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IMPACT OF BACILLUS SUBTILIS ON STRENGTH PROPERTIES OF DIFFERENT GRADES OF CONCRETE

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ABSTRACT

Fractures in concrete, despite its widespread usage as a construction material, are an inevitable fact of life. As a result, water and other salts can leak through the micro-cracks when the load imposed exceeds the concrete's tensile strength. Corruption and vulnerability to structural failure ensue as a result of this process. When water, CO_2, or other chemicals come into contact with reinforcing steel in concrete buildings, cracks occur, reducing the concrete's durability and strength. Cracks can also compromise the structure's structural integrity. To increase the concrete's compressive strength, researchers used microorganisms like Bacillus subtilis in this investigation. Hence, a varying amount of bacillus subtilis is used in the mixes for M20 and M40 grades of concrete and found that the compressive strength of specimens (150 x 150 x 150 mm in size). From the obtained results, it could be concluded that 10 ml of bacteria is optimum to achieve better strength for 7 and 28 days of curing days

Index terms: bacteria, bacillus subtilis, compressive strength, concrete, cracks, self-healing

INTRODUCTION

High ductility and shear strength allow concrete to be used in various applications, including construction. There are many micro-sized cracks in concrete, which may be seen in the human body. At low degrees of hysteria, cement's flexibility is relatively stable; but as the hysteria level rises, the cement's flexibility begins to decrease. The low coefficient of heat extension and psychological stability are two advantages of concrete construction. Cement production accounts for around 3 percent of overall cement output. It needs a substantial number of materials, as well as sedimentary rock. The cement business accounts for around 8 percent of worldwide carbon emissions, a greenhouse gas contributing to global warming]. New technology is necessary to alleviate the adverse repercussions of the cement trade [1], [2], [3], [4]. Because of their better characteristics, alkali-activated binders can aid with this. Concrete binders include inorganic binders (such as gypsum, lime, and cement), organic binders (such as emulsions and epoxy resins), and mineral binders (such as rice husk ash, red mud, silicon dioxide fume, metakaolin, GGBS, and fly ash) (such as rice husk ash, red mud, silicon dioxide fume,

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metakaolin, GGBS, and fly ash). This study combines ground granular blast furnace slag (GGBS) and flyash as binding materials and an alkaline activator (combined hydroxide and silicate solution) (combined hydroxide and silicate solution). Ceramic powder is created from high calcium content tiles and has higher structural properties than concrete [5]. Concrete has a stronger compression zone than a weaker tension zone. Although concrete is reinforced with a variety of fibers [6], [7], aggregate texture substantially affects its strength. The concrete's fire resistance should be evaluated at various temperatures [8]. Every stable form will degrade a little due to shrinkage and strain. After being exposed to long-span powers, a solid becomes docile and patient. Unusual and artificial strands are occasionally employed to improve performance and accentuate the incapacity of cement for elites. Buildings frequently suffer from fractures. In today's modern era of infrastructure projects, cement concrete is an essential building element. Reinforcement in steel bars or rebar is required since this material is highly fragile and susceptible to fracture. Concrete's tensile strength is significantly lower than its compressive strength because of its link with steel bars, making it more effective at resisting stress than concrete that does not have any reinforcement in it. To lengthen the service life of any particular concrete building, self-healing concrete frequently seeks to rectify these faults. On the subject of self-healing concrete, new material is being developed to address some of the typical complaints about concrete. Microorganism concrete is self-healing. Bacteria (Bacillus subtilis) and calcium lactate are combined with nutrition broth food to maintain the microorganisms once they become active in self-healing concrete. The microbe eats the food supply to repair the fracture. Besides examining the mechanisms that underlie microorganism self-healing in concrete, this research will investigate the numerous portions that make up the process and how they interact. Furthermore, the practical uses of this self-healing technology and its integration into existing structures will be discussed in this study. A typical occurrence is the cracking of concrete. If cracks in concrete structures aren't addressed quickly and correctly, they can quickly expand, forcing expensive repairs. Repairing concrete cracks has been a study topic for many years, even though readily available modern technologies can help reduce the damage that attempts can do. Structural epoxy, resins, epoxy mortar, and various synthetic mixtures are commercially available products for repairing concrete fractures. Cracks and fissures are common in structures of all kinds, from houses to bridges to historical landmarks. Repairing fractures using environmentally friendly biological processes that are self-remediating is now possible thanks to our ground-breaking new technology. $CaCO_3$ precipitation was induced by using Bacillus pasteurii, a common soil bacterium. Therefore, a thorough grasp of microbial activity in crack repair is essential.

BACILLUS SUBTILIS CONCRETE'S SIGNIFICANCE:

Calcite crystals are constantly precipitated by the soil bacterium Bacillus subtilis, which considerably enhances concrete's strength and endurance over time. The Bacillus genus causes most human-safe bacteria. This approach makes use of bacteria from the Bacillus species and bacterial nutrients. We have substances like calcium, nitrogen, and

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phosphorus compounds in this category. All of the components are included in the concrete during the production process. Bacillus subtilis is a biodegradable and ecologically beneficial chemical.

MICROBIOLOGY'S HISTORY

Bacteria are tiny, single-celled prokaryotic creatures. A wide range of bacterial species may be found in various shapes and sizes. There are multiple places where bacteria may be found: soil, acidic hot springs, radioactive waste, water, and deep in the Earth's crust. A gram of soil has around 40 million bacterial cells, and a milliliter of freshwater contains nearly a million bacterial cells; in all, there are approximately five nonillions (51030) bacteria on Earth, accounting for most of the world's biomass as stated by the author of [9]. In 1676, [17] discovered bacteria using his single-lens microscope. In a series of letters to the Royal Society, he referred to them as "animalcules." However, bacteria wasn't even coined until 1838 when Christian Gottfried Ehrenberg first used the word. Louis Pasteur established in 1859 that the growth of bacteria is what causes fermentation. Like Robert Koch, Louis Pasteur was a pioneer in advancing the germ hypothesis of disease. There are two primary types of bacterial cell walls: Gram-positive and Gram-negative. Species of bacteria have long been classified using a process known as the Gram stain, which gives rise to the names given to the many subspecies. The three phases of bacterial growth can be summarized as follows. First, cells must adapt to their new environment when they enter a high-nutrient environment that supports proliferation.

Few Studies of Bacterial Concrete

Concrete containing 30 ml of liquid Bacillus Subtilis can survive compressive, flexural, and split tensile strength tests, according to [18] Microbes accelerate calcium carbonate production in substantial gaps, resulting in a smaller void and consequently decreased water permeability in bacteria-treated concrete over regular concrete. The compressive strength test results showed that the strength of the concrete increased by 35.15 percent compared to conventional concrete. Following a seven-day cure test, the cure rate was 12.11%, followed by a 14-day cure rate of 287.11% and a 28-day cure rate of 32.66%. Flexural strength has improved by 17.24%. The author of [19] claim that bacterial concrete may greatly increase concrete's strength by sealing the microscopic holes in the material and increasing its density. After 7, 14, and 28 days, the compression strengths of all bacterial concrete samples are higher than those of conventional concrete. The bacterial concrete performed better than conventional concrete in the ultrasonic pulse velocity test, showing that it is of greater quality. It has been found that when bacteria levels rise, the value of slumps substantially increases. In contrast, when bacteria concentration rises, the compaction factor decreases. To begin with, the compressive strength of bacterial concrete increases up to 10ml bacterium content, after which the compressive strength steadily falls with the corresponding rise in bacteria content in concrete. It was discovered that 10ml bacteria had the greatest bacterial concrete strength. Green and self-recovery properties show it to be an excellent alternative to standard concrete. Shortly, long-lasting, cost-effective, and ecologically friendly

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structures will be built using bacterial concrete. Microbiologically generated bacillus subtilis bacteria increase the compressive strength of cement mortar by 16.15 percent at a certain microbial cell concentration, according to the author of [20]. After 28 days, bacillus subtilis bacteria added to normal concrete increased compressive strength by 13.93% and split tensile strength by 12.60%. An increase in compressive strength, a decrease in water permeability, and water absorption-reinforced corrosion have been found in various cementitious and stone materials by [21]. The highest increase in compressive strength occurs at cell densities of 105 cells/ml for all ages. The study indicated that the 28-day compressive strength of cement mortar was increased by 25 percent. The authors of [22] studied concrete healing and mechanical characteristics in this work. Concrete specimens' compressive, tensile, porosity, and healing properties were studied by adding bacteria to the mix and the curing solution. Four different concrete aggregates were tested to absorb water when incubated with sporosarcina pasteurii and bacillus subtilis, both of which had their cell concentrations varied. The results of this experiment are presented in a paper by [23] Calcium carbonate crystal formation on the surface reduced water absorption by 20–30 percent depending on the bacteria and aggregate porosity. A Compressive First-Rate Bacterial Mixture of 5 Percent Increases to 2.63 Percent, According to [24], with the Control combination, the Compressive best of 10% calcium lactate climbs to a rate of 2.63 percent. Cement loses 20.80% of its compressive fineness at a calcium lactate content of 10%. M. Fossils are filled with microbes from concrete, according to [25]. The mechanical strength of concrete is enhanced by reducing the size of the pores. As concentration improved, so did strength. As a result, the water absorption and Sorptivity coefficient values are reduced while the concrete's durability increases. MV If alkaliphilic aerobic bacterium Bacillus subtilis JC3 is added to cement mortar samples at various cell concentrations in suspension, the compressive strength increases the highest, according to [26] After 28 days, the cement mortar's compressive strength had increased by 25%, according to the study results. Because of the enhanced strength, scanning electron microscopy shows that filler material has developed within the pores of the cement-sand matrix. Using bacteria to enhance the strength and durability of cement concrete is an exciting prospect for researchers like [27]. They found that concrete-immobilized spores of certain bacteria can heal cracks by bio mineral formation. It was revealed that the favorable impacts of [28] [29], Bacteria Pasteurii (Bp M-3) calcifying on the permeability of concrete Coatings made water and other unfriendly materials more impermeable to organisms. Industrial wastes such as maize steep liquor can also be employed as a source of nutrients for bacteria in this study. Microbial addition will serve as the foundation for a high-quality alternative concrete sealer that is both cost-efficient and ecologically acceptable, ultimately increasing the longevity of building materials. There has been an increase in interest in alternative methods for enhancing concrete durability because of the shortcomings of typical surface treatments, according to [30]. Bacterial carbonate precipitation affects the durability of mortar specimens with different porosity levels. In specimens with different porosities, surface deposition of calcium carbonate crystals inhibited water absorption by 65–90%. Carbonation and chloride migration was also decreased by 25–30% and 10–40%, respectively, due to these changes. The ability to withstand freezing and thawing

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was also improved. According to his research, Purified and mixed ureolytic bacteria cultures have been compared to the effectiveness of routine surface treatments. These specimens have less capillary water absorption and permeability due to bacteria depositing an impermeable calcite coating on their exteriors. The type of bacteria and the media in which they were grown affected their form of the calcite crystals. Pure cultures reduced water intake and changed the chromatic aspect less than mixed ureolytic cultures when used as a paste, but the latter had a more dramatic effect. Water repellents based on Bacillus sphaericus bacteria were as effective as those based on normal bacteria cultures. HM If self-healing concrete is used instead of conventional concrete, it improves the structural integrity of the building. It reduces the amount of time and money spent on checking and repairing new fractures, according to [31], Bacteria-mediated calcium carbonate production was investigated in this work. Moreover, according to the results, one-third of the original sample spores were still alive when extracted from freshly-crushed cement stone after ten days of curing. The authors of [32] findings used microbiologically generated calcite as a crack filler. Common soil bacteria Bacillus pasteurii was employed to promote the precipitation of calcite, which is often found in the soil. Since the ammonia released into the environment elevates pH, insoluble calcite builds up, which is the end consequence of the microbial urease hydrolyzing urea to create ammonia and carbon dioxide. Test specimens with microbiologically increased crack repair and control specimens examined their compressive strengths. Microbiologically induced calcite precipitation can be used to repair concrete cracks and fractures, according to [33], the study of bio mineralization includes the technology of microbiologically produced calcite precipitation. Precipitates of calcite can be formed by bacteria often found in the soil, Bacillus pasteurii. As a microbiological sealant, calcite showed promising results in selectively consolidating simulated granite fractures and sand fissures. The precipitation of calcite by microbial activity makes MICP a very desirable chemical process. Cracked concrete specimens can be strengthened and stiffened using this method. Concrete beams treated with bacteria and subjected to alkaline, sulfate, and freeze-thaw temperatures were tested for their long-term stability. Different bacteria concentrations were also examined as a possible factor in determining the durability of concrete. All of the bacteria-containing beams outperformed the control beams in performance (without bacteria). As the concentration of bacteria increased, the product's durability increased. The precipitation of microbial calcite was quantified and visualized using XRD analysis. SEM's unique imaging and microanalysis capabilities were used to demonstrate the existence of calcite precipitation within fractures, rod-shaped bacterial impressions, and a new calcite layer on the surface of the concrete. The specimen's resistance to alkaline, sulfate, and freeze-thaw degradation increases by covering it in calcite. According to [34], a common soil bacteria named Bacillus pasteurii was employed to induce calcite precipitation in concrete crack repair. This Biosealent is intended to be self-remediate since Bacillus pasteurii may generate endospores under harsh environmental conditions. On comparing the compressive strength of treated and control mortar cubes to assess the efficiency of microbiologically enhanced crack remediation. Th author of [35], in proportioning concrete mixtures, explains that the water-cement ratio becomes important when concrete strength is less than aggregate strength.

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The 0.5 w/c ratio concrete trial mix data must be used to proportion the mixes since it encompasses both w/c ratio and aggregate–bond contributions in the interfacial zone. Composite mechanics can re-proportion concrete mixtures with higher strength than aggregate. The author of [36 has stated that other micro silica characteristics, concrete strength rises with age. In addition, micro silica has increased concrete's resilience to acid and sulfate assault. [37] has described a microbiologically induced mineral precipitation technique for strengthening cement–sand mortar. Water is mixed with varied cell concentrations of a thermophilic anaerobic bacterium. To compare, E Coli bacteria were added to the cement mortar, but no improvement in strength was noted. The main objectives of this study are to investigate the effect of bacillus bacteria on concrete at 0, 5, 10, 20, and 30ml levels, to compare the compressive strength of M20 and M40 concrete with microorganisms, and to compare nominal and bacillus subtilis concrete compressive strengths.

Materials used in this investigation

Cement: Ordinary Portland Cement (53 grade) conforms to BIS specification IS: 12269-1987, with a specified strength for 28 days of at least 53MPa or 530 Kg/cm2, 29 percent normal consistency according to IS: 4031-1988(part-4), and a specific gravity of 3.15 conforming to IS 2720. (Part 3).

Fine Aggregate

Sand with a specific gravity of 2.6 and complying with IS10262:2009-Zone II requirements. According to IS: 2386, the fine aggregate has less than 0.2 percent (part-3).

Coarse Aggregate

The aggregate has a specific gravity of 2.6-2.8. Therefore, according to IS: 2386, the fine aggregate has less than 0.2 percent (part-3).

Bacillus Subtilis, (Bacteria)

Bacillus subtilis tiny creatures were among the first to be studied, having been named vibrio subtilis in 1835. These bacteria are a good model for cell progression and differentiation.

Water: Throughout the experiment, potable water was utilized to mix the concrete and cure the concrete to determine the best dose of bacteria to be introduced into the water.

METHODOLOGY

Based on a thorough assessment of the literature, an attempt was undertaken to confirm the feasibility of making bacillus subtilis concrete inexpensively under all realistic situations. The performance of laboratory-prepared bacillus subtilis concrete is principally determined by the cement mortar linked to the aggregate particles. Therefore, the experimental program was developed to investigate the mechanical characteristics of

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bacillus subtilis concrete using various bacillus subtilis doses. The primary goal of the current experimental research is to collect precise experimental data that will aid in understanding the Bacterial concrete and its properties. Studies on the behavior of fresh and hardened characteristics of standard grade concrete and common grade concrete with and without Bacteria addition were carried out in the current experimental inquiry. The hardened qualities of concrete, such as compressive strength, are assessed by performing appropriate laboratory experiments on hardened concrete.

CONCRETE PREPARATION

In an electrically powered concrete mixer, coarse and fine aggregate is introduced and mixed for 3 minutes. Cement is added to the aggregate and left to mix in a concrete mixer to guarantee homogeneity. Water, coupled with a small number of bacteria, is added to the cement, coarse aggregate, and fine aggregate mixture, then mixed for another 3 minutes to achieve a uniform mix. The freshly produced combinations are segregate-resistant. Three layers of Bacillus subtilis concrete are compacted and vibrated to eliminate air gaps before being placed into cube molds with dimensions of 150 x150 x 150 mm. After 24 hours of casting, the specimens are demoulded. Samples are left out in the curing tank until they reach the age of setting.

MIX PROPORTIONS

Five mixtures were considered, along with a bit of mix, with bacillus subtilis content varying from 0ml to 5ml, 10ml, 20ml, and 30ml. First, bacillus subtilis is mixed with water to ensure homogeneity. Then, the weights of cement, coarse aggregate, fine aggregate, water, and bacteria are determined, and the concrete is made.

TABLE 1: Mix proportions for M20 grade concrete

S.NO	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Water (kg/m^3)	Bacillus subtilis (bacteria) (ml)
1	359	1118.16	678.36	197.16	`0
2	359	1118.16	678.36	197.16	5
3	359	1118.16	678.36	197.16	10
4	359	1118.16	678.36	197.16	20
5	359	1118.16	678.36	197.16	30

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TABLE 2: Mix proportions for M40 grade concrete

S.NO	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Water (kg/m^3)	Bacillus subtilis (bacteria) (ml)
1	450	1101.45	668.24	197.16	`0
2	450	1101.45	668.24	197.16	5
3	450	1101.45	668.24	197.16	10
4	450	1101.45	668.24	197.16	20
5	450	1101.45	678.36	197.16	30

RESULTS AND DISCUSSION

CONCRETE CUBE COMPRESSIVE STRENGTH

The capacity of a material or structure to bear stresses on its surface without cracking or deflection is referred to as its compressive strength. When a material is compressed, its size shrinks, and when it is tensioned, its size expands.

Specimen preparation of Ordinary grade concrete and Standard grade concrete design mix is performed, and cubes of 150mm x 150mm x 150mm are cast as directed. Cubes are cast with and without microorganisms. After 24 hours, the specimens are demoulded and immersed in the curing tanks in clean freshwater. After the curing period, the samples are collected and stored in the shade. The cube specimens are taken from the curing tank and cleaned after the requisite duration of curing. The compressive strength of a set of cubes is measured after 7 and 28 days.

M20 grade concrete

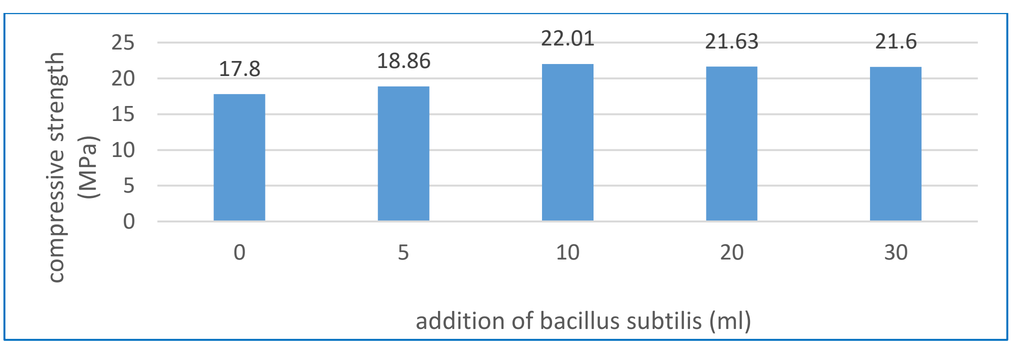

Fig 1: Compressive strength for varying bacillus content at seven days

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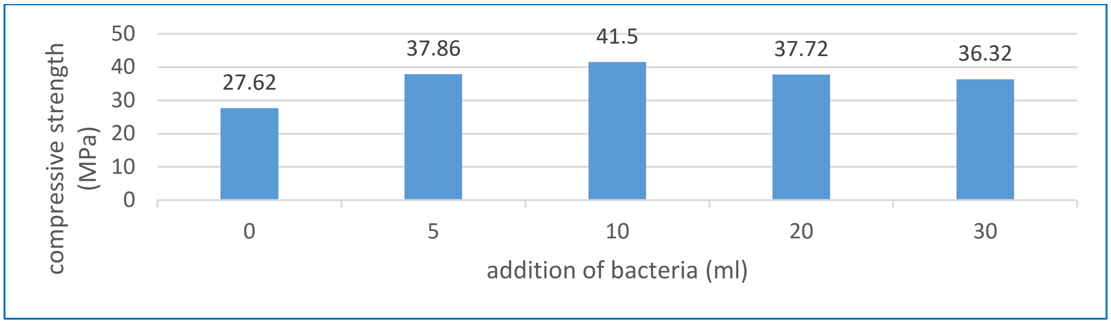

Fig 2: Compressive strength for varying bacillus content at 28 days

The compressive strength of M20 grade concrete gradually increases up to an optimal amount of bacillus subtilis and decreases. The highest compressive strength of bacillus subtilis concrete is seen seven days after adding 10 ml of bacillus subtilis (bacteria). At seven days, the compressive strength of bacillus subtilis concrete rose by 23.65% compared to the little mix's compressive strength. The highest compressive strength of bacillus subtilis concrete is seen 28 days after adding 10 ml of bacillus subtilis (bacteria). Compared to the compressive strength of the little mix, the compressive strength of bacillus subtilis concrete rose by up to 50.2 percent after 28 days.

M40 concrete

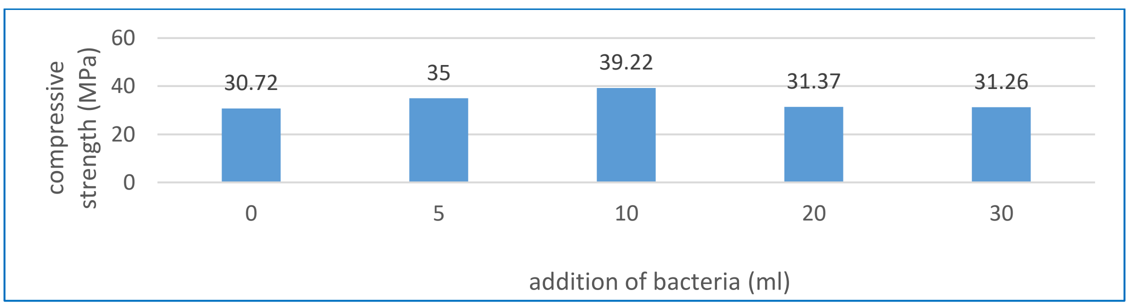

Fig 3: Compressive strength for varying bacillus content at seven days

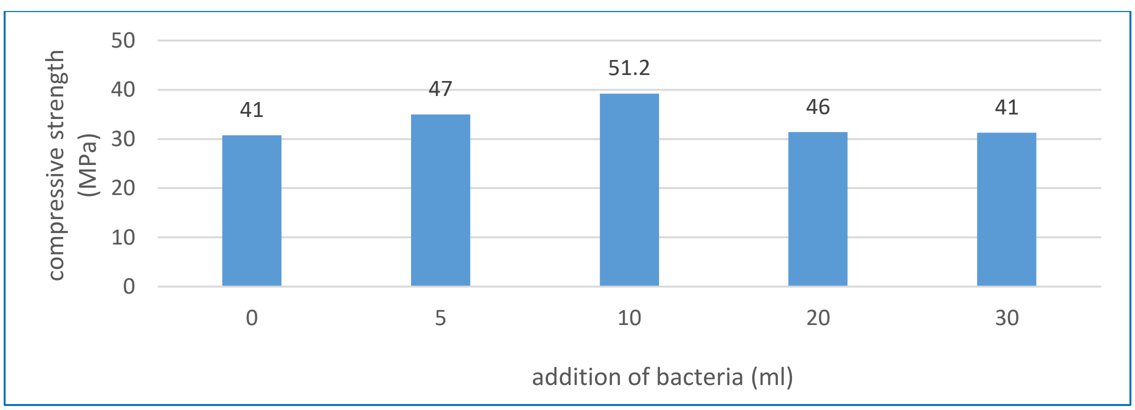

Fig 4: Compressive strength for varying bacillus content at 28 days

The compressive strength of M40 grade concrete is gradually enhanced up to an optimal amount (10ml) of bacillus subtilis and, after that, falls. With the addition of 10 ml of bacillus subtilis, the maximum compressive strength of bacillus subtilis concrete is seen for seven days (bacteria). Compared to the compressive strength of the little mix, the compressive strength of bacillus subtilis concrete rose by 28.92% after seven days. After 28 days, the highest compressive strength of bacillus subtilis concrete is found after adding 10 ml of bacillus subtilis (bacteria). At 28 days, the compressive strength of bacillus subtilis concrete rose by 13.41 percent compared to the compressive strength of the little mix.

CONCLUSIONS

The following conclusions could be drawn from the results are shown below

1. Incorporating bacteria improves mechanical qualities because long-term compressive and tensile strength rises depending on the bacteria incorporated.
2. The addition of 10 ml of bacillus subtilis to M20 concrete grade results in the highest compressive strength for seven days and 28 days, the compressive strength of the little mix, the compressive strength of bacillus subtilis concrete at seven days and 28 days is raised by 23.65% and 50.2 percent, respectively.
3. The addition of 10 ml of bacillus subtilis to M40 concrete grade results in the highest compressive strength for seven days and 28 days, the compressive strength of bacillus subtilis concrete at seven days, and 28 days are raised by 28.92% and 13.41%, respectively.
4. As a result, the addition of Bacillus subtilis causes an increase in compressive strength up to a maximum and subsequently a reduction.

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