain or an absence of toughness. Breaks may speak to the aggregate degree of the harm, or they may point to issues of moreprominent size. Reasons for breaking include: plastic shrinkage splitting; settlement breaking; drying shrinkage; warm burdens; substance response; weathering; consumption of support; poor

development hones; development over- burdens; blunders in plan and itemizing; and remotely connected burdens

Types of cracks in Concrete Structures

- Structural Cracks in Concrete
- Non Structural Cracks in Concrete

Various types of Concrete Crack Repair Methodologies:

- Stitching
- Muting and sealing
- Resin injection
- One of the techniques is self-healing i.e. bio-concrete

CONCEPT OF BIO MINERALIZATION

Bio mineralization alludes to the procedure of mineral arrangement by living beings which is a broad marvel in nature. Bio mineralization can be expert through organically actuated mineralization process. Naturally prompted mineralization normally happens in an open domain as anuncontrolled result of microbial metabolic movement. In this procedure bio minerals are framed through response of metabolic items produced by microorganisms with the encompassing condition. Bacterial structure and a schematic chart of calcium carbonate generationare appeared in Fig.

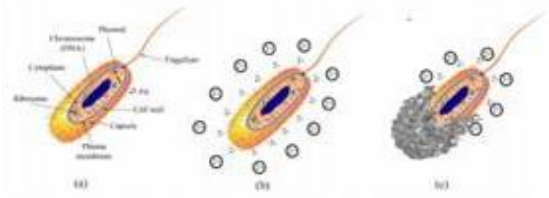


Fig.: (a) Bacteria structure; (b) Negative charged cell wall and presence of positive charged ions; (c) Bio mineral production by means of binding ions to cell wall

APPLICATIONS:

- The utilization of bacterial cement has turned out to be progressively prevalent. It is utilized for construction in new era.
- Repairing of landmarks developed in limestone.
- Healing of solid splits
- Used for development of - minimal effort toughstreets

SCOPE & OBJECTIVE OF THE PROJECT

- Increase a bacterial concrete by introducing the microorganisms of bacillus own family(bacillus subtitles).
- to locate the surest dosage of bacteria required for bacterial concrete
- To decide the viable bacterial cells by using serial dilution technique.
- To understand the presence of voids viaultrasonic pulse speed test.
- To recognize the presence of voids in the internal shape of concrete via sem.
- Take a look at the behavior of microorganism chemically.
- In the experimental work we choose marble dust as partial replacement of fine aggregate
- Study the trade in the properties of concrete consisting of compressive power andpermeability.
- To take a look at the effect of various concentrations of microorganism on thesturdiness of concrete.
- to study the efficiency of microorganism while suspended in unique mediums

II. LITERATURE REVIEW

- In his study, Bahar Demirel examined the impacts of utilizing waste marble dust as a fine material on the mechanical properties of the solid and observed that the addition of waste marble dust would replace the fine material passing through a 0.25 mm sieve at particular proportions displayed an enhancing effect on compressive strength.

Some test results indicated that thereplacement of natural sand by granite powder waste up to 15% of any formulation was favorable for the concrete making without adversely affecting the strength and durability criteria.

- The results suggested that the marble powderis appropriate for the definition of high performance concrete (HPC) and their properties are essentially better contrasted withthe reference concrete. The optimized strength value of concrete was achieved for bothcompressive as well as split tensile strength at 9% metakaolin and 10% marble powder. Intheir study of seven different concrete mixtures, authors investigated the partial replacement of cement and sand by waste marble powder and results found satisfactory.

A detailed cost analysis study was also performed to justify the use of marble powder in concrete which exhibited encouraging results in terms of strength and quality. Cement was replaced with ground granulated blast furnace slag, metakaolin and silica fume. The durability studies such as resistance against sulphate attack, water absorption and sorptivity were done to evaluate the suitability of mineral admixtures. The authors concluded that self-compacting concrete could be produced with supplementary cementitious materials without compromising on durability. The authors suggested that the pozzolanic reaction and the development of the microstructure of the concrete through the use of waste materials are largely responsible fromthe advances in the durability of concrete.

- Boukhelkhal A. et al. have studied the effect of incorporating the marble powder as a supplementary cementations material on the rheological and mechanical properties of self- compacting concrete. Here the authors had found that using of marble powder in self-compacting concrete enhances their fresh properties and at hardened state decreases the mechanical strengths. The authors also found that the self-compacting concrete containingwaste marble powder subjected to magnesium sulfate attack presented a lower expansion and higher resistance to sulfate aggressions.
- Haris H. et al. have studied the strength properties such as compressive strength, split tensile strength, flexural strength, shear strength and the effect on the strength of concrete when it was subjected to sulphate attack. From their study it was found that the basalt fibre increased strength of concrete even when subjected to sulphate attack gradually as compared to conventional concrete

III. MATERIALS AND METHODOLOGY

CEMENT

Concrete can be characterized as the maintaining cloth having firm and cement residences which makes it capable of be part of the diverse improvement substances and shape the compacted get collectively. Portland stone is white dim limestone in island of Portland, dorset. in this trial forty three evaluate traditional Portland concrete is applied. the trying out of concrete is achieved according to is code the particular gravity of bond determined is 3.10.

FINE AGGREGATES

Those particles passing the 9.5 mm (3/8 in.) strainer, all around passing the 4.75 mm (No. 4) strainer, and dominatingly held tight the 75 µm(No. 200) strainer are called fine aggregate. In this examination the locally accessible sand is utilized and the specific gravity of fine full scale is finishedby utilizing the IS 2720 territory 3 code. The particular gravity is discovered 2.62. The fine wholes utilized which encounters the 4.75mm sifter.

Marble Dust (Fine Aggregates)

Marble dust was obtained from the marble processing industry. The chemical composition of marble dust XRD spectrum indicates that magnesium calcium bi(carbonate) ($MgCa(CO_3)_2$) and calcium magnesium aluminum catena-alum silicate are the main crystalline minerals present in marble dust.

The specific gravity of marble is 2.577. Local available Marble powder used as Partial replacement of fine aggregate in concrete.

COARSE AGGREGATES

Coarse aggregate have a wide gathering of headway applications since they take after standardshake particles, instead of fine signify which significantly more energetically look like sand. Coarse totals are a pivotal piece of different enhancement applications, from time to time utilized solely, for example, a granular base put under a region or dark best, or as a section in a blend, for example, dull best or solid blends. The particular gravity is discovered 2.84. The course signifies which are utilized of 20mm size.

Bacteria

In this examination the bacillus pasteuriimicroorganisms is utilized .Sporosarcinapasteurii in the past known as Bacillus pasteurii from dynamically settled consistent plans is a bacteriumwith the capacity to enliven calcite and harden sandgiven a calcium source and urea, through the system of microbiologically incited calcite precipitation or ordinary cementation. Bacillus pasteurii has been proposed to be utilized as atypically unfaltering regular progression material.

WATER

The most practical anyway the most basic component of bond is water. The water which is used for mixing bond should be impeccable and free from ruinous contaminations, for instance, oil, salt, destructive, etc adaptable water was used for mixing and reestablishing work.

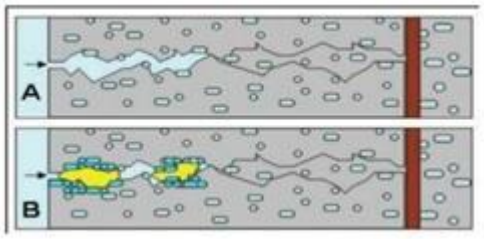
BACTERIAL CONCRETE OR SELF- HEALING CONCRETE

This ordinary trouble of splitting in building has many cures prior after which in a while the ruin.one of the therapeutic technique is bacterial concrete or self-restoration concrete. the manner of self-mending of makes or self-filling chortle uncontrollably of breaks by way of the help ofbacterial reaction within the strong in the wake of solidifying is called self-healing concrete. it may be watched that little splits that happen in a shape of width within the scope of 0.05 to 0.1mm receives definitely constant in dreary dry and moist cycles. the thing of this autogenously mending is, the width of variety 0.05-0.1mm pass about as hair likeand the water debris leak thru the breaks

BIO CONCRETE MECHANISM

At the point when the solid is blended with microbes (bacillus subtilus), the microscopic organisms go into a lethargic express, a great deal like seeds. Every one of the microorganisms require is introduction to the air to actuate their capacities. Any splits that ought to happen give the important presentation. At the point when the breaks frame, microbes closeness to the split, begins accelerating

calcite precious stones. At the point when a solid structure is harmed and water begins to leak through the breaks that show up in the solid, the spores of the microorganisms developon contact with the water and supplements. Having been enacted, the microscopic organisms begin to feast upon the calcium lactate supplement. Such spores have greatly thick cell dividers that empower them to stay in place for up to 200 years while sitting tight for a superior situation to sprout



CULTIVATION OF BACTERIA

The unadulterated culture of microscopic organisms i.e. Bacillus Subtilis is safeguarded on supplement agar inclines. It shapes unpredictable dry white states on supplement agar inclines. Two states of the microorganisms are immunized into supplement both of 350ml out of 500ml tapered cup and brooded at the temperature of 37 degree Celsius and 150 rpm orbital shaker hatchery.

The medium organization utilized for development of bacterial culture comprises of Peptone, NaCl yeast separate.

Fig. Bacteria in incubatorMIX PROPORTIONING

MIX DESIGN

Blend configuration can be characterized as the way toward choosing reasonable elements of cement, for example, bond, totals, water anddeciding their relative extents with the protest ofcreating cementof required least quality, workability and toughness as financially as wouldbe prudent. The reason for outlining can be seenfrom the above definitions, as two-overlay. Theprincipal objective is to accomplish the stipulatedleast quality and solidness. The second goal is to make the solid in the most efficient way. The evaluations of cement utilized as a part of thepresent examination are common review concreteand standard grade concrete. The blend extentsconventional review concrete and standard grade concrete are composed utilizing IS: 10262-1982. The extents of the blends are Materials required for 1 cubic meter of cement in conventional reviewconcrete and standard grade concrete are:

Standard grade concrete (M40)

Mix proportion 1: 1.76: 2.71: 0.45Cement : 400 Kgs
Fine aggregate (100%) : 704 Kgs Marble Dust(0%) : 0 Kgs
Fine aggregate (100%) : 633.6 Kgs Marble Dust(10%) : 70.4 Kgs
Fine aggregate (100%) : 563.2 Kgs Marble Dust(20%) : 140.8 Kgs
Fine aggregate (100%) : 492.6 Kgs Marble Dust(30%) :211.2 Kgs
Coarse aggregate: 1084 KgsWater : 180 Lt

MIXING OF CONCRETE

Mix setup can be portrayed as the path toward picking sensible components of concrete, for instance, bond, sums, water and choosing their relative degrees with the topic of making bond of required least quality, functionality and sturdiness as fiscally as could be normal in light of the currentsituation**.**

- **PHASE - I**

The phase-I of investigation is carried out toculture the bacteria

- **PHASE – II**

The phase-II of investigation is carried out to studythe strength behavior of bacterial concrete

IV EXPERIMENTAL INVESTIGATION

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. In our investigation we have made M40 grade of concrete. The mix ratio obtained after the mix design as per IS 456: was given in pervious chapter .Further, we have poured the concrete in the cube Moulds and six different samples were made whichare as follows

a. Conventional Concrete of grade M 40.
b. Concrete with 15 ml bacterial solution.
c. Concrete with 30 ml bacterial solution.
d. Concrete with 45 ml bacterial solution.
e. Concrete with 60 ml bacterial solution.
f. Concrete with 75 ml bacterial solution.

METHODS OF MIXING BACTERIAL SOLUTION INTO CONCRETE

There are different methods of mixing the bacterial solution in the concrete which are viz.

(a) Direct Mixing
(b) Indirect Mixing
(c) Injection method

CASTING OF CUBES AND CURING

Once the concrete is completely mixed the concrete is poured in the cube, compaction is been done by the vibration machine. Concrete cubes were removed from the Moulds after 24 hrs. And they were put into the curing tank. Curing was done for 7, 14, 28 and 56 days for all samples viz.

Conventional, 15 ml, 30 ml, 45 ml, 60 ml and 75 ml.

EXPERIMENTAL TEST ON BACTERIAL CONCRETE

Different test are performed on bacterial concrete so as to get the outcomes in different structures these test techniques are condensed beneath

Slump Cone Test Compressive strength test-

Concrete cubes of sizes 150mm×150mm×150mm were tested for crushing strength. Compressive strength depends on loads of factor such as w/c ratio, cement strength, excellence of concrete material and excellence control during manufactureof concrete.

These cubes are tested by compression testing machine after 7 days, 28 days curing. The sample is placed centrally on the base plate of machine and the load have to be apply gradually at the rate of 140 kg/cm2 per minute till the specimen fails. Load at the failure separated by area of sample gives the compressive strength of concrete. The sample to increased load breaks down and no greater load greater load can be constant.

The cube compressive strength, then fc=P/A N/mm2

Where P is an ultimate load in N, A is a cross sectional area of cube in mm2

Compression Testing Machine.

ULTRA SONIC PULSE VELOCITY

Prior it was accounted for that sand combination by B. pasteurii diminished porosity by up to half and penetrability by up to 90% in the zones where the cementation occurred. Microbial calcite stopping was specific and its proficiency was influenced by the porosity of the medium, the quantity of cells introduce and the aggregate volume of supplement included. The sand segment stacked with microscopic organisms was so firmly stopped that the section was broken with a mechanical blade for looking at. In an examination directed by Zhong and Islam, a normal split width of 2.7 mm and a blend of silica seethe (10%) and sand (90%) demonstrated the most elevated compressive quality in the microbial remediation of stone. Solid split remediation by microorganisms was altogethernot quite the same as that of rock remediation, for the most part because of the way that solid kept up elevated amounts of pH. An extraordinary basiccondition of pH around 12 is the major obstructing factor for development of B. pasteurii, whose ideal pH for development is around 9

Fig: Test of bacterial concrete samples using Ultrasonic Pulse Velocity Machine

PLATE COUNT TEST

The plate tally test was directed to decide add up to practical cells in a bacterial culture by plate check technique. This strategy is utilized for assurance of the quantity of cells that duplicate under characterize conditions. It requires culture viz. Fluid culture of bacillus subtilis, water, and drain. Encourage the media taken is 20ml supplement agar profound tubes (3 in nos.), likewise the device utilized were test tubes, pipettes, petri plates, glass stamping pencil and spreader.

Fig. Formation of visible massV RESULTS

Tests performed:

- Compressive strength test
- Water absorption
- UPV test

COMPRESSION TEST RESULTS

Table: COMPRESSION TEST RESULT

Mix id	Type of concrete	Compressive strength of concrete after 7 days			
		Sample 1 (0% Marble Dust)	Sample 2 (10% Marble Dust)	Sample 3 (20% Marble Dust)	Sample 4 (30% Marble Dust)
A0	Conventional	23.12	23.32	24.1	23.02
A1	15 ml	25.32	32.02	32.65	31.9
A2	30 ml	29.93	34.01	34.53	33.19
A3	45 ml	33.28	34.02	34.39	33.89
A4	60 ml	35.29	37.89	38.02	36.12
A5	75 ml	37.28	38.21	39.9	37.9

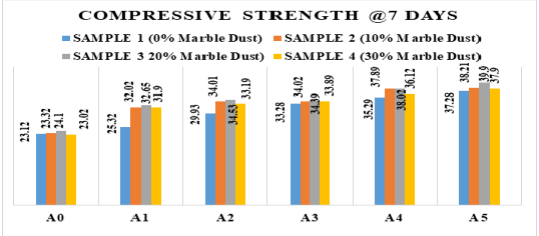


Fig: Compressive Strength test results

Table:. COMPRESSION TEST RESULT

Mix id	Type of concrete	Compressive strength of concrete after 28 days			
		Sample 1 (0% Marble Dust)	Sample 2 (10% Marble Dust)	Sample 3 (20% Marble Dust)	Sample 4 (30% Marble Dust)
A0	Conventional	32.42	34.29	37.45	33.82
A1	15 ml	45.25	47.89	49.2	48.2
A2	30 ml	55.24	52.35	53.2	52.24
A3	45 ml	52.8	54.89	55.96	54.21
A4	60 ml	53.92	55.02	55.32	54.92
A5	75 ml	52.2	53.24	54.09	53.89

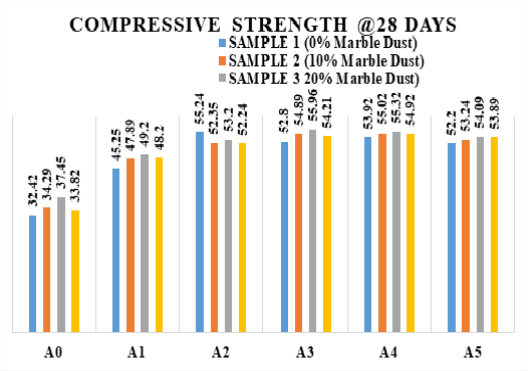


Fig.: Compressive Strength test results Table: COMPRESSION TEST RESULT

Mix id	Type of concrete	Compressive strength of concrete after 56 days			
		Sample 1 (0% Marble Dust)	Sample 2 (10% Marble Dust)	Sample 3 (20% Marble Dust)	Sample 4 (30% Marble Dust)
A0	Conventional	33.45	37.02	38.25	36.42
A1	15 ml	43.23	49.89	50.01	48.24
A2	30 ml	56.265	54.34	54.45	53.1
A3	45 ml	53.8	57.42	58.56	56.89
A4	60 ml	55.9	58.01	58.8	57.01
A5	75 ml	53.2	58.25	59.99	58.1

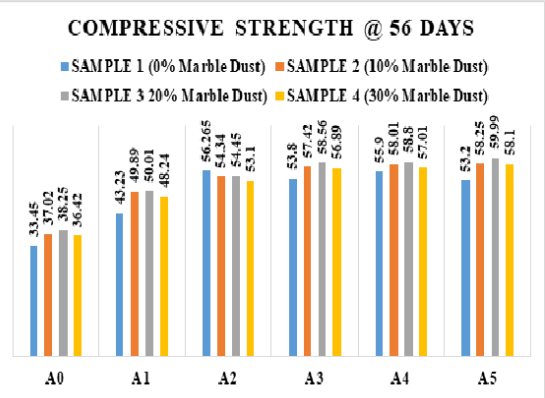


Fig.: Compressive Strength test results

% WATER ABSORPTION TEST RESULT

Mix Details	BACTERIAL CONCRETE				
	15 ml	30 ml	45 ml	60 ml	75 ml
(0% Marble Dust) 2.362	1.232	0.992	1.264	1.436	1.23
(10% Marble Dust) 2.536	0.956	0.926	1.326	1.235	1.28
(20% Marble Dust) 2.532	1.628	1.302	1.074	1.236	1.36
(30% Marble Dust) 2.530	1.72	1.352	1.124	1.32	1.43

Plate count method test

S.No.	Ml of bacterial suspension	Number of viable bacteria
1.	15	69 X 10^3
2.	30	78 X 10^3
3.	45	90 X 10^3
4.	60	51 X 10^3
5.	75	35 X 10^3

V CONCLUSIONS

The microorganisms which are known to be salt safe, for instance they create in indigenous territories depicted by a for the most part high pH. Also, these strains can make spores which are resting cells with solid cell dividers that guarantee them against incredible environmental mechanical- and substance stresses. Subsequently these specific minute creatures may can contradict the high insidestrong pH regards (12-13 for Portland bond based concrete), and remain sensible for a long time as well, as spore reasonableness for as long as 200 years is accounted for.

The test result shows that the use of these Waste Marble Dust have the capability of improving the performance of the hardened concrete

To conclude we can state that the application of bacteria as a self-healing agent in concrete appears promising

- Compressive strength of the concrete is start increasing when we introduce bacteria into the concrete compare to convention concrete
- Compressive strength of the concrete has increased with increasing percentages of marble dust additions at all curing ages.
- In this project we worked with UPV test and plate load count method by the way thevelocity and number of bacterial cell present in the concrete was calculated experimentally
- Water absorption test is also done where from the experiment we can conclude that we got better results in the bacteria concrete compare to conventional concrete.
- By the way increase in bacteria in the concrete leads to increase in the strength and also we can clearly notice that no cracks because of mechanism of bacteria.
- We can also conclude that 20% replacement f fine aggregate with marble dust gives increase in strength and got optimum value for self-healing concrete

FUTURE SCOPE

- More study required to reduce the cost ofself-healing concrete.
- Further study required to overcome on the limitations of bacillus subtilis bacteria.
- More work should be done on the longterm effect of bacteria on human life.
- Can be used in the construction of aircraft runways, bridges and dams reducing the maintenance cost.
- Retaining wall construction.

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