Examining the compressive strength of bacterial concrete of grade M20 reinforced with polypropylene fiber

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ABSTRACT:

Aim: The aim of the study is to Increase the compressive strength of concrete by adding polypropylene fibre to the concrete and to quantify the compressive strength of polypropylene fibre reinforced self compacting M20 grade bacterial concrete using a novel Microbial Induced Calcite Precipitation (MICP) technique. Novel MICP is a biological process in which calcite calcium carbonate ($CaCO_3$) formation is achieved as a result of the active metabolism of bacteria. **Materials and Methods:** A total of 36 samples were prepared for this study in which 18 samples per group. one group with fibre, another group without fibre. The fibre is like polypropylene fibre. Bacillus subtilisbacteria was prepared using novel MICP technique in the Microbiology laboratory using a mother strain brought from the hi-media labs. Using SPSS software version 21, an independent sample T-test was performed, revealing a clear increase in the compressive strength of the polypropylene fibre reinforced self compacting bacterial concrete compared to self compacting bacterial concrete. **Results:** The mean compressive strength of polypropylene fibre reinforced self compacting M20 grade bacterial concrete was 33.3347N/mm^2 and the compressive strength of self compacting bacterial concrete without fibre was 27.5841N/mm^2 using novel MICP technique.Independent sample t-test was performed to analyse the results. Standard deviation for polypropylene fibre reinforced bacterial concrete was 1.98535 Significance of the events was $p=0.003$ ($p>0.05$). **Conclusion:** The polypropylene fibre reinforced self compacting concrete had more strength compared to bacterial concrete without fibres using novel MICP technique. When compared to bacterial concrete, the polypropylene fibre compressive strength increased by 20.85%.

Keywords: Bacterial Concrete, polypropylene fibre, Self compacting concrete, Novel MICP, Compressive Strength.

INTRODUCTION:

The bacteria to be used in our project are Bacillus Subtilis which is a gram positive cell bacterium. The bacteria increase the compressive strength of RC elements in building for the similar grade of conventional concrete. Thus it doesn't allow cracks to occur. The bacteria remain active for 200 years. It is also harmless to humans and eco-friendly.. Bacteria can be used to manufacture CaCO3 in Biological Concrete and Self-Repair or Microbial-Induced Calcite Precipitation (MICP). It fills in any gaps that occur in the concrete. Bacillus pseudo bacillus, Bacillus sphaericus, Bacillus pasteurella, Escherichia coli, Bacillus halodurans, Bacillus sphaericus, Bacillus subtilis, Bacillus halodurans, and other bacteria can be used in concrete. These bacteria can live in an alkali-rich environment, by using the metabolic process including sulphate reduction, urea hydrolysis, and photosynthesis.. Self-healing concrete or bacterial concrete reacts with calcium acetate to release calcium carbonate, thereby self-healing and crack repair. Concrete with polypropylene fibre and bacterial additives has been a huge success as a building material. Self-repairing cracks in concrete helps extend the life of concrete structures and improve the compressive strength of concrete. It can be used for self-densification to enhance both existing and new types of structures. Self-filling bacterial concrete can be used in areas such as tunnel linings, bearing underground walls, highway bridges, concrete floors and offshore structures using new MICP technology.The mechanisms for microbially induced $CaCO_3$ precipitation and its applications in concrete structures are discussed. The efficacy of microbial techniques of healing them has been examined. Finally, a future direction for the development of self-healing concrete is indicated.This high performance concrete should be strong and have low repair and maintenance costs. Therefore, there is an urgent need for concrete that successfully repairs the cracks themselves and reduces repair and maintenance costs . Such materials typically comprise complex architectures of fine fibrous reinforcement e.g. carbon or glass, dispersed within a bulk polymer matrix, e.g. epoxy. This can provide exceptionally strong, stiff, and lightweight materials which are inherently anisotropic, as the fibres are usually arranged at a multitude of predetermined angles within discrete stacked 2D layers (Andersson et al. 2007) Calcium acetate production depends on the calcium content in the cement. It discharges calcite into the crevices and increases durability . This self-filling bacterial concrete is stronger and requires less repair and maintenance. As a result, there is an urgent need for concrete that can successfully self-repair cracks while reducing repair and maintenance costs . Much research has been done on polypropylene fibre reinforced bacterial concrete using new MICP technology. Over the last five years, there have been over 100 publications in the areas of self-healing concrete and self-filling concrete (Google Scholar, Science Direct). The compressive strength of bacterial concrete was found to improve after 7.15% and 26.6%, respectively, and after 28 days of hardening.. From all the studies published in the last five years, it is clear that the effects of fibre on SCC are not fully understood. The effects of Bacillus subtilis on compressive strength, split tensile strength, and bending strength were previously quantified by our senior team. Manvith Kumar Reddy, Ramesh, Macrin, P.V.Y. Reddy 2020, this paper uses a new technology called the novel MICP (Microbial Induced Calcite Precipitation) to quantify the effect of polypropylene fibres on the compressive strength of bacterial self-healing concrete.Previously our team has a rich experience in working on various research projects across multiple disciplines(Madhesh et al. 2021; Bishir et al. 2020);(Vimalraj et al. 2020; Sivasamy, Venugopal, and Mosquera 2020)(Madhesh et al. 2021; Bishir et al. 2020)

The influence of polypropylene fiber in the compressive strength of self compacting concrete is not very well understood as well as the influence of bacteria bacillus subtilis and its effects on cube compressive strength of concrete. This was the existing research on which the present research process depends. The aim of this study is to quantify the influence of polypropylene fiber on the compressive strength of self compacting concrete with bacterial concrete.

MATERIALS AND METHODS:

This study was done in the Concrete and Highway Engineering laboratory, Department of Civil Engineering and Biotechnology laboratory, Department of Bioinformatics, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. In this study Two groups of experiments were carried out. One group is with addition of polypropylene fiber to the self healing concrete with superplasticizer and the other one is the self healing concrete with superplasticizer without fiber. Eighteen samples were prepared per group.To determine the compressive strength of concrete, 150150 mm concrete cubes were constructed. Nectar Composites, Poonamallee, Chennai, provided the fiber. Bacillus Subtilis, a member of the bacillus family, was the bacteria used to make bacterial concrete. Hi-media, T Nagar, Chennai, provided a strip of bacteria that contained ten spores. Hi-media, T Nagar, Chennai, also provided materials for the preparation of bacteria. Figure 1(a) shows the soybean casein digest medium (tryptone soya bath), L-alanine ($C_3H_7NO_2$), and 1(b) shows the manganese sulphate ($MnSo_4.H_2O$) used for bacterial culture growth.and superplasticizer was brought in online amazon app.

Bacteria were prepared in 2L jars after the mother culture media was created. For growing 2L bacteria, 60 grams of soya bean medium, 0.4 grams of alanine, 0.2 grams of $MnSo_4.2H_2O$, and 200 millilitres of water were employed. The concentration of microorganisms was determined using a haecyometer. Figure 2(a) shows the presence of bacteria under the microscope (b) shows the growth of bacteria in the bottle. For casting the quantities are water cement ratio is 0.45added in addition to bacteria the percentage of bacteria added to concrete was 3%. 1.3608 kg of cement, 2.26 kg of sand, 4.110 kg of coarse aggregates, super plasticizer of tech mix 550 and calcium acetate were used to make 1 cube of M20 grade cement concrete. The concrete was treated with 0.1 gm/250 ml water calcium acetate. Using all of the elements listed above, as well as fiber. For the first set of studies, the polypropylene fiber reinforced self-healing concrete with superplasticizer was made 18 times and cast individually. The remaining group specimens were also casted without the addition of fiber. The process for casting the second group of specimens was the same as for the first, with the difference that no polypropylene fibers were used. All of the casted cubes were submerged in water for 28 days to cure.

The compressive strength of cubes from both groups was determined using the compression testing machine (CTM), which has a maximum load capacity of 2000 kN. With a loading rate of 1.4 kN/sec, this electrically driven machine has an accuracy of plus or minus 1. Figure 3 shows the compression testing machine used to collect the compressive strength data. This is done to protect the bacteria from being contaminated by other bacterial strains and pathogens. An autoclave is a piece of equipment that uses steam under pressure to destroy bacteria, viruses, and even spores, providing a physical means of sterilise.In this experiment, the autoclave was set to 121°C for 15 minutes at a pressure of 15 lb/sec. The bacteria were grown in a shaking incubator after the culture with media had been sterilised. A shaking incubator is a device that shakes things in a tube or flask to mix, blend, or agitate them. This was done to ensure uniform distribution of microorganisms in the culture.It was run for four days at a temperature of 37°C and an RPM (Rotations Per Minute) of 90/min. The concentration of cells was determined using a haecyometer to be 107 cells/ml. After the bacteria had reached a stable stage, the bacteria cells were separated from the media using a centrifuge. It ran for 24 hours at a temperature of 37°C and a rotation rate of 90 per minute. A haecyometer was used to determine the cell concentration, which was found to be 107 cells/ml. The bacteria cells were removed from the media using a centrifuge after they had reached a stable stage. Figure 4(a) shows the centrifuge device used to separate the bacteria from media and (b) shows the bacteria after separation from media. All of the ingredients were combined, and cubes were cast. For curing, the specimens were submerged in water for 28 days. The water temperature was 27°C (+/-2°C). After 28 days of curing, the specimens were dried for testing.

STATISTICAL ANALYSIS:

Results of experimentation were analysed using SPSS, version 21 software. Independent samples t-test was done to find the statistical significance between the study and control group. There was no dependent variable for the study, whereas the compressive strength, grade of concrete, water/cement ratio, grade of cement, days of curing were independent variables. Mean, Standard deviation, standard error of mean were also calculated with this tool for compressive strength.

RESULTS:

The mean compressive strength of polypropylene fiber reinforced bacterial concrete was 33.3347 N/mm^2, whereas the compressive strength of bacterial concrete was 27.5841 N/mm^2. Significance of compressive strength by levene's test for equality of variances was 0.003. Compressive strength values of 18 samples with the addition of polypropylene fiber are detailed in Table 1. Whereas, Table 2 displays the compressive strength values of 18 samples without the addition of fiber. Table 3 displays the group statistics for sample group polypropylene fiber. Independent samples t-test results on plastic were presented in Table 4. Figure 5 shows the Bar chart analysis of mean compressive strength of polypropylene fiber reinforced bacterial concrete and bacterial concrete The comparison of mean accuracy values for four groups of plastic fiber reinforced self healing concrete and conventional self healing concrete with p-value 0.05 and error bar 95% with the effective prediction was shown in the Fig. 5. The error bars with the mean accuracy detection +/- 1 SD.

DISCUSSION:

The compressive strength of the polypropylene fiber reinforced bacterial concrete was found to be higher than that of bacterial concrete without fibers. The use of fibers reduces the permeability of concrete, increasing its compressive strength. The compressive strength of bacterial concrete without fibers had a greater standard deviation than that of bacterial concrete with fibers. It reveals that the bacterial concrete without fibers has a higher variance of compressive strength from its mean value. The compressive strength of bacterial concrete without fibers was higher than that of bacterial concrete with fibers, with a larger standard deviation. It demonstrates that the compressive strength variance of bacterial concrete without fibers is larger than the mean value.

Compressive strength after cracking could be improved in the case of using lightweight aggregate immobilised bacteria in the mixture. The healing capacity increased over curing time with the increasing of compressive strength(Huynh, Imamoto, and Kiyohara 2020). The self-healing with fibers had a greater healing ratio and recovery ratio of flexural strength and modulus than traditional self-healing concrete(Li et al. 2018). The most successful way to improve the flexural performance of fiber-reinforced self-healing concrete in terms of strength and deflection capacity was to use fibers with high aspect ratios(Kim et al. 2019). It can be done by adding a great plasticizer and experimenting with various substances that may be beneficial to the developed structure(Flores, n.d.; Ghosh 2009). This study is the most recent and has a lot of potential in the future.With a wider standard deviation, the compressive strength of bacterial concrete without fibers was higher than that of bacterial concrete with fibers. It shows that the variation in compressive strength of bacterial concrete without fibers is greater than the mean value.More research is needed to determine the impact of other fibers, such as glass and polypropylene fibers, as well as e-waste, on the compressive strength of bacterial concrete. The bacteria bacillus subtilis from the bacillus family were the only ones studied.Bacillus bacteria such as megatherium, sphoracis, and others can be used to conduct more research. Only 3% bacteria and (0.1g/250ml water) calcium acetate were used in this experiment in M20 concrete.

In the future, studies on different grades of concrete with varying bacterial concentrations could be done. Fiber dispersion, bacterium distribution, and calcium carbonate formation can all be studied using SEM and XRD analyses.

CONCLUSION

Compressive strength of polypropylene fiber reinforced M_{20} grade self-healing concrete was 33.3347 N/mm^2. The percentage increase in compressive strength compared to the bacterial concrete was 20.85%.

Declarations

Conflict of Interests

No conflict of interest in this manuscript.

Author Contribution

Author RS is involved in data collection, experimental study and manuscript writing. Author BR involved in conceptualization, guidance and critical review of manuscript.

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TABLES AND FIGURES

Table 1: Represents the compressive strength value of polypropylene fiber reinforced M20 grade bacterial concrete.

S.NO	Weight (Kg)	Strength (KN)	Compressive strength (N/mm^2)
1	8.851	671	29.80
2	8.696	701	31.155
3	8.805	780	34.66
4	8.656	719	31.955
5	8.764	707	31.422
6	8.564	746	33.155
7	8.699	740	32.88
8	8.555	756	33.6
9	8.805	721	32.044
10	8.609	808	35.911
11	8.745	834	37.066
12	8.767	768	34.133
13	8.678	785	34.888

S.NO	Weight (Kg)	Strength (KN)	Compressive strength (N/mm^2)
14	8.546	705	31.33
15	8.676	796	35.37
16	8.542	744	33.066
17	8.643	806	35.82
18	8.565	715	31.77

Table 2 : Represents the compressive strength value of without fiber reinforced M20 grade bacterial concrete.

S.NO	Weight (Kg)	Strength (KN)	Compressive strength (N/mm^2)
1	8.861	547	24.311
2	8.795	715	31.777
3	8.785	690	30.66
4	8.805	539	23.95
5	8.656	502	22.311
6	8.799	543	24.13
7	8.750	496	22.04
8	8.632	872	38.755
9	8.41	494	21.955
10	8.823	688	30.577
11	8.824	588	26.133
12	8.745	632	28.08
13	8.623	560	24.88
14	8.731	580	25.77
15	8.693	788	35.02
16	8.725	644	28.62
17	8.820	596	26.48

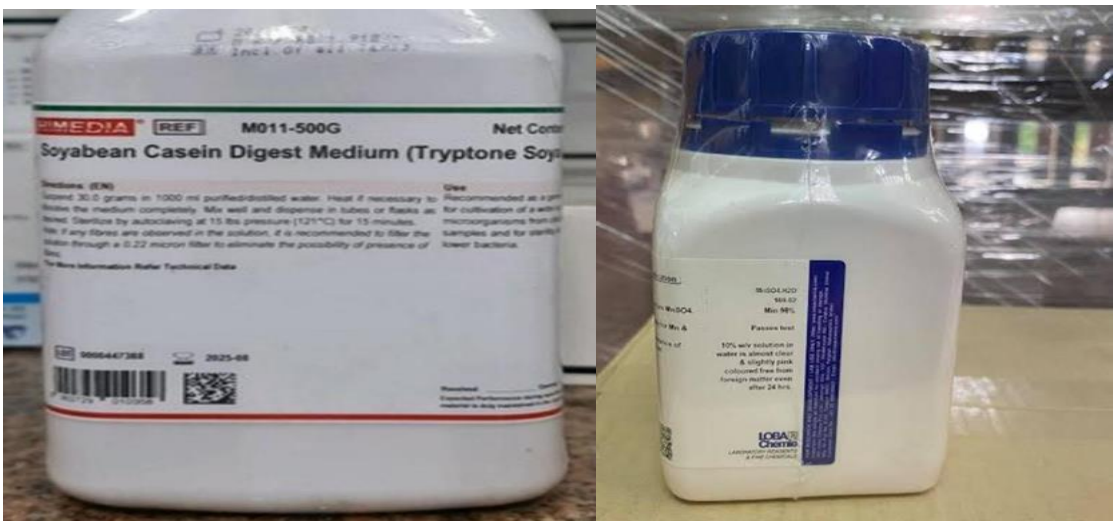
18	8.685	699	31.066

Table 3: Represents group statistics for sample group polypropylene fiber. Mean (27.5827,33.3347),standard deviation (4.66155,1.98535),standard error mean (1.09874,0.46795).

	Group	N	Mean	Std.deviation	Std.Error mean
Compressive strength (N/mm^2)	**Without fibre**	18	27.5827	4.66155	1.09874
	With fibre	18	33.3347	1.98535	0.46795

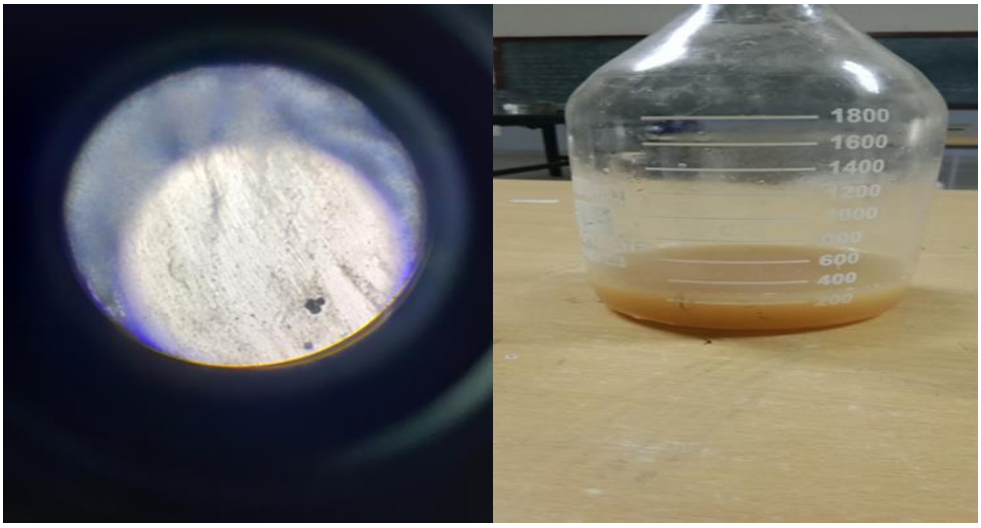
Table 4: Independent samples t-test results: No statistical significance difference observed for compressive strength as a result of an independent samples t test with p=0.013 as it is greater than p=0.05

Independent-samples-t-test									
Compressive strength	**Levene's Test for Equality of Variances**		**t-test for Equality of Means**						
								95% Confidence Interval of the Difference	
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Equal Variances Assumed	10.374	0.003	-4.817	34	0.000	-5.75206	1.19424	-8.17904	-3.32507
Equal Variances Not Assumed			-4.817	22.971	0.000	-5.75206	1.19434	-8.22270	-3.28141



(a) (b)

Fig. 1. Materials used for the preparation of bacteria. (a) tryptone soybean bath (b) manganous sulphate.



(a) (b)

Fig. 2. (a) represents the presence of bacteria under the microscope, (b) represents the growth of bacteria in the bottle.

Fig. 3. Compression testing machine used to collect the compressive strength data.

(a) (b)

Fig. 4. (a) Centrifuge device used to separate the bacteria from media, (b) represents the bacteria after separation from media.

Fig.5. Polypropylene fibre concrete mix

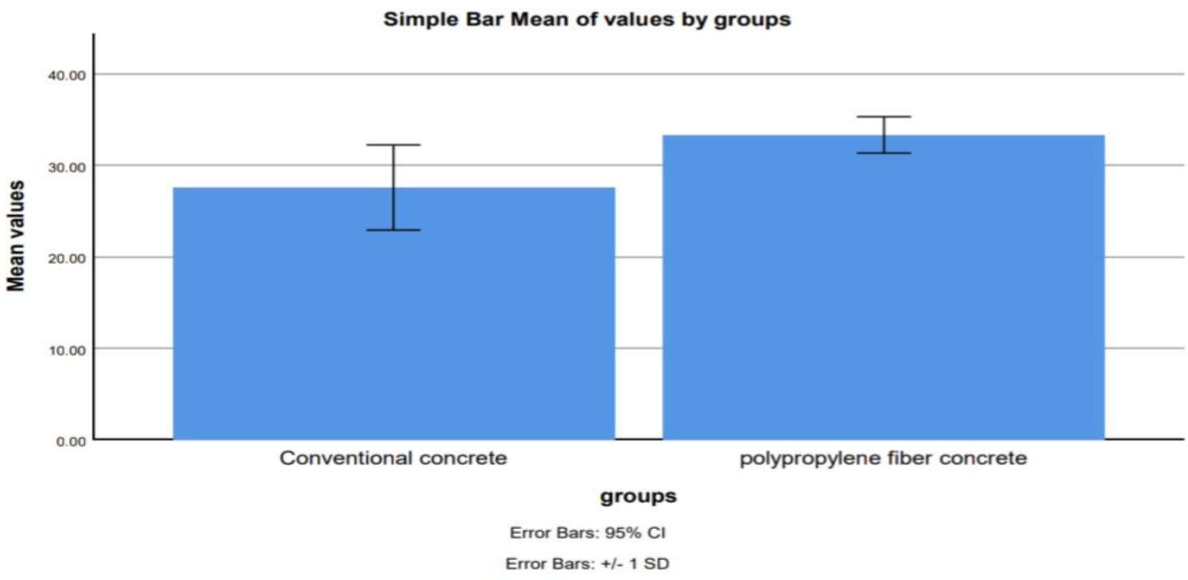


Fig. 6 Bar chart analysis of mean compressive strength of polypropylene fiber reinforced bacterial concrete and conventional concrete . Polypropylene fiber reinforced concrete shows better accuracy compared to conventional concrete. Mean accuracy of detection=+/- 1 SD, Xaxis represents polypropylene fiber reinforced self-healing concrete and conventional self-healing concrete groups, Y axis represents mean compressive strength.