STUDY ON STRENGTH PROPERTIES OF CONCRETE USING BACTERIA

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by

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DECLARATION

I, Puja Kalita (11203943), hereby declare that this thesis report entitled "**STUDY ON STRENGTH PROPERTIES OF CONCRETE USING BACTERIA**" submitted in the partial fulfillment of the requirements for the award of the degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: **PUJA KALITA**

CERTIFICATE

Certified that this project report entitled "**STUDY ON STRENGTH PROPERTIES OF CONCRETE USING BACTERIA**" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara, carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

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ABSTRACT

Strength and sustainability are the demand of globe. Creating and developing new resources is better than to conserve the available ones. In this study, the use of micro-bacterial influenced concrete is presented. Bio-concrete is emerging as a compatible alternative to conventional concrete with enhanced quality of self-healing. This property of self-healing along with appreciable strength requirements motivates for using Bio-concrete as a sustainable construction material. Use of Bio-concrete reduces the general flaws in performance of concrete caused due to cracks in concrete. This ultimately reduces the maintenance cost of structure as compare to conventional concrete. Microbes is an exquisite remedy for service life of concrete. Due to enormous causes, the service life of concrete structure is affected. Out of these one main cause is cracks formation. The crack formation can be due to flaws in composition, mixing and placing along with improper curing. Crack formation is difficult to control but can be handled in a better way using bio-concrete. In Bio-Concrete microbes are added for precipitation of $CaCO_3$. It fills the space or pore between concrete material and hence improve the strength and performance behavior of concrete. Hence, Bio concrete fulfill the demand of new generation concrete with less economic investment.

In the ongoing report, study about compressive strength & flexural strength of Bio-Concrete is explored. When we incorporate partial replacement of water with 2% and 4% of microbe along with making 2% of starch constant with concrete blend and test the specimens after 7days, 28 days, and 56 days, it fulfills the objective of this investigation, i.e. enhanced the strength properties. Bio-concrete develops durability at a great extent. This assist, after adding the microbes to the concrete material, strength properties are enhanced as microbes fills the pore and micro-internal cracks.

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Mm	Millimeter
%	Percentage
Cm	Centimeter
M	Meter
L	Liter
Sec	Second
KN	KILO NEWTON
Kg	Kilo Gram
Mcb	Microbe
Str	Starch
C_2S	Dicalcium silicate
C_3S	Tricalcium silicate
$CaCO_3$	Calcium carbonate
mcb2str2	Microbe 2% starch 2%
mcb4str2	Microbe 4% starch 2%

CHAPTER 1

INTRODUCTION

Concrete is most fundamental material for this new era. For their more extended administration life we require some new method alongside great material. One of such strategy is self-recuperating procedure of concrete, where microscopic organisms is utilized to mend the concrete makes and to fill laugh hysterically the pores and in this way improved their life span. Durability of concrete is weakened by splits since they give a simple way to the transportation of fluids and gasses that conceivably contain unsafe substances. In the event that small_scale breaks develop and achieve the fortification, the concrete itself might be assaulted, as well as the support will be eroded. In this manner, it is essential to control the crack width and to recuperate the splits at the earliest opportunity. Concrete as of now has an inherent mending system due to on-going synthetic, physical and mechanical procedures. Most notable is precipitation of calcium carbonate. Microorganisms is the most appropriate and monetary material which can be utilized as self-recuperating item for concrete. It can precipitate the calcium carbonate, and it can fill the cracks width. Uncommon intrigue lies in the impact of consolidated mineral forerunner mixes on concrete properties. Lion's share of recuperating operator comprises of the natural mineral antecedent compound which is by the microscopic organisms metabolically changed over to carbonate particles which in this way encourage with calcium particles in type of limestone on the break surface. A few natural antecedent materials, for example, particular amino acids seemed appropriate applicants as these barely influenced concrete compressive strngth (Jonkers 2007). The mix of appropriate microscopic organisms and calcium lactate as mineral forerunner compound calcium lactate in fact brought about generation of calcium carbonate accelerates in concrete cracks/splits. The watched mineral generation in time nonetheless seemed constrained when calcium lactate and bacterial spores were straightforwardly included unprotected shape to the concrete mix, most likely because of full joining of the forerunner compound in the framework restricting its entrance to

microscopic organisms (Jonkers_and_Schlangen 2009). Calcium lactate be that as it may, had all the earmarks of being the most suitable compound as its application as principle mending operator fixing brought about even upgraded concrete compressive strength qualities (Jonkers and Schlangen 2009). As an after effect of late reviews, bio`concrete or bio affected self-recuperating cement is rising as a reasonable arrangement for controlling cracks/splits engendering. Bio cement is an item which includes recuperating of cracks by generation of mineral mixes through microbial movement in the solid. Independent mending through this procedure builds the auxiliary toughness through lessening in concrete cracks/splits and then again decreases the support required for strengthened concrete structures. Recuperating operator principally comprises of microscopic organisms and a mineral antecedent compound. To begin with vital thought was to pick concrete perfect microscopic organisms. Microscopic organisms ought to survive and stay dynamic in the exceedingly antacid environment. Since concrete structures are intended to last no less than 50 to 100 years, microorganisms ought to stay feasible for a drawn out stretch of time. In this manner, a particular gathering of alkaliphilic spore-shaping microscopic organisms was chosen. The thick cell-walled spores are delivered by microorganisms when living conditions turn out to be less great. Spores are described by imperviousness to high mechanical and substance push (Sagripanti_and_Bonifacino 1996) what's more, have amazingly long life expectancies in torpid state, for a few species up to 200 a long time (Schlegel 1993). Expanded potential for long haul practicality and action might be achieved when coordinated bacterial spores are immobilized or secured and the antecedent compound is kept open for bacterial change. Selected arrangement is epitome of the two-compound mending specialist in a defensive store (Jonkers_and_Schlangen 2009, Jonkers et al. 2010). At the point when conditions are reasonable spores sprout and change into dynamic vegetative microscopic organisms, to be specific in soluble surroundings with get to water and a nourishment source. Current material outline in designing takes after the idea of harm avoidance. An option plan standard is that of self-mending materials. Harm

development does not really bring about issues, on the off chance that it is along these lines mended in a self-sufficient process. Self-healing materials need to serve a few parts and meet a few properties. such as Harms ought to be detected, trailed by transportation of mending specialist to the harm site, activating repair of the harm. In the perfect case self-mending materials are modest and have properties equivalent or better than as of now utilized materials, with the capacity to mend deformities of any size, numerous circumstances, totally and independently. If there should be an occurrence of solid sturdiness execution is for the most part considered for harm to be mended, keeping in mind the end goal to lessen expenses of repair and support. Bio mineralization is favored as it is a characteristic procedure, ecological well-disposed and enhances the compressive strength of cracked/spited concrete. Bacterial cement is likewise eco-accommodating, which is most critical in nowadays. The real downside of concrete is its low rigidity which makes it vulnerable to movement also, blend in small scale splits bringing about low quality and sturdiness. These pliable anxieties can be because of malleable stacking, plastic shrinkage and sweeping compound responses. This obligation to splitting outcomes in quality diminishment of cement, as well as makes concrete defenseless against malicious environment. Section of unsafe chemicals through these splits may bring about cement crumbling through compound assault and can likewise bring about erosion of steel fortification. This consumption prompts to increment in split harm bringing about loss of quality and firmness of concrete structures. Little splits in cement may form into substantial breaks to reduction benefit service life of concrete structures. It is important to limit the advancement of early age little breaks quickly. When splits show up it will furtherly affect solidness of solid structures. Numerous strategies, for example, renovating in time or self-mending for cracks could drag out the administration service life of them. Distinctive methodologies are utilized to retard split proliferation and connect breaks prompting to expanded solidness of cement. The use of microbes for biological designing purposes is turning out to be progressively well known as is reflected by late reviews where microscopic organisms were connected for expulsion of

chemicals from squander water streams (Gross et al., 2007), for bioremediation of polluted soils (Chaturvedi et al., 2006) and evacuation of nursery gasses from junkyard (Jugnia et al., 2008). The relevance of particularly mineral-creating microbes for sand union and limestone landmark repair (Gollapudi et al, 1995; Stocks-Fischer et al, 1999; Bachmeier et al, 2002; Dick et al, 2006; Rodriguez-Navarro et al, 2003) and stuffing of pores and breaks/splits in cement have been as of late examined (Bang et al., 2001; Ramachandran et al., 2001; De Muynck et al., 2008a,b; Ramakrishnan, 2007). Nearly all recent survey on self-recuperating cement was by Wu et al. (2012) who highlighted on the natural and man made self-mending process. Their survey likewise secured extensive clarification on the synthetic and organic techniques. Siddique and Chahal (2011) nitty-gritty the utilization of ureolytic microorganisms for the planning of self-mending concrete. Toohey et al. (2007) surveyed smaller scale vascular as self-recuperating material. Jonkers(2007) explored on natural strategies to plan self-healing concrete in light of calcium carbonate precipitation. Al-Thawadi (2011) distinguished the system of quality improvement of sand utilizing ureolytic microorganisms and calcium carbonate development. In any case, the majority of the methodologies, for example, epoxy frameworks, acrylic tars and polymers which is silicone based, include the utilization of materials which are noncompatible with concrete, costly & for the most part unsafe to environment. If there should arise an occurrence of extreme harm, the auxiliary part is supplanted completely while repairs are endeavored for less broad harm. Unfathomable measures of cash are spent every year on review and repair as immediate and backhanded costs, the last frequently being much higher than the previous. For example, in the USA, the yearly financial effect related with looking after, repairing, or supplanting weakening structures is assessed at $18–21 billion. The American Society of Civil Engineers assessed that $2.2 trillion are required for a long time, beginning from 2012, for repair and retrofit; a cost of $2 trillion has been anticipated for Asia's foundation for a similar period. Europe spends the greater part of its yearly development spending plan on repair works, while in the UK, repair and support costs represent more than 45% of the

aggregate consumption on development. In this manner, creating inventive innovations to overcome these difficulties has turned into a dire need. Over the past couple of decades, the idea that concrete can be planned with an adequate mending ability and recuperate its splits with no outside help has been moving field of work for some exploration bunches around the globe. Self-recuperating as characterized by RILEM may be "any procedure by the material itself including the recuperation and consequently change of an execution after a prior activity that had diminished the execution of the substance" (M.R._de Rooij_and_E. Schlangen, 2011).

CHAPTER 2

A CRAFT OF REVIEWING THE LITERATURE

2.1 Huaicheng Chen, Chunxiang Qian* , Haoliang Huang (2016)

Qian et al (2016) present the prevention of early age cracks formation in concrete materials by a method of bio restoration and through which they improve the effectiveness of the self - healing process and consequently increase the strength of concrete. They represent the bio-mineralization process of precipitation of calcium carbonate by some bacteria which can heal the cracks in concrete. They mentioned this effect was earlier followed by Ramakrishnan et al. This report says that the cracks/splits formed within 7 days, bacteria can heal that fearlessly. They used bacteria named Bacillus_mucilaginous & Brewers_yeast and blended them to make a solution and put them into a suction flask with the help of ceramsite carrier and 1 hour filtration is done by vacuum pump. Glucose solution, as a supplement was incapacitated into another ceramsite carrier with the help of similar strategy. They made four specimens and did tests on them. 1st one is without any addition 2nd one with glucose only 3rd one with Bacillus_Mucilaginous and Brewers_Yeast and 4th one is the mixture of supplement and microscopic organisms in the meantime. They had made prism specimen of size 40 mm *40 mm *160 mm and cylindrical specimen of dia 110 mm & height 45 mm. After demolding they kept the specimen for curing with temperature of 20 ±2 ℃. The pre-cracks of four specimens were taken in the wake of curing 28_days. The cracks/splits were shaped on the crystal samples with the help of installed technique. The crystal samples were covered/wrapped with sticky tape prior to bowing test. The beginning splits were formed with the help of bowing burden whichever stacked to the crystals samples till the time breaks entered the cross_segment. At that point nails with various widths were implanted toward the underlying splits/crakck to accomplish distinctive width. The width of splits/cracks was quantified by the crack/splits width measuring device/apparatus with an exactness level of 0.01mm. The tempered cracks/splits samples were submerged in faucet water in a warmth condition of 30 ± 2 ^{o}C which was presented to the environment amid the entire

repair time frame. They had done the water permeability test to check the efficiency of crack healing specimen. Previously the barrel sample was thrown inn to a PVC form that's why the PVC shape could be associated with that PVC pipe. Earlier to the test conducting, the junction point was fixed firmly to keep away from spillage. At that point the water level in PVC pipe was kept in a settled tallness to keep up a consistent weight on the facial side of barrel sample. The total volume of passing water could be calculated effectively amid a timeframe. Penetrability coefficient of barrel specimen prior and then afterward mending could be computed by Darcy's Law,

K= Q. L/A. Dh

Where, k=permeability coefficient, m/s; Q=amount of water flow, m3/s; L=height of specimen, m; A=area of section, m2; Dh=head difference, m.

They had also done the flexural test after repairing with different self-healing agents. For conducting the flexural test the samples were previously stacked under 3-point_flexural_design & amassed an entirety by the help of tape. At that point, Nails* were embedded the breaks to manage the crack/split width. In the wake of curing a specific time in water, the samples were relocated as a similar testing. In results, they found the flexural quality of specimen repaired could be expanded from 56% to 72% than different strategies

They represent their results as, they had observed that ceramsite-3 was initially arranged through utilizing Bacillus_mucilaginosus and Brewers_Yeast, while ceramsite-2 was set up with the assist of utilizing glucose. At that point, the samples were made with a water to cement proportion of 0.420. In the wake of curing 28.0 days, breaks with a width of 0.40_to_.50 mm was created through the inserted technique, and the tempered broke examples were submerged in faucet water with a warmth condition of 30 ± 2 ^{o}C Once the breaks developed, the glucose and Brewers_Yeast demobilized would discharge & respond, later CO2 would create. Afterwards, carbonic anhydrase discharged through ceramsite bearer could catalyze the between change of CO2 and HCO3 to make strides the ingestion of CO2. At long last, the breaks could be loaded with the CaCO3 precipitation. The area shade of samples with ceramsite varied minimal next re-curing of 28 days in

water. Also, there was a minute increment in the area shade of samples with no bearer however microbes. In any case, the test with microscopic organisms and supplements demobilized inn to ceramsite was secured by an extraordinary amount of white precipitation. This bio-reclamation technique was further compelling inn enhancing the rehabilitate rapidity of the breaks of Cementous materials. All in all, the outcomes exhibited in this review demonstrate about bacterial self-mending strategy could be utilized for accomplish the objective of enhancing mending viability materials splits/cracks which is of cement based. From the alteration of area shading, it demonstrated about greater amount of white precipitation produced on the facial area of examples retrieved through this bio rebuilding technique next to curing of 28 days. The consequences of H_2O saturation coefficient what's more, the flexural quality of the retrieved specimens show that this bio-rebuilding technique is successful in greater extent for progressing the rehabilitate rapidity and profundity of the splits of cementitious substances.

2.2 E.Schlangen , E.Tziviloglou*, H.M.Jonkers, V.Wiktor. (2016)

Tziviloglou et al (2016) describe the innovative techniques by which autogenous recuperating of concrete is upgraded & after spliting the substance is fit for recoup H_2O snugness. Fine splits, presented to sodden conditions can often close totally. Autogenous recuperating, permits the break to seal through synthetic, physical, what's more, mechanical procedures that happen inside the crack. This paper, declared that Researchers over 10 years have taken a shot at different self-recuperating concrete ideas, with a specific end goal to improve the autogenous recuperating of cement. Among the most mainstream ideas are those which: a) point of confinement the break width by joining filaments, b) grow the concrete lattice when in contact with water by utilizing hydrogel c) present a recuperating specialist that is initiated and discharged after breaking and d) join the past. As of late, self-mending concrete which is blended to microbes has strained a considerable measure of consideration. The applicable premises of a self-recuperating material, that’s the capacity to isolatel the break & recapture H_2O snugness, essentially researched in an unexpected way. Keeping in mind the end goal to survey the recuperation of

water snugness a great many splitting and mending, different reviews have created a few break porousness experiments. The point of this review is for examine what sort of the expansion of mending operator influences the new & solidified state premises of the mortar & to assess the RWT in the wake of breaking and recuperating through two diverse mending medications. The microscopic organisms based recuperating specialist comprised of germ-cells got out of alkaliphilic microscopic organisms of the family Bacillus and natural mineral mixes. Three sorts of blends were researched. 1st is reference blend (REF) with ordinary weight totals, 2nd is control blend (CTRL) with non-fertilized LWA & 3rd is blend with fertilized LWA. The mending operator is fused in LWA through an fertilization under vacuousness with calcium lactate (200 g/L), yeast extrication (4 g/L) and microbe germ-cells (108 germ-cells/L) arrangement. Microscopic organisms based mending specialist comprised of spores got from alkaliphilic microscopic organisms of the sort Bacillus and natural mineral mixes. The mending operator is fused in LWA by means of an fertilization in a vacuousness condition with calcium lactate (200 g/L), yeast separate (4 g/L) and microbes germ-cells (108 germ-cells/L) arrangement. Quickly in the wake of blending, three new condition mortar premises were tried, i.e. consistency, bulk density & air content. Flexural strength & compressive strength was resolved on 3rd day, 7th day & 28th day aged (unreinforced) samples. Comparison was led in two stages; first on new blends and afterward on solidified prisms. The tests uncovered about the supplanting of sand with LWA prompts to significant lessening of the mass thickness and leads to expand the air content, at the same time, it barely influences the firmness/consistency of the new blend. Moreover, the nearness of the mending specialist appears to influence the greater part of the previously mentioned attributes driving in a lesser weight and more smoothly moving blend. Tests uncovered that the mending specialist influences fundamentally the solidified properties of the blend at 3 years aged days, driving in a weaker material. Be that as it may, after the completion of 7 days the flexural strength of each of the three sorts of blends drops in a similar horizone. Furthermore, the compression strength of samples with NWA is always greater at all duration of time (3rd , 7th and 28th

days) contrasted with the further two blends with LWA. Also, both CTRL & fertilized light weight blends demonstrate a very comparative compressive strength followed by the duration of 7 days.

2.3 W. Verstraete, N. De Belie*, J.Y. Wang, H. Soens, (2014)

Belie et al (2013) illustrate, Microbial CaCO3 is viewed like earth benevolent & conservative material which has a auspicious possible for has an extensive variety of engineering operations. The essential rule of operating microbial CaCO3 being self-mending cement is that microscopic organisms and alternative significant specialists are included inn to the solid lattice amid casting. When breaks show up, microscopic organisms around the break surfaces will be actuated (by dampness, O2, and so on.) and hasten CaCO3 to mend the breaks. In this review, microbial CaCO3 was accelerated by Bacillus_sphaericus through urease catalyzed urea hydrolysis. Because of the cruel environment inside the concrete, epitome or demobilization of mocrobe in a defensive transporter prior to adding that microbes to the concrete is best. Microcapsules were utilized as bacterial transporters. The Microcapsules were impervious to the high pH of cement and stickiness delicate. They are adaptable under high moistness (like in water) and get to be weak at low dampness. This means that the containers can withstand the blending process and are effectively broken when breaks show up. The point of this exploration was to illustrate the possibility of utilizing microencapsulated spores to lf recuperate splits in a cementitious grid. Recuperating prevalence in the specimens with bio-operators was watched following 40 days; the most extreme cracks width recuperated achieved 0.46 mm. B. sphaericus spores were created in the minimal basal salts (MBS) medium. The MBS medium was autoclaved at 120 °C for 20 min before utilize. Develop spores were exchanged as inoculum (1%) into MBS medium. The way of life was hatched (28 °C, 100 rpm) for 28 days. Six arrangement of samples were contrived and the piece were specimens without any additions, specimens with all nutrients needed for bio precipitation, specimens with the microcapsules (3%) without bacterial spores, specimens with nutrients and microcapsules (3%, no bacterial spores loaded), the specimens with nutrients and

microencapsulated bacterial spores. Due to addition of the microcapsule the mechanical properties of the concrete degraded. Compressive strength decrease drastically by 15% to 34 % by addition of 1% to 5% of microcapsule. Split tensile strength degraded with 3% addition of same. They prefer addition of nutrient as compare to microcapsule as they had less negative effect on long term strength of concrete than later one. They had reported that cracks were healed within 3 weeks after test was performed. The cracks recuperating proportion in the specimens without micro-encapsulated spores was in the scope of 18% to 50% in the specimens following 8 weeks (56 days) under various brooding conditions. As a rule, two primary mechanisms are in charge of the autogenous mending: consequential hydration of the unhydrated cement particles and precipitation/gathering of calcium carbonate. Other than that, the swelling of the hydration items additionally adds to the abatement of the break region. The recuperating productivity from this source is significantly subject to the age of the concrete, the water to cement proportion (w/c) and the accessible water in the cracks. Autogenous mending from the precipitation of calcium carbonate could happen in a concrete. The most extreme split width mended in the samples of the microscopic organism's arrangement was 970.0 μm, which was much more extensive (around 4 times) than that in the specimens of non-microbe arrangement (max 250 μm). The by and large water porousness in the micro-organisms arrangement was additionally lower than that in non-microscopic organism arrangement. It was seen that free water is the basic part to acquire huge measure of self-mending, both for the specimens with and without embodied bacteria.

2.4 Wasim Khaliq*, Muhammad Basit Ehsan (2016)

Khaliq et al (2016) presents that among all the strategies of self-healing process like acrylic resins, polymers basically of silicon & epoxy systems, bio-influence self-healing concrete is best. As it is not hazardous to environment and also economic. Bio cement is an item which includes recuperating of splits/cracks by generation of mineral mixes with the help of movement of microbes in the concrete_marerial. Independent mending with the help of this procedure builds

auxiliary sturdiness by lessening in concrete splits/cracks and then again decreases the support required for fortified concrete structures. Self-mending procedure is specifically identified with the generation of calcium carbonate that is relies upon many variables including pH level of concrete material, broke down nucleation locales, nearness of calcium particles & inorganic carbon, all through the blend. Among the diverse microscopic organisms equipped for break mending and its joining strategies in concrete utilized for self-mending reason, there is have to recognize the adequacy of microscopic organisms to be specific, "Bacillus_subtilis", presented in concrete material by various fuse methods. The impacts of all expained strategies on size of break mending & significance of impact on compressive quality of cement is likewise visualized vital. The bacteria which is used for self-mending of concrete must be uphold in some situation like It must have the capacity to acclimate to basic/alkaline environment in concrete to the creation of $CaCO_3$, it ought to deliver extensive measure of $CaCO_3$ in absence of being influenced by Ca(calcium) particle fixation, it surely have the capacity to confront greater weight and ought to be O_2(oxygen) splendid to expend much O_2(oxygen) furthermore, reduce consumption of steel. So “Bacillus subtilis” is selected because it fulfills all the requirement. In this investigation, different types of 4 blends are used. The mixture are 1st one is Control specimens, in which no bacterial spore examples were included, 2nd one is bacteria were fused straightforwardly by blending the microbial arrangement in H2O amid blending of concrete, in absence of utilization of any defensive transporter mixes, 3rd one is Similarly, those joined with microscopic organisms by the utilization of LWA as defensive transporter, 4th one is specimens incorporating GNP as a mean of microscopic organisms presentation, Keeping in mind the end goal to join microbes, LWA were continuing absorbed microbial answer for 24 hrs till they were soaked preceding their blending in cement. The blend extent for these four unique classifications of samples included conventional Portland cement(OPC). To a compressive quality of 4000 psi was intended to the blend. After 24 hours of casting the specimens were sent to the curing process and the test for compressive strength was done for 3,7,14 and 28 days and after that kept the specimen for the scanning electron microscope (SEM)

and XRD analysis. Generally, it is seen that all microbial consolidation strategies give outcome as in expanded compressive strength of the blend. 29.43 Mpa of Maximum strength was got by the specimen possessing LWA as a transporter compound for microbes fuse and achieving 12% more compressive strength then control specimen. GNP containing samples demonstrated an expansion in compressive strength of 9.8%. GNP is filler material. Insignificant greatness of GNP similarly lessens the game plan of weak interfacial move zone (ITZ) in cement by allowing filling of penetrable and crystalline internal microstructure of ITZ. Mortar network become denser by diminish in ITZ & smaller bringing about higher compressive quality. Compressive strength patterns of all blends recommend that, expansion of microscopic organisms "Bacillus subtilis" brought about slight increment in compressive strength, regardless of the consolidation system, with noteworthy change through LWA strategy.

2.5 R. Alghamri*, A. Kanellopoulos, A. Al-Tabbaa (2016)

Alghamri et al (2016) describes the how self-healing property of bio concrete is cheaper and eco-friendly and how much it has scope for future development of the construction industry. They portrayed the types of self-recuperating forms inside cement based materials. i.e. of two forms, one is autogenic and another one is autonomic. Autogenic self-mending is the wonder where the material mends breaks utilizing its own bland parts and constituents. Autonomic self-mending be that as it may, includes the utilization of built options that are not traditionally included into cementitious materials. These options are added particularly to improve self-mending capability. Material used in this project were sodium silicate solution with Density at 20 ‘C 1.39 g/mL, rounded course of size 4-8 mm and angular fine aggregates of size 0-4 mm, cement used in this analysis was with a particle density of 2.7–3.2 g/cm3 and a specific surface area of 0.30–0.40 m2/g. Lightweight aggregates with a width scope of 4–8 mm were filled with a sodium silicate arrangement as a potential self-recuperating operator. Following 28 days mending in water, the examples containing the impregnated LWA indicated 80% recuperation of the pre-splitting strength, which accounts more than five

circumstances of the control samples' recuperation. X-ray diffraction investigation (XRD), Fourier transform spectroscopy (FTIR), and scanning electron microscopy (SEM) tests were utilized to describe the created recuperating items by the researchers. In both specimens, precious stone testimonies can be watched, demonstrating that the control samples had experienced a certain degree of autogenous recuperating amid drenching in water. Hence, incomplete filling at the cracks appearances can be seen on the control samples. Break surfaces at the examples with sodium silicate impregnated LWA were fixed totally inside 28 days. In this paper, the filling of lightweight aggregates by a fluid self-mending mineral and after that their exemplification in a polymer-based covering layer was recommended as a technique for change the self-mending execution of concrete composites. The achievability and productivity of this strategy were examined with reference to strength recuperation, water snugness, and split conclusion what's more, checked by microstructure examination for the mending products. The SHM examples demonstrated a viable and surprising execution in examination with control examples in both split fixing what's more, quality recapture parameters. This was accomplished without relinquishing the normal mechanical properties of the concrete samples. For example, the impregnation of the LWA particles with sodium silicate prompted to enhance quality recover by more than five times and diminish the narrow water assimilation to about a half. This demonstrates extremely encouraging outcomes contrasted and a number of the other beforehand recommended methods. XRD, FT-IR and SEM systems are exceptionally valuable to give data on the compound organizations of the mending materials, which bolster the past outcomes about the commitment of sodium silicate in delivering more calcium silicate hydrate (C–S– H) gel to recuperate the splits.

2.6 Mian Luo*, Chunxiang Qian (2016)

Luo et al (2016) presents in this paper that at the point when the splits/cracks in concrete, the torpid germ_cells could be initiated by the H2O what's more, O2(oxygen) penetrating with the help of the breaks. At that point, the substance in the splits/cracks moving from cementitious_materials framework could be

metabolized with the help of the initiated microscopic organisms to deliver CaCO3 gathering/precipitation next to a progression of bio_chemical responses & accomplish the reason for break self-bending. The comes about demonstrated that microscopic organisms based self-recuperating operators could enhance the capacity of cementitious_materials splits/crack self-rehabilitation and decrease the likelihood of disintegration medium through the breaks inn to the lattice coming about in change of the substance toughness. It is critical to examine the similarity between microscopic organisms based self-recuperating specialists and cementitious materials. They use the bacteria named Sporosarcina pasteurii to repair the concrete splits. This review researched the impacts of three sorts of microorganisms construct self-mending operators with respect to the compressive quality, rheology, & hydration energy of cementitious_materials to additionally check the plausibility of microscopic organisms basically self-recuperating for split rehabilitation. In this paper, the researchers used the three types of specimens to repair the cracks, i.e. RB, JB and NB. RB operator was comprised of calcium lactate (R) and microbe's spores powder (B), JB operator was comprised of calcium formate (J) & microbe's spores powder (B) what's more, NB operator was comprised of calcium nitrate (N) and microbes germ-cells granulate (B). Germ-cells-shaping salt safe microscopic organisms were utilized for current review. The micobes were cultivated in the culture_media where 5.0 gram of peptone and 3.0 gram of yeast extract is used per liter of distilled H2O, which was sanitized at 121.0 ^{o}C for 25.0 min. They used the water cement ratio of 0.4 and used instrument named Micrometrics Auto Pore IV 9500, which has a pore/vent measuring go somewhere around 0.00360 and 400.0 lm distances across. The rheology of bond mortar was essentially enhanced through expansion of the basically microbes self-mending operators. Fuse of microscopic organisms based self-recuperating operators in cement significantly impacted the hydration energy. The self-recuperating operator RB could defer the hydration of cement bringing about conclusive setting time increment, nontheless the self-mending specialists JB and NB quickened the hydration bringing about beginning & last setting time diminish. What's more, compressive strength testing outcomes appeared that consolidation of RB in

concrete mortar brought about compressive strength decline, yet the 28 days' compressive quality expanded contrasted with control. Joining of JB in concrete mortar upgraded compressive quality, however fuse of NB in bond mortar could bring about undesirable compressive_strength degradation.

2.7 Henk M. Jonker*, Arjan Thijssena, Gerard Muyzerb, Oguzhan Copuroglua, Erik Schlangena (2010)

Jonker et al. (2010) The use of cement is quickly increasing worldwide and in this way the advancement of manageable cement is desperately required for natural reasons. As in the blink of an eye around 7% of the aggregate anthropogenic barometrical CO2 outflow is because of bond generation, systems that would add to a more drawn out benefit life of concrete structures would make the material grounded as well as more practical. A particular gathering of soluble base safe spore-framing microscopic organisms identified with the sort Bacillus was chosen for this study. Particularly they used the Bacillus pseudofirmus, B. cohnii. Ordinary Portland cement was used in this study and cement to water proportion was 0.4 or 0.5. The fundamental goal of this review was to build up whether bacteria joined in the concrete stone network could go about like self-recuperating operator to catalyze the procedure of self-governing repair of naturally shaped breaks. One noteworthy issue connected with break development is that the procedure brings about an exceptional increment in material permeability expanding the danger of framework and embedded support debasement by ingress water and other forceful chemicals. The procedure of bacterial mineral arrangement from calcium lactate speaks to an option instrument to the urease-based framework explored in past reviews. As opposed to the last component, metabolic transformation of calcium lactate does not come about underway of huge measures of smelling salts what radically builds the danger of support consumption and corruption of the solid grid especially when further oxidized by microscopic organisms to yield nitric acid. The reasonableness of the microbes connected in this review as self-mending specialist unmistakably relates to their ability to shape spores, which are known to have the capacity to withstand high mechanical powers and are portrayed by a long-term

feasibility of up to 200 years under dry conditions. Nonetheless, it is seen in this review evidently time related diminished usefulness is likely identified with the watched loss of suitability of cement stone consolidated bacterial spores. In turn, the loss of spore suitability has all the earmarks of being connected to the proceeding diminish in framework pore measurement sizes as MIP investigation uncovered that the bigger size class (0.1–1m pores) still present in youthful (3 and 7 days cured) samples nearly vanished in support of the littler (0.01–0.1m) estimate class in 28 days cured samples. While pores of the bigger size class exhibit in youthful samples can in any case oblige bacterial spores with common measurements of 0.8–1m, the lion's share of joined spores obviously turned out to be squashed in matured examples, coming about not just in loss of feasibility additionally in decreased mineral-shaping limit. At the conclusion of this study the researchers said that antacid safe spore-framing microorganisms identified with the class Bacillus speak to promising applicants for application as self-recuperating specialist in concrete and most likely other bond based materials.

2.8 Virginie Wiktor*, Henk M. Jonkers (2011)

Wiktor et al(2011) represents that measure the split mending capability of a particular and novel two-segment bio-synthetic self-recuperating specialist implanted in permeable extended dirt particles, which go about as store particles furthermore, supplant a portion of customary concrete aggregate. Upon break arrangement, the two-part biochemical operator comprising of bacterial spores and calcium lactate are discharged from the molecule by split entrance water. The essential drivers of autogenic recuperating are thought to be founded on synthetic, physical, and mechanical forms. In this study, they used “Bacillus alkalinitrilicus” an antacid safe soil bacteria. In investigation the the instrument used by researchers are environmental_scanning_electron microscopy (ESEM), energy_dispersive_spectroscop,Energy_Dispersive_X-ray element_analyzing_system & Fourier-Transform_Infrared_(FT-IR)_spectrometry. Oxygen is devoured by vigorous bacterial metabolic change of calcium lactate. We along these lines utilized as a part of this review optical oxygen microsensors (small

scale optodes) for the measurement of oxygen utilization of water submersed control-and bio-concoction recuperating operator containing mortar samples. The fundamental procedures required in this abiotic autogenous mending were credited to: (a) bulging and hydration of concrete glues, (b) precipitation of calcium carbonates precious stones, and (c) blockage of stream ways because of testimony of water debasements or development of concrete sections that separate amid the splitting procedure. While in this review we concentrated on utilization of microscopic organisms as inbuilt recuperating operator, in a few past reviews the impact of outer bacterially initiated carbonate precipitation on building materials and in soils was researched Exploratory outcomes indicated make mending of wide to 0.46 far reaching breaks in bacterial concrete yet just up to 0.18 all-inclusive splits in control mix following 100 days submersion in water. That the watched multiplying of break mending potential was to be sure because of metabolic movement of microscopic organisms was bolstered by oxygen profile estimations which uncovered O_2 utilization by microorganisms based yet not by control mix.

2.9 Mian Luo, Chun-xiang Qian ⇑, Rui-yang Li (2015)

Luo et al (2015) represents the idea about self-healing concrete and they present that the impact of crack width, curing ways and splitting/cracking age on the split self-recuperating of concrete glue with microbial self-mending specialist was looked into by the portrayal techniques for territory repair rate and against drainage repair rate. The researchers used Electron_Microscope_(SEM) outfitted with an Energy_Dispersive_X-beam_Spectrometer (EDS), and after that analyzed by X-beam_Diffraction (XRD). The outcomes demonstrated that the microbial self-mending specialist could be utilized to accomplish the objective of solid break self-recuperating. The precipitations framed at the breaks surface were calcite, which showed up lamellar close pressing morphology. At the point when the splitting age was more than 60 days, the split recuperating proportion was little. The outcomes above proposed that the ideal conditions were required for the pragmatic utilization of microbial self-recuperating specialist. Breaking builds the likelihood of entrance of forceful substances into the concrete, jeopardizing the strength of the material.

For the most part, breaks are repaired by hand, which is inadmissible on the grounds that splits are frequently difficult to distinguish and the support and repair cost is high. As needs be, self-recuperating of broke cement would be profoundly valuable and examining on self-mending concrete has been generally did. The general water penetrability in the microbe's arrangement was around 10 times lower than that in non-microorganism's series. Spore-framing soluble base safe microbes were utilized for this review. The microorganisms were refined in fluid medium containing 5.0 g peptone and 3.0 g yeast extricate per liter of refined water (pH = 7), which was autoclaved at 121 ^{o}C for 25 min. After immunization on laminar stream, the medium was hatched at 30 ^{o}C on a shaker at 170 rpm for 24 h. The convergence of microscopic organisms in the suspension was 109 cells/mL.It can be seen that the breaks was mended by white precipitations. The mending proportion of various width breaks was distinctive. The break with a width of 0.3 mm was about completely mended following 20 days of inundation in faucet water, while break with a width of 0.8 mm was just mostly mended.

2.10 Jianyun Wanga, Jan Dewanckele, Veerle Cnudde, Sandra Van Vlierberghe, Willy Verstraete, Nele De Belie* (2014)

Belie et al.(2014) demonstrate that the break conclusion conduct of the examples with/without bio-hydrogels was considered quantitatively by light microscopy. To have a perspective of the self-recuperating inside the samples, a high determination X-beam registered microtomography (X-beam lCT) was utilized. The bacterial strain utilized as a part of this examination was Bacillus sphaericus. The bacterial spores were epitomized into the hydrogel amid the procedure of crosslinking. The suspension of the spores was initially blended with the 20% w/w polymer arrangement (Pluronic-BMA). At that point, the initiator was likewise added to the arrangement. The entire blend was degassed and blended for 5 min, and was subjected to UV radiation for 1 h after which a gel sheet shaped. The aggregate sum and the appropriation of the mending items in the entire lattice were examined. This review shows that the examples fused with bio-hydrogels had particular moved forward recuperating effectiveness contrasted with the reference ones with

unadulterated hydrogel as it were. They used 2D_light_microscopy, a famous method use to crack closure purpose. The recuperating proportions in the examples with bio-hydrogels were in the range from 70% to 100% for the breaks littler than 0.3 mm, which is more than half higher than for the ones with unadulterated hydrogel; and the most extreme break connecting was around 0.5 mm (in 7 day), while unadulterated hydrogels just permitted recuperating of breaks of around 0.18 mm. The aggregate volume proportion of the mending item in the examples with bio-hydrogels added up to 2.2%, which was around 60% higher than for the ones with unadulterated hydrogel (1.37%).

2.11 Jianyun Wanga, Kim Van Tittelboom a, Nele De Belie*, Willy Verstraete (2012)

Belie et al(2012) described a promising route is to pre-include mending operators to the concrete to mend early age splits when they show up, i.e. the supposed self-mending approach. Notwithstanding the all the more usually concentrated polymeric mending materials, bacterial CaCO3 precipitation likewise can possibly be utilized for self-recuperating. It is better with the concrete framework what's more, it is environment cordial. Be that as it may, bacterial movement diminishes a ton in the high pH (>12) environment inside cement. In this investigation, the likelihood to utilize silica gel or polyurethane as the transporter for ensuring the microorganisms was researched. The bacterial_strain utilized as a part of the trials was B. sphaericus. This strain has a high urease action (40_mm urea hydrolyzed. OD1 ,h1), long survival time and can deliver CaCO3 in a basic and administrable way. Researchers used Thermogravimetric-analysis(TGA) to recognize the arrangement of CaCO3 inside the silica gel and PU foam and also used Scanning electron magnifying lens investigation. The mending effectiveness was additionally explored by measuring the water penetrability after crack mending. Exploratory outcomes demonstrate that silica gel immobilized microscopic organisms displayed a higher action than polyurethane immobilized microscopic organisms, and consequently, more CaCO3 accelerated in silica gel (25% by mass) than in polyurethane (11% by mass) in light of thermogravimetric. Be that as it may, crack

mortar samples mended by polyurethane immobilized microscopic organisms had a higher quality recover (60%) and bring down water porousness coefficient (10.10–10.11 m/s), contrasted and samples recuperated by silica gel immobilized microorganisms which demonstrated a quality recapture of just 5% and a water penetrability coefficient of (10.7–10.9 m/s). The outcomes showed that polyurethane can possibly be utilized as a bacterial transporter for self-recuperating of concrete splits. It is promising to utilize polyurethane immobilized microscopic organisms to self-mend early cement small scale breaks. Additionally, research is required to expand the measure of bio-CaCO3 to get more self-recuperating productivity.

2.12 Ravindranatha, N. Kannan, Likhit M. L (2014)

Likhit et al(2014) explore data about the goes for expanding the quality and the aggregate toughness of the concrete utilized as a part of the present day by presenting microorganisms (Bacillus pasteurii) in this research. This smaller scale living being is a dirt bacterium. Bacillus pasteurii shows a marvel referred to as bio-calcification as a piece of its metabolic movement. Bio-calcification is a procedure through which the small-scale organism remotely secretes calcium accelerate, which within the sight of a carbonate particle shapes CaCO3 which tops off the voids in the solid surface in this manner making it more conservative. This in turn enhances the quality in cement because of development of the filler material inside the pores of the solid blender. An examination study was made with solid 3D shapes and bars subjected to compressive and flexural quality tests with and without the bacterium. The bacteria turned out to be effective in improving the properties_of_the_concrete by accomplishing a high starting strength increment and in this manner, we can presume that the created calcium carbonate has filled some rate of void volume in this manner making the surface more reduced and resistive to leakage. At the point when bacterial cement is completely created, it might turn out to be yet another option technique to supplant OPC and its risky impact on ecological contamination. Thus can be utilized for development as it is impervious to erosion also.

2.13 Chew Tin Lee ,Mohamad Ali Fulazzaky, Amirreza Talaiekhozani, Muhd.Zaimi Abd Majid* (2014)

Majid et al.(2014) describes the how microbial_concrete makes utilization of calcite precipitation by ideal microscopic organisms. In this method urolytic microorganisms (microorganism) are utilized henceforth the solid is called Bacterial or Microbial cement. The "Microbial cement" can be arranged by including spore framing microbes in the solid that can ceaselessly encourage calcite, this procedure of creation of calcite precipitation is called Microbiologically Induced Calcite Precipitation (MICP). The Calcite precipitation involves the voids between bond grids and in this way prompts to denser cement. The fundamental rule for this procedure is that the microbial urease hydrolyzes urea to deliver alkali and carbon dioxide furthermore, the smelling salts discharged in encompassing hence expands pH, prompting to gathering of insoluble calcium carbonate They presents the greater utilization of bio_concrete like enhancement of compressive strength, corrosion_resistance, eco_friendly behavior, reduction of freeze & thraw attack. The utilization of microbial cement to development may likewise improve a portion of the current development forms and upset the methods for new development forms.

CHAPTER 3

SCOPE AND OBJECTIVE OF THE STUDY

3.1 OBJECTIVE OF THE STUDY:

In this investigation, experimental study on strength properties of Bio-Concrete is done. Here, this thesis work reveal how microbes can use as a durable material for concrete. In the present work, partial replacement water is done with different percentage the microbes like 2% and 4% and by taking starch percentage constant as 2%. The parameter that are consider for the research study are compressive strength and flexural strength.

Main Objective of The Study:

1. Study on different proportions of concrete blend.
2. Study about the mechanical properties of specimens.
3. Determine the percentage variation on different concrete mixture.
4. To compare the different concrete blend with the control blend.
5. To determine the exact percentage on which concrete mixture give optimum results.

3.2 SCOPE OF THE STUDY:

This investigation is all about replacement of water with microbes and starch and comparing the mechanical properties of specimens.

1. This inspection is done for compressive and flexure strength which may extend to split tensile strength and some chemical and physical properties also may studied
2. In this study microbes are directly mixed with the concrete blend, it may mix with the help of encapsulation process and impregnation of LWA technique.
3. Partial replacement of microbes can done also cement percentage.

4. In spite of starch, which is used as food for bacteria, some other material may use which has carbohydrate origin.
5. This study is done for IS codes, same may be considered with ASCE code.

CHAPTER 4

MATERIALS AND RESEARCH METHODOLOGY

4.1 GENERAL:

In this chapter, the results obtained from testing of various materials, which is used for further casting purpose (cube & beam) is presented. The tested materials are cement, fine aggregate, course aggregate (10mm & 20mm). The mechanical properties of materials used to make the concrete mix, are checked in Concrete Laboratory according to the relevant code of practice.

4.2 MATERIAL:

Fig 4.1: Picture of materials used (aggregate, sand, cement, water, microbe)

4.2.1 Portland Cement:

Cement is one of the most important constituent of concrete, which possesses strong adhesive premises. It binds all other ingredient of concrete through a series of chemical reaction known as hydration reaction with the help of water and does it hardens. Cement is a bluish grey colored fined powder, which is manufactured by smashing, milling and proportioning of CaO (calcium oxide, 67% - 61%), SiO_2 (silica, 23%- 19%) & Al_2O_3 (alumina, 6%-2.5%) in a kiln at 2600 F. Portland cement also called Ordinary Portland Cement (OPC) is categorized into three grades i.e. OPC 33 grades, 43 grades, 53 grades on account of their 28day

compressive strength. In the current study, OPC 43 grade of cement is used for mix design.

Table 4.1: Cement Properties: OPC 43 grade of cement.

S. no.	Characteristic of cement	Values obtained by experimental investigation	Values specified by IS8112:1918
1	Fineness of cement	1.5%	Less than 10%
2	Standard consistency of cement	30.5%	
3	Specific gravity	3.145	3.15
4	Initial setting time	45 minutes	30minutes(minimum)
5	Final setting time	290 minutes	600minutes(maximum)
6	Soundness of cement	3.5 mm	Less than 10 mm

4.2.2. Aggregate:

Aggregates are the crushed stone which forms a predominant part of concrete mixture by making concrete unyielding. Aggregate provides firmness and makes dense the resulting mix when using two or more dimensions of it. Fine aggregate fills the pores and most essential capacity of it to help with creating workability and consistency in mixture. It facilitates the cement paste to clasp the coarse aggregate to respite.

4.2.2.1. Coarse aggregate:

Crashed stone whoever sized from 10mm- 20mm which retained over IS sieve 4.75mm is used as course aggregate in casting the concrete. As to qualities of various sorts of aggregate, coarse aggregate has a tendency to enhance the strength of the concrete material by interlocking the angular particles while the smooth round shaped aggregate helps in fluidity of the fresh concrete mixture. Aggregates are locally available which is used in concrete mix after removing the dirt and dust particle and drying it in oven. IS 383:1972 is used for the specification of coarse aggregate. Below the testing results of coarse aggregate is discussed.

Table 4.2: Properties of coarse aggregate

Characteristic	Values
Color	Grey
Shape	Angular
Maximum size	20 mm
Minimum size	10 mm
Specific gravity of 20 mm	2.75
Specific gravity of 10 mm	2.72

Table 4.3: Sieve analysis for 20mm coarse aggregate

Sr.no	IS-Sieve (mm)	Wt. Retained (gm)	%age retained	%age Passing	Cumulative % retained
1.	80	0.00	0.00	100.00	0.00
2.	40	0.00	0.00	100.00	0.00
3.	20	59	1.97	98.03	1.97
4.	10	2932.4	97.75	.28	99.72
5.	4.75	5.8	0.19	.09	99.91
6.	Pan	2.80	0.09	0	
7.	Total	3000.0		Sum	(201.6 + 500)/100 =7.016

Note: Total Wt. of coarse aggregate taken= 3000 gram

Table 4.4: Sieve analysis for 10mm coarse aggregate

S. no.	IS- Sieve(mm)	Wt. retained (gm)	%age retained	% passing	Cumulative retained
1.	40	0	0	100	0
2.	20	0	0	100	0
3.	10	2022	67.40	32.60	67.40
4.	4.75	933	31.1	1.5	98.5

5.	Pan	45	1.5	0	
6.		Total =3000 gm		sum	165.9
					FM = (165.9 +500)/100=6.66

Note: Total Wt. of coarse aggregate taken= 3000 gram.

4.2.2.2. Fine aggregate:

Fine aggregate is found from natural disintegration of rocks and by crushing natural gravel and by crushing hard stone. According to IS 383:1970, depending upon the region from where it is available, is divided into four parts i.e. Zone I, II, III, IV and it should retain in IS sieve 4.75mm. In the present study, brown sand is used for the casting of specimen.

Table 4.5: Sieve analysis for Fine Aggregate

Sr no.	**IS-Sieve** (mm)	**Wt. Retained** (gm)	**%age retained**	**% passing**	**Cumulative retained**
1.	4.75	13.5	1.35	98.65	1.35
2.	2.36	35	3.5	95.15	4.85
3.	1.18	240.5	24.05	71.1	28.9
4.	600 μ	207.5	20.75	50.35	49.65
5.	300 μ	294.5	29.45	20.9	79.1
6.	150 μ	179	17.9	3	97
7.	pan	30	3.0	0	
8.				sum	260.85
					260.85/100= 2.60

Note: Total Wt. of fine aggregate taken= 3000 gram.

4.2.3. Water:

Plain portable water is conventionally measured equitable when blending and curing of concrete. Water which is available for curing and blending purpose,

having pH of 7 and free from impurities. Pure water is also not suitable to use with OPC, it is good to use with high alumina cement.

4.2.4. Bacteria:

In this thesis, Bacillus subtilis is used which is derived from alkaliphilic bacteria of the genus Bacillus with starch powder blend properly in water and utilize in concrete mixture. The machine used for the production of these bacteria were autoclave, laminar flow air flow, BOD incubator. The culture medium was autoclaved at 121^{o}C for 20 minutes at a pressure of 15 psi. The cultures medium was incubated 37^{o} C, 120 rpm for 24 hours. These bacteria would produce the spores which can live further and heals cracks by enhancing mechanical properties.

Fig4.2: Picture of Bacteria

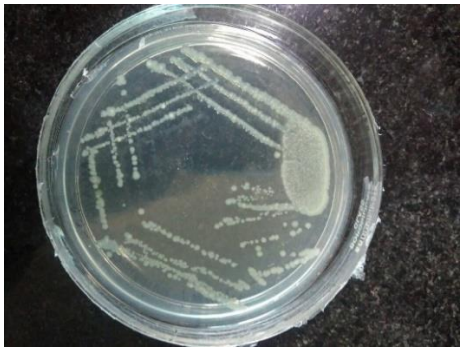
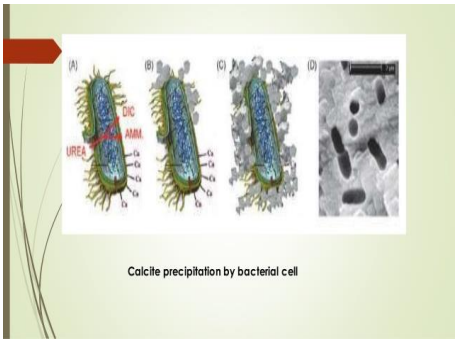


Fig 4.3: Picture calcite precipitation of bacterial cell.



MECHANISM:

Microscopic organisms based self -healing specialists are accepted to remain rested inside the concrete up-to two hundred years. When due to enormous reasons the cracks & pores appear inside the concrete structure, these microbes are help to heal that. When there is any pores or cracks inside the concrete the water is consciously going inside the pores or cracks and the precursor is activated. Activated precursor orderly persuade the microbes to react with that precursor & form CaCO3 (limestone) which is act as a healing(filler) material for the pores or cracks. During the time spent, encouraging Calcite crystal through nitrogen cycle the dissolvable supplement are changed over to insoluble caco3, in this way sealing it up.

$$Ca(C_3H_5O2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$$

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O \text{ (carbonation)}$$

Bacteria may inject into the concrete material through following process.

1. Mix the microbes with concrete when it is mixing in site i.e. before keeping the concrete mix in the mould. Bacteria is directly poured to the fresh concrete and after that mix it well & put the concrete in to mould.
2. Impregnation of Light Weight Aggregate with calcium lactate solution & spores of bacteria. In this process, a part of course aggregate is replaced by LWA & it is act as a carrier compound for the microbes.
3. Micro capsulation process to encapsulate the bacterial spores in bio-concrete. Micro capsulation is used to ensure protection of bacteria from the harsh environment of concrete. In preliminary state these encapsulate bacteria is immobilized state. But when the pressure inside the concrete is increased then capsules are broking down & bacteria come with the contact of concrete material directly and start reacting with the help of water present there.

4.5. TEST METHODS:

The testing strategies which is operate for testing of cement, fine aggregate, coarse aggregate and concrete are stated below:

4.5.1. Specific Gravity:

Specific gravity is proportion of the heaviness of a given volume of a substance to the heaviness of an equivalent volume of some reference substance, or identically the proportion of the masses of equivalent volumes of two substances.

4.5.2. Sieve Analysis for Coarse and Fine Aggregates as per IS: 2386 (Part I) – 1963:

The Sieve Analysis is utilized for the assurance of molecule size dispersion and fineness modulus of fine and coarse aggregate by sieving or screening process.

4.5.3. Slump test:

Slump test quantifies concrete fluidity and workability along with, it educates us regarding the concrete consistency and firmness. The consistency shows the measure of water included and generally utilized as it is straightforward and less mechanical assembly required. It gauges the workability of crisp concrete.

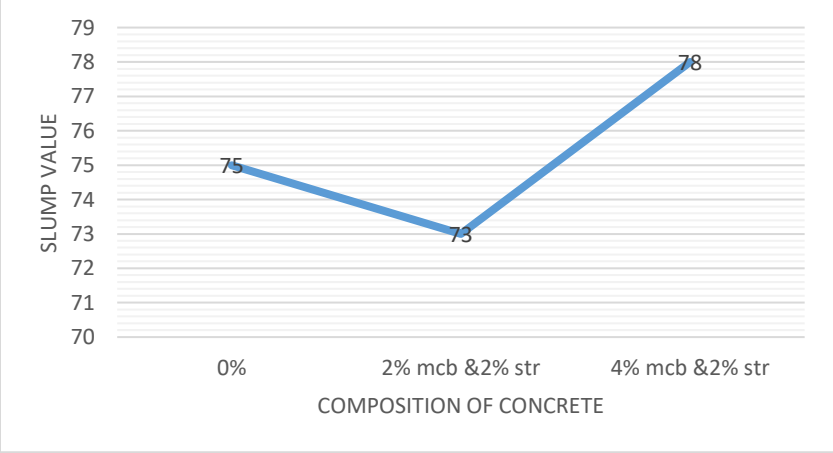
4.3.3.1. Principle

To estimate the consistency and wetness of concrete, slump cone test is utilized under the action of gravity. Apparatus required for this test are slump cone, tamping rod, scale for measurement. Slump cone used for this test having dimension like 300mm height, 200mm base diameter and 100mm top diameter. The rod having diameter of 16mm and length 500mm. The base is placed in a smooth tray where slump cone is filled with three layers by tamping each layer 25 blows. After that, uplift the slump cone in vertical direction and measure the uppermost unsupported concrete height with the help of scale, which is the slump value.

Table 4.6: slump value when % replacement of water with microbes and starch.

% of microbes and starch	Slump values(mm)
0%	69
2% mcb &2% str	65
4% mcb &2% str	73

Figure 4.4: Graphical representation of slump values



4.6 Compressive Strength Test:

3-dimensional cube specimen bearing size 150 x 150 x 150 is withdrawn from the curing tank at the time interval of 7 days, 28 days and 56 days and place it in room temperature for some times to get surface dry. After drying the surface, place it in the compression testing machine in right angle to that as cast and applying load gradually without giving it any type of shock according to the IS 516:1959. Loading is given to the specimen until proper break down of cube is occurred. From CTM, result getting in kilonewton which is applied 150 x 150 surface area of cube from the display screen and convert into N/mm^2 by using the formula P\A, where P= applied load and A= surface area of cube and note it down.

Fig 4.5: Compressive strength test of cube

4.7 **Flexural Strength Test**:

3-dimensional beam specimen bearing size 500 x 150 x 150 is casted to calculate the flexural strength of it. It is withdrawn from the curing tank at the time interval of 7 days, 28 days and 56 days and place it in room temperature for some times to get surface dry. After drying the surface, place it in the compression testing machine and tested it for two-point loading, at one third from both the end and load is applied gradually without giving it any type of shock. Loading is given to the specimen until proper break down of beam is occurred. From CTM, result getting in kilonewton which is applied 500 x 150 surface area of beam from the display screen and convert into N/mm^2 using the formula written below and note it down.

Formula for flexure= PL/bd^2

Where P=applied load by CTM, L= effective length of beam, b=breath of beam, d=depth of beam.

When ‘a ' is greater than 13.3 cm for a 10·0 cm specimen.

Formula for flexure =3Pa/bd2

When ‘a’ is less than 13·3 cm but greater than 11·0 cm for a 10·0 cm specimen.

Where ‘a’ is the distance between the line of fracture and the nearer support, measured on the
Centre line of the tensile side of the specimen.

Fig 4.6: Flexural strength test of beam.

4.8. MIX DESIGN (M20):

Design mix of M20 grade concrete was prepared according to the IS 10262-2009, by replacing the water with percentage by weight of bacterial solution and starch solution, where two proportion is taken one is 2% bacterial solution and 2% starch solution and another is 4% bacterial solution and 2% starch solution.

3.4.1. Test data for materials:

(i) Specific gravity of cement 3.145

(ii) Specific gravity of coarse aggregates 2.75

(iii) Specific gravity of fine aggregates 2.60

(iv) Zone of fine aggregates II

(v) Water absorption of coarse aggregates 0.43%

(vi) Water absorption of fine aggregates 0.89%

(vii) Compaction factor 0.90

3.4.2. water-cement ratio:

It is taken as W/C= 0.48, based on IS 10262-2009.

3.4.3. Water and Cement content:

Water content(w)= 186+ (186x3)/100 = 191.6 l/m^3

Cement content= w/(0.48)= 191.6/0.48 = 399.16 kg/m^3

3.4.4. Some formulas used in calculating mix design:

(A)Target_strength_of_mix_proportioning,

f*ck= fck+ 1.65s

where,

f*ck= target avg. comp. strength at 28 days.

fck= characteristic comp. strength at 28 days.

S= std. deviation.

Taken s= 4.6 MPa

Therefore, target strength = 20+ 1.65*4.6 = 27.59 MPa.

(B)Volume of coarse aggregate and fine aggregate

V= [W + (C/Sc) + (1/P) . (Fa / Sfa)] X (1/1000)

V= [W + (C/Sc) + {1/(1-P)} . (Ca / Sca)] X (1/1000)

Where,

V= vol. of fresh concrete minus the volume of entrapped air.

W= mass of water (kg) per m3 of conc.

C= mass of cement (kg) per m3 of conc.

Sc= sp. gravity of conc.

P= ratio of fine agg. to total agg. by absolute vol.

fa= mass of fine agg. (kg) per m3 of concrete.

Ca= mass of coarse agg. (kg) per m3 of concrete.

Sfa= sp. gravity of fine agg.

Sca= sp. gravity of coarse agg.

For fine agg. vol.

980=[191.6+(399.16/3.15)+(1/0.311)x(fa/2.60)]x(1/1000)

fa= 535.34 kg/m^3

For coarse agg. vol.

980=[191.6+126.71+(1/0.689)x(Ca/2.75)]x(1/1000)

Ca= 1255.57 kg/m^3

Table 4.7: Material used in blending of concrete.

Mix designation	Water (W) kg/m3	Cement (C) kg/m3	Fine Aggregates(FA) kg/m3	Coarse Aggregates (CA) kg/m3	Ratio of W:C:FA:IS:CA
M20	191.6	399.16	535.34	1255.57	0.48:1:1.34:3.145

Table 4.8: Composition of concrete mixture.

S. no	Mix design	Mcb %	Mcb l/m^3	Str %	Str l/m^3	Cement Kg/m^3	F.A. Kg/m^3	C.A. (20mm) Kg/m^3	C.A. (10mm) Kg/m^3	W/C	Water l/m^3
1	Mcb-0 Str-0	0	0	0		399.16	535.34	753.342	502.228	0.48	191.6
2	Mcb-2 Str-2	2	3.832	2	3.832	399.16	535.34	753.342	502.228	0.48	183.94
3	Mcb-4 Str-2	4	7.664	2	3.832	399.16	535.34	753.342	502.228	0.48	180.10

CHAPTER 5

RESULTS AND DISCUSSION

5.1. GENERAL:

Previous chapter we discuss the results of raw materials and the proportion of concrete blend which we consider to make specimens along with test procedure. In the present chapter, discussion about the mechanical strength properties which got from testing of specimen is explored. With a specific end goal to accomplish the targets of present review, a test program was wanted to research the impact of microbes into the strength properties of concrete like compressive and flexural strength test. This investigation comprises of casting, curing & controlled testing of specimens i.e. cube and beam.

5.1.1. Compressive Strength Results:

In most basic applications, concrete is utilized fundamentally to oppose compressive anxieties. At the point when a plain concrete part is subjected to pressure, the disappointment of the part happens, in its vertical plane along the inclining. The vertical break happens because of sidelong tensile strains. Here results of the 7 days, 28 days, 56days are given below in tabular form and also graphical representation.

Table 5.1: Compressive Strength of cube specimens.

Composition	**Sr. No.**	**7 Days (N/mm^2)**	**7 Days average (N/mm^2)**	**28 Days (N/mm^2)**	**28 Days average (N/mm^2)**	**56 Days(N/mm^2)**	**56days average(N/mm^2)**
Normal Concrete	1	15.11	17.7	24.72	25.87	30.58	29.5
	2	18.85		25.23		29.77	
	3	17.71		26.24		28.56	
	4	18.5		25.42		29.08	

	5	18.73		26.37		30.25	
	6	17.3		27.34		28.78	
2% bacteria & 2% starch	1	21.56	24.765	25.83	27.37	30.74	30.61
	2	28.92		27.72		30.9	
	3	27.08		26.36		30.47	
	4	23.43		27.38		30.68	
	5	22.37		28.79		30.93	
	6	25.23		28.18		29.95	
4% bacteria & 2% starch	1	18.07	19.88	26.58	26.36	30.59	30.2
	2	20.52		27.34		29.76	
	3	20.14		26.11		30.64	
	4	21.36		25.79		29.56	
	5	20.94		26.48		29.89	
	6	18.25		25.83		30.89	

Fig 5.1: Graphical Representation of Compressive Strength with increase in curing days.

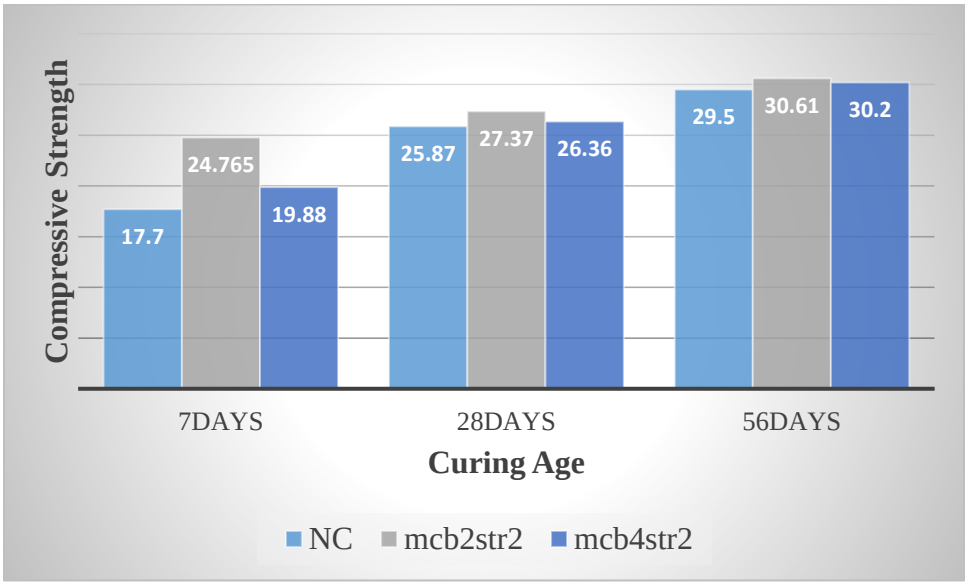
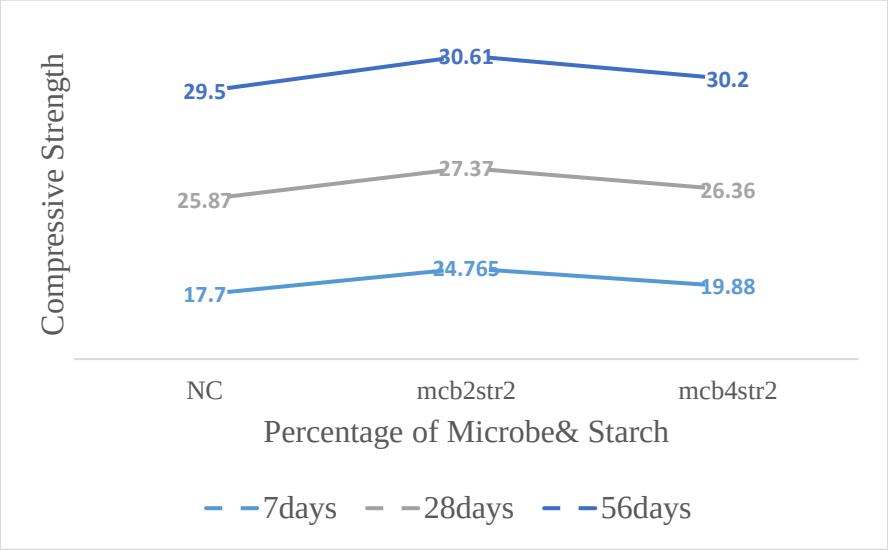


Fig 5.2: Variation of Compressive Strength with different microbe and starch percentage.



5.1.2. Flexural Strength Results:

The most well-known concrete structure subjected to flexure is bar component and is usually assessed by methods for bending tests. At the point when concrete is subjected to twisting, then pliable and compressive burdens and much of the time coordinate shear stresses are created. Results of flexural testing in three point bening is discussed below and variation is also described in a graphical manner.

Table 5.2: flexural strength of beam specimens.

Composition	Sr. No	7 Days (N/mm2)	7 Days average (N/mm2)	28 days (N/mm2)	28 Days average (N/mm2)	56 Days (N/mm2)	56 Days average (N/mm2)
Normal Concrete	1	5.81	5.6	6.21	6.09	6.57	6.35
	2	5.54		6.53		6.53	
	3	5.58		6.11		6.24	
	4	5.62		6.06		6.89	
	5	5.6		6.1		5.92	
	6	5.45		5.54		5.94	
2% bacteria & 2% starch	1	6.08	6.09	6.93	6.73	7.07	7.08
	2	5.85		6.48		7.16	
	3	6.05		7.56		7.24	
	4	6.08		6.26		7.51	
	5	6.14		6.37		6.49	

	6	6.35		6.79		7.02	
4% bacteria & 2% starch	1	5.81	5.85	6.78	6.34	6.26	6.41
	2	5.79		5.98		6.62	
	3	6.45		6.35		6.55	
	4	5.67		6.78		6.58	
	5	5.43		5.89		6.1	
	6	5.96		6.32		6.35	

Fig 5.3: Graphical representation of flexural strength with increase in curing days.

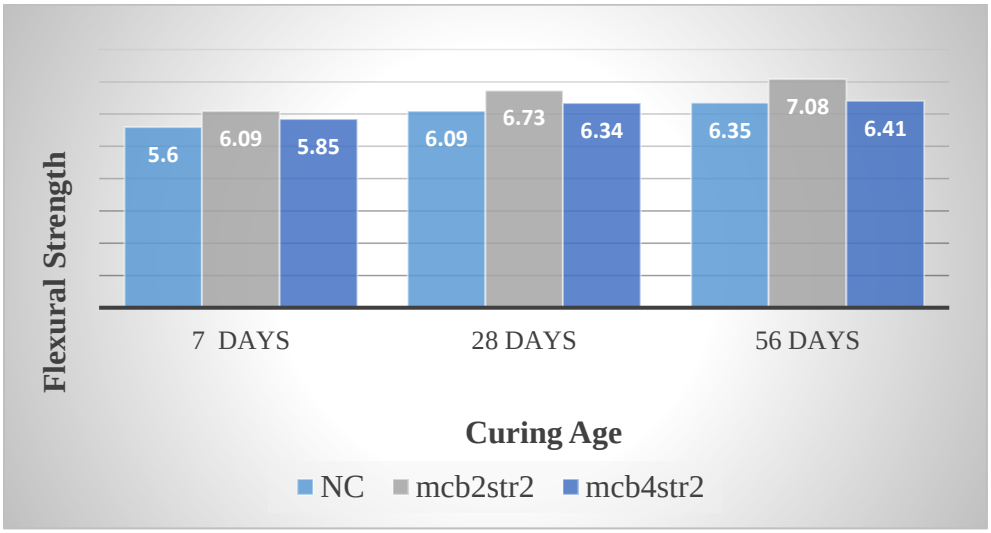
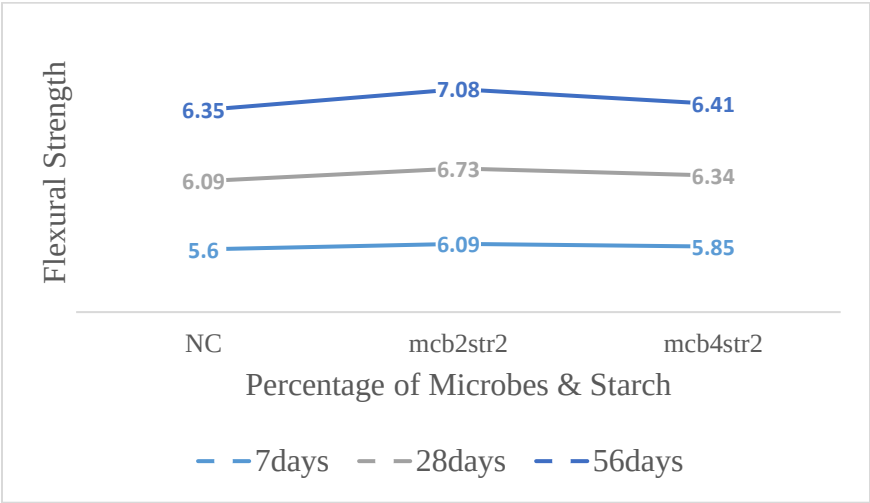


Fig 5.4: Variation of Flexural Strength with different microbe and starch percentage



5.2. **DEMONSTRATION OF TEST RESULTS:**

1. Compressive strength increases when we apply microbes to the concrete mixture.
2. Early-age strength gaining is higher for both the samples but later age strength gaining propensity is lessen.
3. At the age of 7days, compressive strength of mcb2str2 (microbe 2%, starch 2%) is 39.92% increased as compare to NC & mcb4str2 (microbe 4%, starch 2%) is 12.32% increased. At 28days compressive strength increase 5.8% in case of mcb2str2 & in case of mcb4str2, 1.89% increased. At 56 days, compressive strength for mcb2str2 increase percentage is 3.76% & for mbc4str2 increase percentage is 2.37%.
4. From the above discussion, it is clear that mcb2str2 sample gives the optimum results and mcb4str2 also give more compressive strength as compare to control mix though it has less compressive strength than mcb2str2.
5. Flexural strength also comes with positive results when microbes are mixed with the concrete mixture.
6. In case of flexural strength also, it can easily be seen that, early age flexural strength increased in higher rate as compare to later age.
7. Flexural strength is increased in the ratio like for 7day rise in flexural strength is 8.75% for mcb2str2 & 4.46% for mcb4str2 as compare to NC. At 28days flexural strength increased by 10.51% for mcb2str2 & 4.11% for mcb4str2. And like-wise for 56 days, flexural strength is obtained 11.5% more for mcb2str2 & 0.95% for mcb4str2.
8. In flexural strength also, it is clear that for the sample mcb2str has optimum value and mcb4str has a strength value more than NC but it gives lessen than mcb2str2.

Here the tabular and graphical representation is presented below:

Table 5.3: Percentage increase in compressive strength.

Composition	7days (in %)	28days (in%)	56days (in %)
Mcb2str2	39.92	5.8	3.76
Mcb4str2	12.32	1.89	2.37

Table 5.4: Percentage increase in flexural strength.

Composition	7days (in %)	28days (in%)	56days (in %)
Mcb2str2	8.75	10.51	11.5
Mcb4str2	4.46	4.11	0.95

CHAPTER 6

CONCLUSION

By the experimental setup, it can conclude that compressive and flexural strength increases when the bacteria named bacillus subtilis and starch are blended in concrete substances. By adding this microbes and starch powder in water C_3S is shows more active than C_2S. once C_3S is more active we gain more early age strength than later age strength.

By replacing water with microbe, the water content in concrete decrease. Once water content is decreased then the strength of concrete is increased. Also for that added microbes they heal the micro cracks and pores of concrete, that's why it enhanced the mechanical properties of concrete specimens. When there is any pores or cracks inside the concrete the water is continuously going inside the pores or cracks and the precursor is activated. Activated precursor orderly persuade the microbes to react with that precursor & form $CaCO_3$ (limestone) which is act as a healing(filler) material for the pores or cracks. During the time spent, encouraging Calcite crystal through nitrogen cycle the dissolvable supplement are changed over to insoluble $CaCO_3$, in this way sealing it up.

REFERENCES

1.Huaicheng Chen, Chunxiang Qian, Haoliang Huang, Self-healing cementitious materials based on bacteria and nutrients immobilized respectively, Materials Science and Engineering,2016

2.E. Tziviloglou, V. Wiktor, H.M. Jonkers, E. Schlangen, Bacteria-based self-healing concrete to increase liquid tightness, construction and building materials 2016

3.Wasim Khaliq, Muhammad Basit Ehsan Crack healing in concrete using various bio influenced self-healing Techniques, construction and building materials, 2016.

4.Mian Luo,Chunxiang Qian, Influences of bacteria-based self-healing agents on cementitious materials hydration kinetics and compressive strength, Construction and Building Materials,(2016).

5.R. Alghamri, A. Kanellopoulos, A. Al-Tabbaa, Impregnation and encapsulation of lightweight aggregates for self-healing concrete, Construction and Building Materials, 2016.

6.M. Roig-Flores, F. Pirritano,Effect of crystalline admixtures on the self-healing capability of early-age concrete studied by means of permeability and crack closing tests, Construction and Building Materials,2016.

7.J.Y. Wang, H. Soens, W. Verstraete, N. De Belie, Self-healing concrete by use of microencapsulated bacterial spores, cement and concrete research, 2014.

8.Ruoting Pei, Jun Liu, Use of bacterial cell walls to improve the mechanical performance of concrete, Cement & Concrete Composites, 2013.

9.Mayur Shantilal Vekariya, Prof. Jayeshkumar Pitroda, Bacterial Concrete: New Era For Construction Industry, International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 9- Sep 2013.

10.Henk M. Jonkersa, Arjan Thijssena, Gerard Muyzer, Application of bacteria as self-healing agent for the development of sustainable concrete, Ecological Engineering 36 230–235, (2010).

11.H. M. Jonkers, (2007) Self -Healing Concrete: A Biological Approach, Self-Healing Materials. An Alternative Approach to 20 Centuries of Materials Science, 195–204.

12. Chaturvedi et al., Bio-remediation of polluted soil, 2006.

13.Ramachandran, S.K. , "Remediation of concrete using micro-organisms". ACI Materials Journal 98(1), pp. 3–9. 2001.

14. R. P. Wool, "Self-healing, Materials: a review", Soft Matter, 4: 400–418, 2008.

15. M.W. Keller, N.R. Sottos, "Mechanical properties of microcapsules used in a self-healing polymer", Exp. Mech. 46 (2006) 725–733.

16.H.M. Jonkers,A. Thijssen,G.Muyzer, O. Copuroglu, E. Schlangen, "Application of bacteria as self-healing agent for the development of sustainable concrete", Ecol. Eng. 36 (2010) 230–235.

17.P.K. Mehta, P.J. Monteiro, Concrete: Microstructure, Properties, and Materials, McGraw-Hill, New York, 2006.

18.Dr.P. R. Swarup, Director General, Construction Industry Development Council (CIDC), Special lecture on "Repair & Maintenance needs of the concrete structures in India".

19. Horner-Devine MC, Carney KM, Bohannan BJM, "An ecological perspective on bacterial biodiversity". Proceedings Royal Society Biological Science B 271, 2004, pp.113–122.

20. J. L. Day, A. V. Ramakrishnan, and S. S. Bang, "Microbiologically Induced Sealant For Concrete Crack Remediation," 16th Engineering Mechanics Conference, 2003, pp.1–8.

21. P. Tiano, L. Biagiotti, G. Mastromei, "Bacterial biomediated calcite precipitation for monumental stones conservation: methods of evaluation", Journal of Microbiological Methods, Vol.36, Issues 1–2, 1999, pp.139-145.

22. Ghosh P, Mandal S, Chattopadhyay BD, Pal S., "Use of microorganism to improve the strength of cement mortar." Cement and Concrete Research 35, 2005, pp.1980-1983.

23. N. Ter Heide, E. Schlangen, K. van Breugel, "Experimental Study of Crack Healingof Early Age Cracks", Technical University of Denmark, Denmark, 2005, p. 2005.

24.J. Wang, D. Snoeck, W. Verstraete, N. De Belie, Application of hydrogel encapsulated carbonate precipitating bacteria for approaching a realistic self-healing in concrete, Constr. Build. Mater. 68 (2014) 110–119.

25. V. Ramachandran, J.J. Beaudion, "Handbook of Analytical Techniques in Concrete Science and Technology", Principles Techniques and Applications, Noyes Publications, New York, 2001.