International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
November 2018

Enhancement of Properties of Recycled Coarse Aggregate Concrete Using Ureolytic Bacteria

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Abstract:

Construction industry utilizes Portland cement which is known to be an overwhelming supporter of the CO2 discharges and natural harm. Consolidation of mechanical wastes like pulverized old concrete as beneficial cementing materials (SCMs) could result in a generous decrease of the general CO2 impression of the last concrete item. In any case, utilization of the valuable materials in construction industry particularly really taking shape of concrete is highly testing. Huge research endeavors are required to think about the designing properties of concrete joining such modern wastes. Present research is a push to improve the properties of reused coarse total concrete utilizing microscopic organisms.

1.1. Reused coarse total (RCA) concrete construction system can be called as 'green concrete', as it limits the ecological peril of the concrete waste transfer. The enhancement of properties of RCA concrete with the expansion of ureolytic-type microscopic organisms, Bacillus subtilis to improve the properties of RCA concrete. Ureolytic microorganisms are the ones which can enhance the strength of cement mortar by the precipitation of calcium carbonate within the sight of urea and a calcium source.

In the present examination, Bacillus subtilis is utilized to check its relevance in such manner. Different tests like consistency and starting setting time are done to discover the impact of bacterial arrangement on cement. Tests, for example, pressure strength, split tensile test and sorptivity test are utilized in the present examination to recognize the variety in the mechanical properties of cement mortar.

Keywords: *bacterial concrete, compressive strength, calcite precipitation, cement mortar, microstructure*

INTRODUCTION

Most building constructions are not eco-accommodating. Construction industry utilizes Portland cement which is known to be an overwhelming supporter of the CO2 outflows and natural harm. In India, measure of construction has quickly expanded since most recent two decades. Utilizing different sorts of beneficial cementing materials (SCMs), as a cement replacement could result in a generous decrease of the general CO2 impression of the last concrete item. Lesser the amount of Portland cement utilized in concrete creation, lesser will be the effect of the concrete industry on nature.

The testimony of construction refuse which is progressively amassed because of different causes, for example, obliteration of old construction is likewise an ecological concern [Topcu and Guncan 1995]. In India, the Central Pollution Control Board has evaluated that the strong waste age is around 48 million tons for each annum of which 25% are from the construction industry. This situation isn't so extraordinary in whatever is left of the world. With the end goal to diminish the construction waste, reusing of waste concrete as total is advantageous and successful for protection of common assets [Khalaf and Venny 2004].

Utilization of decimated concrete in construction industry is more all encompassing as it adds to the biological equalization. Be that as it may, utilization of these waste materials in construction industry particularly really taking shape of concrete is highly testing. Critical research endeavors are required to ponder the designing properties of concrete made of such modern wastes. Decimated concrete can be utilized as reused coarse total (RCA) to make new concrete (RCA concrete) by partially or completely supplanting the regular coarse total (NCA). Different specialists have analyzed the physical and mechanical properties of RCA concrete and discovered that the mechanical strength of the RCA concrete is lower than that of ordinary concrete with NCA. This is because of the highly permeable nature of the RCA contrasted with NCA and the measure of replacement of NCA [Rahal 2007]. The physical properties of the RCA rely upon the measure of followed mortar and its quality. Measure of followed mortar relies upon the way toward smashing of parent concrete. Because of these reasons, RCA indicates greater porosity, more water retention, low thickness and low strength when contrasted with the regular total. Past analysts revealed that up to 25% decrease in compressive strength has been happened due to above reasons [Amnon 2003; Elhakam et al. 2012; Tabsh and Abdelfatah 2009, McNeil and Kang 2013].

The connection between the water-to-cement (w/c) proportion and the compressive strength is fundamental for the primer estimation of water and other constituent materials for blend structure of concrete. Indian standard prescribes such relationship for NCA concrete. This relationship might be distinctive for RCA concrete contingent upon its age and number of reusing. Numerous examinations [Rahal 2007; Amnon 2003; Tabsh and Abdelfatah 2009; Kou et al. 2011, Kou and poon 2009; and Padmini et al. 2009] are accounted for in writing that centers around the conduct, properties, and utilitarian employments of RCA. Be that as it may, no examinations have been accounted for on the conduct of RCA concrete with respect to above angles. The present work is an endeavor to ponder the relationship of w/c proportion with compressive strength thinking about age and number of reusing of RCA.

The rising tide of reception of RCA for construction requests an examination of techniques to enhance the nature of RCA concrete. Utilization of urease-creating microorganisms can address the issues related with RCA concrete to some degree. Such microscopic organisms can encourage CaCO3 through urease movement [Pei et al. 2013; Pacheco-Torgal and Labrincha 2013; and Siddique and Chahal 2011] which catalyzes the hydrolysis of urea into ammonium and carbonate. To start with, urea is hydrolyzed intracellular to carbamate and alkali. Carbamate suddenly hydrolyzes to shape extra smelling salts and carbonic corrosive. These items along these lines shape bicarbonate, ammonium, and hydroxide particles. These responses increment the encompassing pH, which thus moves the bicarbonate harmony, bringing about the development of carbonate particles. This prompts collection of insoluble CaCO3, which tops off the pores of theconcrete and enhances the impermeability and strength. Bacterial calcium carbonate mineralization utilizing urease creating microscopic organisms is proposed in the present investigation to enhance the nature of RCA concrete.

Afterward, it was discovered that, a calcite hastening microorganisms, Bacillus pasteurii, was in charge of the coupling operator generation for this transformation. This mineral affidavit system can respond in due order regarding the characteristic technique for the fixing of pores and breaks of concrete and mortar. Biomineralization is characterized as a naturally instigated precipitation in which a creature makes a neighborhood small scale condition with conditions that permit ideal extracellular substance precipitation of mineral stages. This can be seen in numerous organic species living in different regular habitats, for example, soil, land arrangements, new water biofilms, hot springs, saline lakes and seas. The correct component behind the microbial calcium carbonate precipitation isn't found till date.

The inspiration of the present work is to consider the impact because of expansion of Ureolytic microbes in the microstructure, compressive strength and fine water assimilation of cement mortar

OBJECTIVES AND SCOPES

In view of the finishes of writing survey, the fundamental target of the present investigation is recognized as to enhance the designing properties of reused coarse total cement mortar utilizing a solitary bacterial animal groups. This primary goal is separated in to following sub-destinations:

a) To examine the variety of compressive strength of cement mortar with microscopic organisms and land at an ideal measurement of microbes

b) To consider the setting time of cement within the sight of microscopic organisms

c) To contemplate the variety of tensile strength of cement mortar with microorganisms

TEST SETUP AND TESTING

Moulds

Metal molds, ideally steel or position press, thick enough to forestall bending are required. They are made in such a way as to encourage the expulsion of the shaped example without harm and are machined to the point that, when it is collected prepared for utilize, the measurements andinternal faces are required to be precise with in as far as possible The stature of the form and the separation between the contrary appearances are of the predetermined size +0.2 mm.the edge between nearby inside countenances and between inner faces and best and base spots of the molds is required to be 900 + 0.50 .the form having the measurements like 150mmX150mmX150mm.

1.9. Fig:5.1-molds for concrete cubes

Procedure of Mixing:

Water used for mixing concrete, extremely its contaminations, may impact the concrete Strength, setting time, blooming (stores of white salts on the surface of concrete),and the disintegration of sustaining and prestressing steel. By far most of concrete mixes Specifications have the essential concerning the idea of water included: water should be consumable, as city drinking dilutes just now and again contain broken solids in excess of 1000 ppm (parts per million). Thusly, by having low substance of dirtying impacts, it is star Vided that mixing water itself is now and again a factor in concrete strength.

It doesn't imply that water that is unsatisfactory for drinking isn't suitable for concrete blending. Marginally acidic, basic, salty, saline, hued, or water described by deficient smellShould not be dismissed inside and out. This is critical in view of the water lack in numerous Areas of the world. Reused waters from urban communities, mining, and numerous mechanical tasks Can be securely utilized as blending waters for concrete. The most ideal approach to decide the appropriateness Of water is to analyze the setting time of cement and the strength of mortar blocks when Specimens are made with water with non-indicated qualities and with reference water that is determined as spotless. The cubes made with water that is tried ought to have 7-and 28-day compressive strengths equivalent to or possibly 90 percent of the strength of reference Specimens made with clean water; the nature of blending water ought not influence the setting Time of cement to an inadmissible degree. Impact of the concrete droop on compressive strength Seawater, which contains around 35,000 ppm disintegrated salts, isn't hurtful to The strength of plain concrete. Be that as it may, with strengthened and prestressed concrete it expands the danger of steel consumption; in this manner, the utilization of seawater as concrete-blending water ought to be maintained a strategic distance from under these conditions. The nearness of inordinate measures of green growth, oil, salt, or sugar in the blending water ought to be viewed as a high hazard factors..

Compacting

The test cubes examples are made when practicable subsequent to blending and in such away as to deliver full compaction of the concrete with neither isolation nor exorbitant laitance.The concrete is filled into the shape in layers around 5cm profound. Each layer is compacted either by hand or vibration.

While compacting by hand, the standard packing bar is utilized and the feeds of the are circulated in a uniform way over the cross-area of the form. The quantity of stirs per layer to deliver the predetermined conditions differ in like manner to the kind of concrete. For cubical examples, for no situation should the concrete be exposed to under 35 feeds for each layer for 15 cm or 25 stirs for every layer for 10cm 3D shapes

Process of Curing:

Restoring the concrete guides the compound response called hydration. Most crisply blended concrete contains impressively more water than is required for finish hydration of the cement; in any case, any calculable loss of water by dissipation or generally will postpone or forestall hydration. In the event that temperatures are ideal, hydration is generally quick the initial couple of days after concrete is set; holding water amid this period is essential. Great restoring implies dissipation ought to be anticipated or lessened. The examples in the wake of throwing are permitted to dry for 24 hrs. After the finishing of drying, the solid shapes are submerged in a restoring tank. Every one of the blocks are fluctuated with the kind of totals that are utilized in the concrete blend. The test program conveyed, is to discover the highest compressive strength for the totals. After the restoring time of 28 days the solid shapes will be tried in the Compressive strength testing machine. Meanwhile of 28 days, the 3D squares will be tried for 7 days and 21 days moreover.

Test Methods For Hardended Concrete

A discussion of mechanical properties such as compressive strength, split tensile strength, flexural strength, modulus of elasticity and ultra sonic pulse velocity, durability properties such as water permeability, rapid chloride permeability, water absorption and shrinkage, deterioration studies such as chloride penetration, sulphate and acid resistance, corrosion studies such as half-cell potential and electrical resistivity test are conducted for SCGC, NCRS and NCCRD. The testing methods used to evaluate these properties are given in the subsequent sections.

Compressive Strength Test

Compressive strength of concrete is often considered as the most important property of concrete, and is the most common measure used to evaluate the quality of hardened concrete (Mather et al 2002). Principal factors governing the compressive strength of concrete are the W/C ratio, curing conditions, age of the concrete, cementitious material, aggregates, mixing time, degree of consolidation, and air content (Mather et al 2002). The compression load is appliedcontinuously until failure using compression testing machine at the rate of 0.3MPa/sec.Figure 3.15 represents the general view of compressive strength test setup and Figure 3.16 represents the concrete cube at failure.

Figure3.15View of compressive strength test setup

Figure3.16Concretecube at failure

The results are recorded for further analysis. Three specimens are tested at each age to compute the average strength.

Compressive Strength = P/A (3.2)

Where, P : Ultimate compressive load of concrete (kN)

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
November 2018

A : Surface area in contact with the platens (mm^2)

1.1. Tensile Strength

The tensile strength of concrete is much lower than the compressive strength, due to the simplicity with which splits can spread under tensile loads, and is generally not considered in plan. Usually thought to be zero. Nonetheless, it is a vital property, since splitting in concrete is most by and large because of the tensile burdens that happen under load, or because of natural changes. The disappointment of concrete in strain is represented by miniaturized scale splitting, related especially with the interfacial district between the total particles and the cement, additionally called interfacial progress zone. The tensile strength of the concrete can be resolved tentatively by the accompanying three strategies:

(1) Uniaxial tensile strength
(2) Split cylinder test
Beam test in flexure

The first method of obtaining the tensile strength is referred to as a direct test for determining the tensile strength, while the second and third methods are indirect tests. In the direct test, the specimen is gripped at its ends and pulled apart in tension, the tensile strength is the failure load divided by the area experiencing tension. It is very difficult to apply pure tension force, free from eccentricity. It is also difficult to avoid secondary stresses such as those induced by grips or by embedded studs. The splitting tensile test and the flexure test (modulus of rupture test) are the indirect methods for determining the tensile strength.

1.2. Splitting Tensile Strength

The indirect method of applying tension in the form of splitting is conducted to evaluate the effect of MSP and CRD on tensile properties of SCGC. In this test, a concrete cylinder of size 150 mm diameter and 300 mm length is placed with its axis horizontal between the plates of the testing machine. Figure 3.17 and Figure 3.18 shows the experimental setup used for the split tensile test.

1.3. Figure 3.17 General view of split tensile test setup

Figure 3.18 Close-up view of the split

tensile strength test

It is loaded in the compression on the plane between the loaded sides, and the specimen fails in tension and the plane between the loaded sides along the vertical diameter of the specimen. Any element on this vertical diameter is subjected to vertical compressive stress and the split tensile strength is calculated as follows.

$F_{sp} = 2P / LD$ where,

F_SP= split tensile strength in MPa

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
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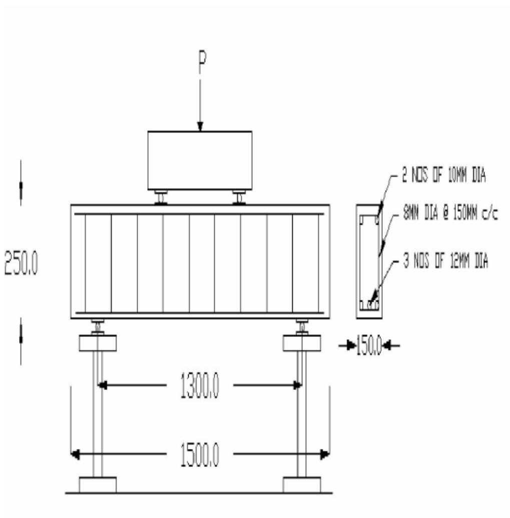

= compressive load in N
L=length of the specimen in mm
D=diameter of the specimen in mm.

However, immediately under the load, a high compressive stress would be induced by a narrow strip of a packing material, such as plywood, or thin steel rod is placed between the cylinder and the plates of testing machine. The split tensile strength of
150 mm diameter and 300 mm length concrete cylindrical specimens is used to assess the effect of CRD and MSP on the tensile properties of the concrete.

1.4. Flexural Strength

For the purpose of investigating the flexural conduct of concrete, a four point stacking shaft test is done of every example. This shaft test gave an unadulterated flexural zone within the sight of shear. The flexural conduct for SCGC, NCCRD and NCRS are led by utilizing pillars which are rectangular in cross area, 150 mm wide, 250 mm in generally profundity with a front of 25 mm and 1500 mm since a long time ago furnished with 2 quantities of 10mm dia longitudinal reinforcement in pressure and 3 Nos of 12mm dia in strain zone with 8mm dia stirrups at 150mm c/c dispersing, for M30 review concrete. Figure 3.19 shows test set-up. Four point flexural tests are completed on all shafts utilizing a stacking outline. The hub of the example is painstakingly lined up with the pivot of the stacking gadget. Amid testing, on all beams using a loading frame. The axis of the specimen is carefully aligned with the axis of the loading device. During testing,
formation and growth of cracks are marked on the surface of the beams by drawing lines on the cracks. The load

points and reactions points are marked on the beams. All the beams are tested under four point loading as shown in Figure 3.20.

1.5. Figure 3.19 Set-up for four-point bend test of beam specimen

Figure 3.20 Flexural test for the beam

The load has applied by means of 50 tones capacity hydraulic jack, powered by hand operated pump at a slow loading rate of 20kN per minute for the beams. A load cell placed above the jack and the applied load is read from load indicator arrangement for application of four point loading. The load is applied without shock and increased continuously and the corresponding deflection is taken until the specimen reaches the ultimate load. A dial gauge is

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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fixed at the center and loading points of the beam to measure the deflection for various stages of loading. The initial dial gauge readings of deflectometer and load cell are recorded. The deflectometer and load cell readings are recorded at different stages of loading up to ultimate load. While taking reading, care was taken not to touch any of the loading and measuring equipment.

RESULTS

Compressive strength:

Compression test has been carried out on concrete cubes with standards confirming to IS 516-1999.All the samples were tested in a 2000 KN capacity Compression testing machine. After 28 days of curing, the cubes were permitted to turn in to dry condition before testing. Plane surfaces of the specimen were between platens of compression testing machine and subjective to loading. The compressive strength of the concrete cubes are given in Table3. In this compressive strength of cubes for M20, M30&M40 grade concrete made with and without bacteria for 7 days & 28 days was tested

1.6. Table5 Compressive strength of cubes for M20, M30 & M40 grade concrete made with and without bacteria 7 & 28 days

Table 5 summarizes the 7 days and 28 days compressive strength of the mortar cubes containing different cell concentration of alkaliphilic microorganism (Bacillus subtilus). The greatest improvement in compressive strength occurs at Culture of 10ml for all ages: this increase reaches to 17.92, 18.16 & 16.22 for M20, M30 & M40 % at 28 days. This improvement in compressive strength is due to deposition on the microorganism cell surfaces and within the pores of cement–sand matrix, which plug the pores within the mortar. The extra cellular growth produced by the microorganism is expected to contribute more to the strength of cement mortar with a longer incubation period and thus the strength improvement is found to be more at 28 days. Even the dead cells may simply remain in the matrix as organic fibers.

Cell Concentration/ml of mixing bacteria	Compressive strength of Concrete in mpa			
	7days	% Increase	28days	% Increase
M20 Control (nil)	19.21	-	27.89	-
5 ml	24.13	25.61	31.37	12.47
10 ml	25.08	30.55	32.89	17.92
15 ml	22.19	15.55	30.79	10.39
20 ml	21.33	11.03	29.40	5.41
M30 Control (nil)	24.32	-	39.26	-
5 ml	29.72	22.20	45.26	15.28
10 ml	32.16	32.16	46.39	18.16
15 ml	30.16	24.01	43.26	10.10
20 ml	28.65	17.80	41.33	5.20
M40 Control (nil)	35.46	-	50.29	-
5 ml	40.76	14.96	53.26	5.90
10 ml	43.26	30.55	58.45	16.22
15 ml	41.46	16.92	56.12	11.59
20 ml	39.32	10.80	55.10	9.60

Splitting tensile strength test on concrete cylinders

International Journal of Research
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e-ISSN: 2348-6848
p-ISSN: 2348-795X
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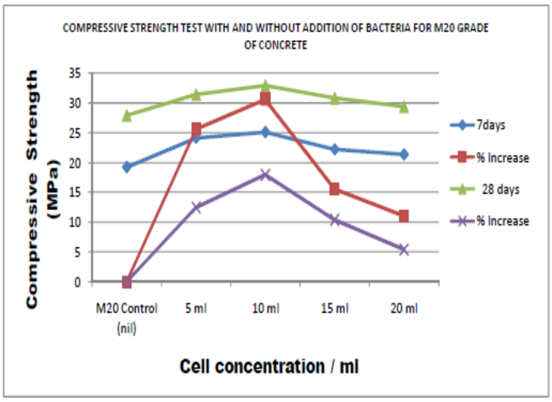
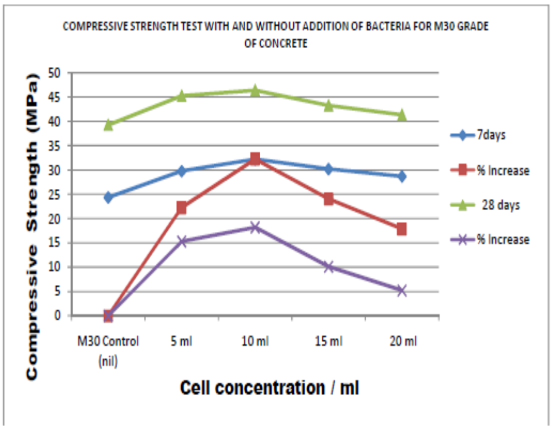
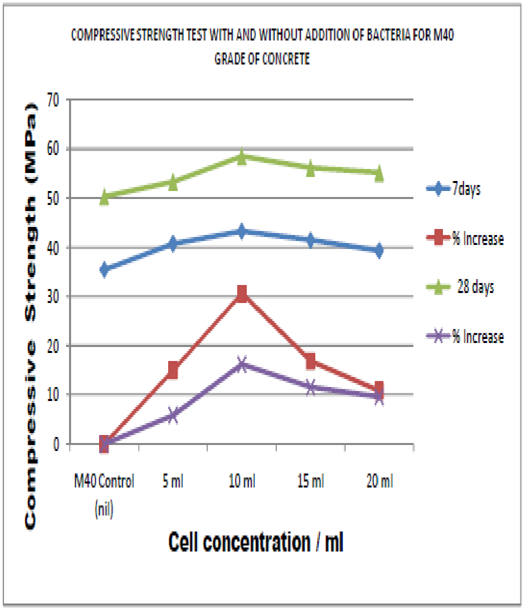




The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. Splitting tensile test has



1.7. Table 6 Results of the Split Tensile strength Test with and without addition of bacteria for M20, M30 and M40 grade of concrete

Cell concentration/ ml of mixing bacteria	Tensile strength of Concrete in mpa	
	28 days	% Increase
M20 Control (nil)	2.42	--
5 ml	2.65	9.50
10 ml	2.81	16.11
15 ml	2.72	12.39
20 ml	2.56	5.76
M30 Control (nil)	3.43	--
5 ml	3.79	10.49
10 ml	3.92	14.21
15 ml	3.81	11.02
20 ml	3.69	7.50
M40 Control (nil)	4.12	--
5 ml	4.46	8.25
10 ml	5.01	21.60
15 ml	4.76	15.53
20 ml	4.52	9.70

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Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
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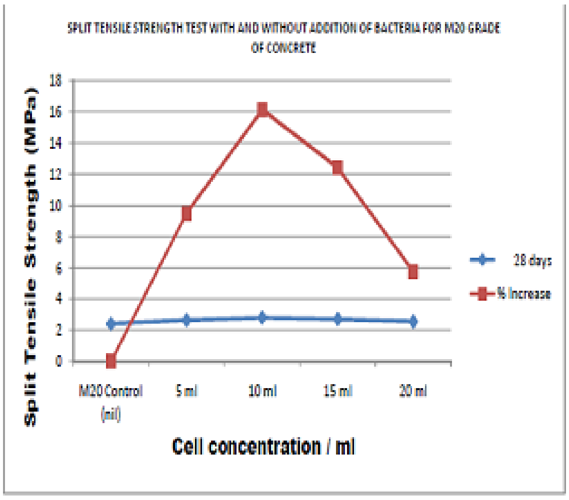
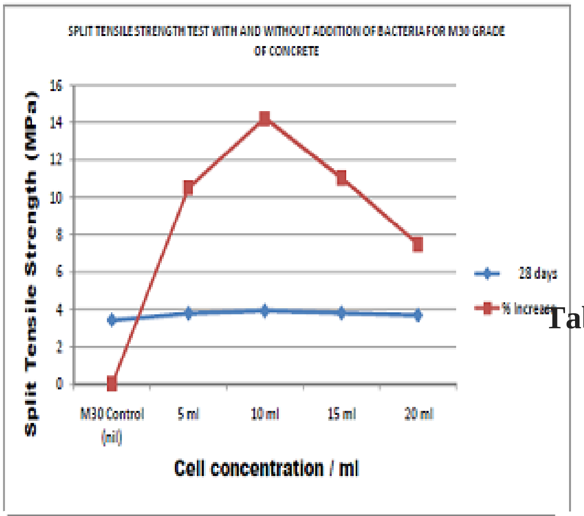
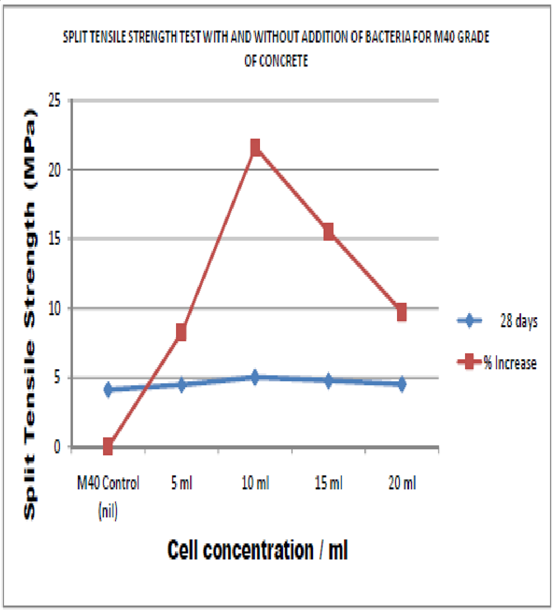






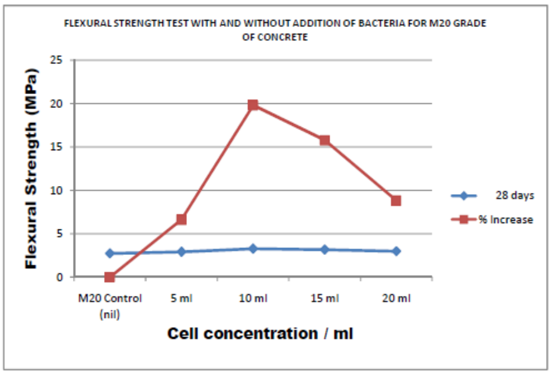
In M20, M30 and M40 grade concrete the Split Tensile Strength on standard cylindrical specimens at 28 days are given in Table 4 It is observed that with the addition of bacteria there is a significant increase in the spilt tensile strength by 16.11%, 14.21% and 21.60% at 28 days respectively

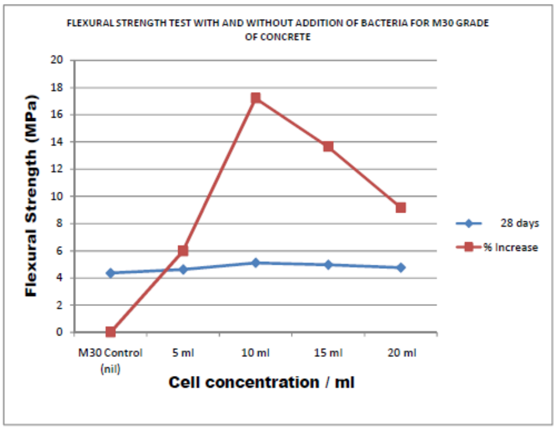
Flexural strength test

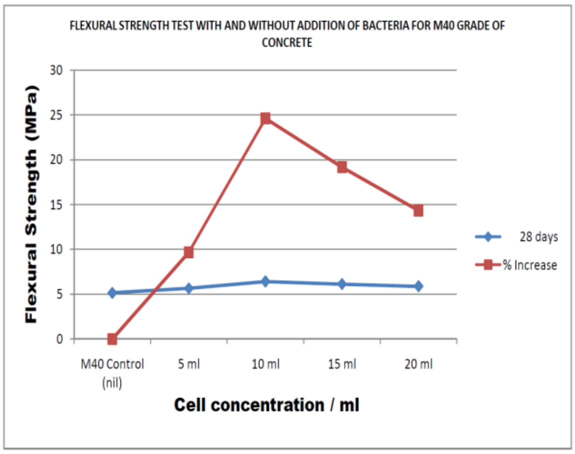
The investigation is carried to study the flexural behaviour of concrete. 3 simply supported beams consisting of balanced section are cast and tested. The cross section of the beam specimen is 100mm x 100mm x 500mm. The beams are cast using with bacteria and without bacteria in M20, M30&M40 grade concrete. The flexural strength of both controlled and bacterial concrete is calculated and the result is tabulated in Table 5. Flexural strength test has been carried out on concrete beams with standards confirming to IS 516-1999

Table 7 Results of the Flexural Tensile Strength test with and without addition of Bacteria for M20,M30&M40grade of concrete.

Cell concentration/ ml of mixing bacteria	Flexural strength of Concrete in mpa	
	28 days	% Increase
M20 Control (nil)	2.72	--
5 ml	2.90	6.61
10 ml	3.26	19.81
15 ml	3.15	15.80
20 ml	2.96	8.82
M30 Control (nil)	4.36	--
5 ml	4.62	5.96
10 ml	5.11	17.20
15 ml	4.97	13.65
20 ml	4.76	9.17
M40 Control (nil)	5.16	
5 ml	5.66	9.68
10 ml	6.43	24.61
15 ml	6.15	19.18
20 ml	5.90	14.34







Based on the experimental results the Flexural Tensile Strength is as shown in Table 7. It is observed that with the addition of bacteria there is a significant increase in the Flexural Strength by 19.81%, 17.20% and 24.61% at 28 days for M20,M30&M40 Grades respectively.

The experimental investigation is carried out to study the enhancement of properties such as compressive strength, split tensile strength and flexural strength of RCA concrete with the addition of B. subtilis. The salient conclusions of the present study are as follows:

- Properties of RCA concrete such as compressive strength, split tensile strength and flexural strength are improved by the addition of B. subtilis. The maximum compressive strength of bacterial RCA is observed at an optimum concentration of 10 cells/ml at both 7 and 28 days.

Due to the inclusion of bacteria in concrete, we achieved slight increase in compressive strength, split tensile strength and flexural strength up to 15% than the conventional concrete.

- B. subtilis plays a vital role in the increment in compressive strength of RCA concrete by way of calcium carbonate precipitation in the pores.
- The main advantage of bacterial concrete is that we can improve the life span of aconcrete structure up to 200 years if this technology has been further enhanced and bring into special importance.
- These bacterial concrete is a self-healing concrete which heals cracks for effective duration of initial 5 hours up to as long as possible and the bacterial cell life is 200years.
- These bacterial usages can save the cement and the construction of a building can bemade economical, as we know cement production gives rise to production of carbon dioxide to the higher levels, so further controlling is made very effective.
- These bacterial concrete usages can be made common in next few decades heading towards victory of civil engineering structures as per the scientific view of highly authorized laboratories.

From the results it can be concluded that easily cultured Bacillus subtilis can be safely used in improving the performance and characteristics of concrete. In order to improve the quality of RCA concrete, calcium carbonate mineralization with the help of
B. subtilis bacteria is proposed in this study. This method can address the problems associated with RCA concrete to some extent. The present study is focused on three properties of RCA concrete: compressive strength (at 7 & 28 days), split tensile strength (at 28 days) and flexural strength (at 28 days). Other properties such as modulus of elasticity, creep, rapid chloride penetration tests, and long-term effects need to be investigated for an assessment of the general behavior of RCA concrete.

1.8. SCOPE FOR FURTHER STUDIES

[1] The present work is concentrated on ordinary grade (M20) and standard grade (M40) conventional and bacterial concrete. The same work can be extended to the higher grade concrete.
[2] The present study can be extended to develop the design code provisions required for RCA concrete in line with that of normal concrete.
[3] The present study considered RCA concrete having minimum age. This study can be extended to consider much older demolished concrete to represent more realistic situations.
[4] This study can be extended to make the bacterial concrete to more commercial friendly.
[5] The cost benefit analysis for the use of recycled materials can be studied.

[6] Further the long term effects need to be studied. Also it is recommended to develop the bacterial concrete by using different mineral admixtures like silica fume, metakaoline and their combinations and study the compatibility.

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