SSRG International Journal of Civil Engineering
ISSN: 2348-8352/https://doi.org/10.14445/23488352/IJCE-V10I7P104
Volume 10 Issue 7, 58-64, July 2023

Original Article

Study on the Tensile Strength of Glass Fibre Reinforced Self-Compacting Bacterial Concrete using a Novel Microbial Technique- Microbial Induced Calcite Precipitation

G. Pradeep[1], B. Ramesh[2], Ragi Krishnan[3]

[1,2,3]Institute of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India.

[2]Corresporing Author : bramesh@saveetha.com

Received: 25 April 2023 Revised: 27 June 2023 Accepted: 16 July 2023 Published: 31 July 2023

Abstract *- The study aimed to analyze the effects of fibre-reinforced self-healing concrete on the tensile strength of concrete and its comparative study with traditional concrete by using a microbiological approach called Calcite precipitation caused by microorganisms. Here we have considered 2 groups for the study, and 18 samples were prepared per group with 80 percent of Glass Powder. Group-1 refers to traditional concrete without any addition in concrete, and group-2 refers to special concrete included with Glass power. The complete data analysis of samples was done by using analytical simulation software. The independent sample T-test has been used for the particular study. It has been carried out by using statical analysis software SPSS version 21. Finally, the comparison of the output has been done. M_{20}-grade concrete has been considered for the study. There was around a 38.78% increment in tensile strength compared to traditional concrete. The corresponding standard deviation was shown as 0.49932, and A drastic difference between the two groups was observed with a p-value of 0.012 ($p<0.05$). The study came to the conclusion that adding fibres to self-healing concrete can increase its tensile strength compared to the concrete of the standard M20 grade.*

Keywords *- Tensile strength, Glass fibre, Self-compacting bacterial concrete, M_{20} grade concrete, Superplasticizer (Tec mix 550) Mineral precipitation, Novel MICP technique.*

1. Introduction

A detailed demonstration of concrete structures' self-recuperating and self-fixing capabilities is given. There are numerous studies carried out during the last decades regarding the self-healing of concrete, but recently got, the idea that particular building technologies are very helpful in stimulating the building capacity of concrete to be self-healed [1]. Self-healing could be a process in which biological organisms respond to the harmful effects of concrete deterioration. The germs can survive around 200 years. It will not cause any harmful effects to humans, and also it is environmentally friendly. The bacteria are used to take the moisture in the building and which helps to multiply the growth and replication. Even if there is a probability of a crack, the bacteria self-heal the crack [1]. In an examination, a self-recuperating method was completed by truly infusing a mending substance. The outcomes uncover that a large-scale break is filled, and in this way, the substantial's solidarity is re-established. As a result, the possibility of self-repair mechanisms in concrete is considered [2]. Several research publications on self-healing concrete have been published in the last few years.

Approximately sixty papers were discovered in Google Scholar and thirty in PubMed. The film in the calcination process is melted using the proper heating. The heat applied selectively surrounding a crack softens the film, allowing the repairing agent to replenish the break and set the maintenance specialist inside the break. To validate the proposed methodology, a three-dimensional temperature associate study and an experimental investigation were assigned[3]. Bio-calcification is a procedure in which the being generates ionic number 20 precipitate, which, when combined with a carbonate particle, creates CaCO3 and fills the holes in the concrete texture, resulting in a lot of compactness [4]. Self-healing materials are those that can fix their injuries on their own or with just a little help from an external source. Self-healing parts might get more common in the structure industry [5]. The effective active life span of concrete is drastically become less to the formation of fractures on its surface, which may result in a concrete corrosion situation. To address such challenges, most modern technologies in concrete production sections are being adopted, and one such advanced method is self-healing concrete via Microbiologically evoked spar Precipitation (MICP)[6]). Concrete cracks are unavoidable or can't be stopped manually by any method directly. And it is one of the material's inherent flaws. Water and other salts seep into these fissures, which usually causes corrosion and reduces the overall lifetime of the concrete. As a result, there was necessary to develop a fundamental biomaterial, a self-repairing material that could repair fractures and fissures in concrete. Microorganism masonry could be a substance that successfully helps for repairing concrete cracks [7].

Few researchers with contented knowledge which has resulted in high-quality publications of research articles [8]–[17]. Till now, the effect of Glass fibres in self-healing concrete is fully accomplished its aim of the study. The regular impact of tiny organisms' bacillus subtilis on the splitting tensile strength of cement is also under the study of so many researchers. This is the earlier study on which the current research is based. This research aims to determine the effect of glass fibre on the tensile strength of self-compacting concrete.

2. Materials and Methods

Glass fibre, a particular kind of bacterial strain, concrete ingredients, calcium source, and nutrient medium are the primary components of the experiment's materials. To increase the concrete's tensile strength and crack resistance, glass fibres are used as reinforcing material.

It is necessary to have bacterial strains that can cause calcite to precipitate. Bacillus species, Sporosarcina pasteurii, or other urease-producing bacteria are frequently utilized for this purpose. Concrete materials typically consist of cement, fine aggregate (sand), coarse aggregate (gravel or crushed stone), and water for M20 grade self-compacting concrete. Based on the design combination, the ratios are decided. The diameter of the cylindrical specimens is 150 mm, i.e. approximately 5.91 inches, and the length of the specimen taken was 300mm. Two different testing categories, each with 20 samples, were chosen. The regular M20 mix is the first category, and the glass fibre-reinforced self-healing concrete is the second. The chosen bacterial strain is cultivated in a nutrient medium until it reaches the desired concentration before being used to create the bacterial solution.

Then the bacteria were collected and combined with the nutritional medium containing the soluble calcium source during the activation of calcite precipitation. In this way, the process of microbially caused calcite precipitation starts. To create the glass fibre-reinforced M20 grade self-compacting bacterial concrete, all of the concrete's ingredients, cement, fine and coarse aggregates, water, and the activated bacterial solution, are fully combined. The desired shape and size were achieved by utilizing moulds or forms while casting concrete samples.

In contrast, some specimens might be made of plain concrete without glass fibres. Under carefully monitored conditions, the cast specimens were allowed to cure to ensure proper development of strength and durability. Following the proper curing time, the specimens were tested for tensile strength using an industry-standard technique called the Split Tensile Test. This entails exerting a force along the axis perpendicular to the applied load during testing. To assess the success of the microbial-induced calcite precipitation technique in enhancing the tensile strength of the glass fibre-reinforced M20 grade self-compacting concrete, the data from the tensile strength tests are statistically analyzed. To evaluate the improvement in tensile strength made possible by the innovative microbial approach, study findings are contrasted with plain concrete (without microbial treatment) and traditional glass fibre-reinforced concrete[18].

Fig. 1 Figure showing the batching and mixing of the concrete

A Gram-positive, spore-forming bacteria called Bacillus subtilis is noted for being able to manufacture urease, which is necessary for the MICP procedure. In this experiment, this kind was employed. And obtaining a pure culture of Bacillus subtilis from a reliable microbial culture collection or a laboratory stock is the first step in the inoculum preparation process. For well-isolated colonies, spread the bacteria onto an appropriate agar plate (such as nutritional agar) and incubate it for 24–48 hours at the ideal temperature (about 30-37°C). After that, a single colony from the agar plate will usually insert into a flask containing a liquid medium rich in nutrients. Peptone, yeast extract, and mineral salts were used in the medium to promote bacterial growth. For 12–16 hours, the flask was placed in an orbital incubator set at the proper temperature and shaken to grow the seed culture. Then the entire thing is transferred to a suitable volume of the seed culture onto a larger fermenter or bioreactor that includes a greater volume of the nutritional medium when the seed culture has reached the necessary cell density. The bioreactor's temperature, pH, and aeration levels have been adjusted for the best possible bacterial growth. The process of primary culture is continually incubated for another 24-48 hours, depending on how quickly the bacteria grow. During the study, the filtration method was utilized to remove the germs from the culture once they had reached the correct density. The cleansing procedure was very prominent. Thus, by using a sterile buffer solution, washed the bacterial pellet to get rid of any remaining growth medium. After the process of cleansing, reattached the bacterial pellet in a nutrient solution, including urea, to activate the germs for MICP. The urease enzyme uses urea as a substrate and kickstarts the creation of carbonate ions and ammonia during the MICP procedure. When making the concrete mix, the activated bacterial solution is added in accordance with the ratios and procedures outlined in the experimental design.

Fig. 2 Figure showing the final collection of the bacteria after mixing

Fig. 3 Casting of cylinder specimen

Fig. 4 Figure showing the compressive testing machine when testing the sample

As demonstrated in Fig.2, bacterial content and vitality in the culture were checked microscopically using a light microscope at 60X magnification. Using a haeyo metre, the cell concentration was estimated and found to be 107 cells/ml. The bacteria cells were detached from the media once they had reached a stable stage, and then the bacteria cells were isolated from the media using centrifugal force. To separate bacteria from the centrifuge, it was run at an RPM of 4000/min and a temperature of 27°C for 10 minutes. The germ microbes were then mixed into the concrete with calcium acetate. All of the ingredients were combined, and cylinders were cast. For curing, the specimens were fully submerged for 28 days [1]. The water temperature was 27(+/-) 2 degrees Celsius. Immediately After 28 days of curing, the specimens were dried for testing. The compressive testing machine, whose maximum load capacity was 2000 KN, was used to depict the tensile strength of the cylinders from both groups, as shown in Fig. 4. This machine is controlled by hand with an efficiency of plus or minus 1. The tensile strength of 18 samples of group 1, i.e., ordinary self-compacting materials, was determined. Similarly, the tensile strength of 18 specimens from group-2, i.e., fibre-reinforced self-compacting concrete, was determined.

Analytical statistics: The SPSS Adaptation 21 program was utilized to break down the discoveries of the analysis. A free examples t-test was utilized to inspect the review and control gatherings' measurable meaning of the review and control gatherings. The rigidity of the material, substantial level, water/concrete extent, concrete grade, and long drying stretches were autonomous variables in the review. This was additionally used to process the rigidity middle, standard deviation, and normal mean mistake of the mean.

Bacterial substance and reasonability in the way of life were affirmed minutely through a little magnifying lens at 60x goal. The convergence of cells was determined utilizing a haeyo meter and was viewed as 107 cells/ml. After the microscopic organisms had arrived at a steady state, the microbes' cells were separated from the media involving a diffusive power, as displayed in Fig.4. The rotator was run at 4000 RPM and 27°C for 10 minutes to separate microscopic organisms from the axis, which was then quickly infused to the substantial along with calcium acetic acid derivation. The prior was all combined as one, and chambers were projected. For relief, the examples were kept lowered for 28 days. The water temperature was 27(+/ -) 2°C. Following 28 days of restoring, the examples were dried for testing. The compressive testing gear, with the greatest burden limit of 2000 KN, was utilized to decide the elasticity of the chambers from the two gatherings. The accuracy of this physically worked machine is plus or minus 1. The tensile strength of 18 examples of primary gathering and regular self-compacting is not entirely set in stone. Likewise, the rigidity of 18 examples of the subsequent gathering, i.e., fibre-supported self-compacting concrete, is not entirely set in stone.

The trial's outcomes were dissected utilizing the factual examination programming SPSS, adaptation 21 program. The new review's measurable meaning and base gatherings were resolved using a free examples t-test. The review had no reliant elements, yet free factors like rigidity, substantial grade, water/concrete proportion, concrete grade, and long restoring stretches. This instrument additionally resolved the mean, standard deviation, and standard deviation of the mean for rigidity.

3. Results and Discussions

The average tensile strength for both groups was determined. The group-1 samples have a mean tensile strength of 3.2694N/mm2, while the group-2 samples have a mean tensile strength of 4.3306 N/mm2. Table 4 shows the tensile strength of glass fibre-reinforced self-compacting concrete. When comparing group-2 samples to group-1 samples, the average tensile strength was discovered to be higher in group-2 samples. The percentage increase in group-2's mean tensile strength was 32.455%. According to the statistical parameters, the disparity between the two groups seems substantial. The standard deviations for both groups were found to be relatively low. The standard deviation for group-1 is 0.17162, whereas it is 0.47252 for group-2. Table 5 shows the results of 18 samples after including glass fibre. Table 4 shows the tensile strengths of 18 samples before including glass fibre. Table 5 contains details on group statistics. Furthermore, Figure 5 portrays a relationship of the mean exactness scale for two gatherings of plastic fibre-reinforced self-compacting concrete and customary self-compacting concrete having a p-worth of 0.05 and a blunder bar of 95% with the genuine expectation. The blunder bars notice the mean recognition proficiency +/ - 1 SD. The conventional self-compacting concrete specimens were found to be heavier than the fibre-reinforced self-compacting composite samples. When tensile strength is compared, the glass fibre-reinforced reinforced self-compacted concrete samples had a higher value. This clearly shows that fibre-reinforced self-compacting concrete outperforms traditional self-compacting concrete samples. Nitrite was produced as an intermediate metabolic product by microbial granules containing denitrifying cultures, which preserved the reinforcement during the fracture healing process[19]. As part of the study, crack repair needs to be done, but because it is labor intensive and the building is out of service during the repair, the overall price of concrete construction rises by 50%. [20]. Previously, steel fibres were discovered to be good at arresting micro-cracks and providing significant strength; in any case, when presented with air or dampness, it consumes, bringing about a deficiency of solidarity and strength. [21].

Table 1. Table displaying the fibre qualities added to the group 2 samples (glass fibre)

S.no	Parameters	Results
1	Length of fibre	12 mm
2	Colour	White
3	Thermal conductivity	1.2
4	Melting point	1135°c
5	Bulk modulus	43
6	% fibre added	3%
7	Amount of fibre used to cast 18 cylinders	342.82

Table 2. Table showing the weight of materials required to cast a sample (cylinder of dimension 200*100mm)

S.no	Materials	Quantity (kg/lit)
1	Cement	0.633kg
2	Fine aggregate	1.219kg
3	Coarse aggregate	2.044kg
4	Water	0.27852 lit
5	Fibre (3%)	18.99 gms
6	Superplasticizer (Tec mix 550)	0.83345ml
7	Bacteria	12ml
8	Calcium acetate	0.09gms

Table 3. Table showing the tensile strength of the group-1 samples (conventional concrete samples)

Sl. No	Strength (KN)	Tensile strength (N/MM^2)
1	67	3.35
2	68	3.4
3	69	3.45
4	60	3
5	67	3.35
6	61	3.05
7	66	3.3
8	66	3.3
9	60	3
10	69	3.45
11	64	3.2
12	69	3.45
13	65	3.25
14	60	3
15	71	3.55
16	63	3.15
17	65	3.25
18	67	3.35

There are some drawbacks to this study. 1) For this experimental study, just one type and percentage of fibre were employed; 2) Only M20 grade concrete was used. 3) The bacteria Bacillus subtilis is employed for self-compaction. 4) The concentration of bacteria for addition is similarly limited [22]. Basalt fibre (BF) is a novel type of inorganic fibre that is commercially accessible and is produced by extruding melted basalt rock. This study compares the use of basalt and glass fibres as fibre reinforcement in high-strength concrete [23]. It investigated the redirection conduct of cement flexural parts supported with lustrous fibre-built-up polymers (GFRP) bars.

It is generally recognized that usefulness is a significant thought in advancing GFRP-supported cement footers [24]. We all know how expensive it is to maintain construction structures. However, with this strategy, that can be mitigated to some amount. It can be done by adding a superplasticizer and experimenting with various chemicals that may be beneficial to the created structure. This examination is the most recent study, and it has a lot of potential in the future.

Table 4. Table showing the tensile strength of group 2 (fibre-reinforced self-compacting concrete.)

S.no	Strength (KN)	Tensile strength (N/mm^2)
1	91	4.55
2	84	4.2
3	93	4.65
4	106	5.3
5	89	4.45
6	97	4.85
7	96	4.8
8	78	3.9
9	95	4.75
10	93	4.65
11	79	3.95
12	84	4.2
13	78	3.9
14	73	3.65
15	85	4.25
16	70	3.5
17	95	4.75
18	78	3.9

Table 5. Group data for both samples are represented. Standard deviation (0.17162,0.47252), and the standard error of the mean (0.04045,0.11137) Group statistics

	Group	No	Mean	Std. deviation	Std. error mean
Tensile strength	Without fibre	18	3.2694	.17162	.04045
Tensile strength	With fibre	18	4.3306	.47252	.11137

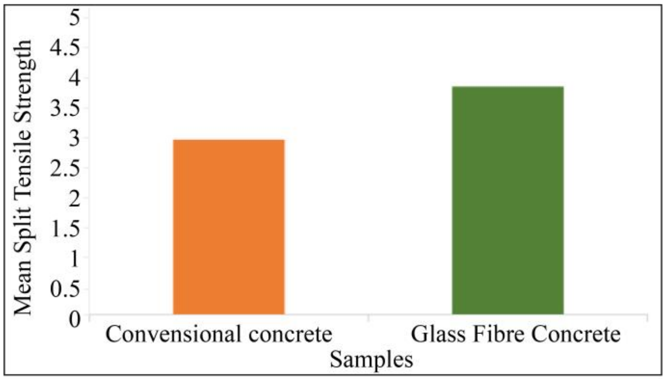

Fig 5. A bar chart depicting the mean yield strength of glass fibre-strengthened concrete as well as bacteria-based concrete (independent sample t-test means = +1SD). It shows that the typical elasticity of glass fibre M_{20} type self-compacting concrete is more prominent than that of customary cement, where the level pivot demonstrates the gatherings and the vertical shows the examples' rigidity

4. Conclusion

We came to the conclusion that the M20 grade self-compacting concrete's tensile strength is effectively increased by the innovative microbial technology of MICP using particular bacterial strains, such as Bacillus subtilis. In comparison to normal concrete without these treatments, MICP and glass fibre reinforcement may have synergistic effects that increase tensile strength. Glass fibre embedded M20 grade self-healing concrete had a tensile strength of 4.3305 N/mm^2. Tensile strength increased by 32.455% when compared to bacterial concrete.

Acknowledgment

The authors would like to express their sincere gratitude towards the Saveetha School of Engineering, and Saveetha Institute of Medical and Technical Sciences, for providing the necessary infrastructure to complete this work successfully.

Funding: We thank the referenced Organizations for offering monetary help that empowers us to finish the review

1. Velsa Technologies.
2. Saveetha School of Engineering.
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha University.

References

[1] M. Madhan Kumar et al., "Experimental Investigation on Fiber Reinforced Bacterial Concrete," *Materials Today: Proceedings*, vol. 22, no. 4, pp. 2779–2790, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Senot Sangadji, and Erik Schlangen, "Development of Self-Repairing Concrete Structures by Means of Porous Network," *IABSE Conference, Rotterdam 2013: Assessment, Upgrading and Refurbishment of Infrastructures*, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[3] Tomoya Nishiwaki et al., "Development of Self-Healing System for Concrete with Selective Heating around Crack," *Journal of Advanced Concrete Technology*, vol. 4, no. 2, pp. 267–275, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[4] Ravindranatha, N. Kannan, and M. L. Likhit, "Self-Healing Material Bacterial Concrete," *International Journal of Research in Engineering and Technology*, vol. 3, no. 15, pp. 656–659, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[5] Marta Roig Flores, "*Self-Healing Concrete: Efficiency Evaluation and Enhancement with Crystalline Admixtures*," Polytechnic University of Valencia, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[6] Shradha Jena et al., "Impact of Bacillus Subtilis Bacterium on the Properties of Concrete," *Materials Today: Proceedings*, vol. 32, pp. 651–656, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[7] Venkataswamy Ramakrishnan, K. P. Ramesh, and S. S. Bang, "Bacterial Concrete," *Smart Materials*, 2001. [CrossRef] [Google Scholar] [Publisher Link]

[8] P. Pandiyan et al., "A Comprehensive Review of the Prospects for Rural Electrification using Stand-Alone and Hybrid Energy Technologies," *Sustainable Energy Technologies and Assessments*, vol. 52, p. 102155, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[9] P.R. Yaashikaa, M. Keerthana Devi, and P. Senthil Kumar, "Advances in the Application of Immobilized Enzyme for the Remediation of Hazardous Pollutant: A Review," *Chemosphere*, vol. 299, p. 134390, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] Harish Venu et al., "Analysis of Particle Size Diameter (PSD), Mass Fraction Burnt (MFB) and Particulate Number (PN) Emissions in a Diesel Engine Powered by Diesel/Biodiesel/n-Amyl Alcohol Blends," *Energy*, vol. 250, p. 123806, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[11] P. Ganesh Kumar et al., "Ultrasonication Time Optimization for Multi-Walled Carbon Nanotube based Therminol-55 Nanofluid: An Experimental Investigation," *Journal of Thermal Analysis and Calorimetry*, vol. 147, no. 19, pp. 10329–10336, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] V. Nagaraju et al., "Role of Silicon Carbide Nanoparticle on Electromagnetic Interference Shielding Behavior of Carbon Fiber Epoxy Nanocomposites in 3-18GHz Frequency Bands," *Silicon*, vol. 14, no. 16, pp. 10931–10938, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] M. Karpagam et al., "A Novel Face Recognition Model for Fighting against Human Trafficking in Surveillance Videos and Rescuing Victims," *Soft Computing*, vol. 27, pp. 13165-13180, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[14] P. Baraneedharan et al., "Advances in Preparation, Mechanism and Applications of Various Carbon Materials in Environmental Applications: A Review," *Chemosphere*, vol. 300, p. 134596, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Niwooti Whangchai et al., "Effect of Biogas Sludge Meal Supplement in Feed on Growth Performance Molting Period and Production Cost of Giant Freshwater Prawn Culture," *Chemosphere*, vol. 301, p. 134638, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Karthik Nagarajan et al., "Combined Economic Emission Dispatch of Microgrid with the Incorporation of Renewable Energy Sources Using Improved Mayfly Optimization Algorithm," *Computational Intelligence and Neuroscience*, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[17] Santhana Raj Deena et al., "Enhanced Biogas Production from Food Waste and Activated Sludge Using Advanced Techniques – A Review," *Bioresource Technology*, vol. 355, p. 127234, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Ragi Krishnan et al., "Effective Tuned Mass Damper System for RC Tall Chimney Dynamic Wind Response Control," *Materials Today: Proceedings*, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[19] Prasad Bishetti et al., "Glass Fiber Reinforced Concrete," *SSRG International Journal of Civil Engineering*, vol. 6, no. 6, pp. 23-26, 2019. [CrossRef] [Publisher Link]

[20] Kim Van Tittelboom, Manuel Dierick, and Nele De Belie, "Durable Concrete Structures with Cracks Which Heal Themselves," *Brittle Matrix Composites*, vol. 10, pp. 285–294, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[21] S. Subhashini, K. K. Yaswanth, and D. S. V. Prasad, "Study on Strength and Durability Characteristics of Hybrid Fiber Reinforced Self-Healing Concrete," *International Journal of Engineering & Technology*, vol. 7, no. 4.2, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[22] Dong Xiao, "State-of-the-Art and Prospect for Self-Healing Asphalt Concrete," *AIP Conference Proceedings*, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[23] Ajmal Paktiawal, and Mehtab Alam, "Experimental Evaluation of Sorptivity for High Strength Concrete Reinforced with Zirconia Rich Glass Fiber and Basalt Fiber," *Materials Today: Proceedings*, vol. 49, pp. 1132–1140, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[24] Seyyed-Asgar Hosseini, Mahdi Nematzadeh, and Carlos Chastre, "Prediction of Shear Behavior of Steel Fiber-Reinforced Rubberized Concrete Beams Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars," *Composite Structures*, vol. 256, p. 113010, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[25] Nele De Belie et al., "Durability of Self-Healing Concrete," *MATEC Web of Conferences*, vol. 289, p. 01003, 2019. [CrossRef] [Google Scholar] [Publisher Link]