

Effectiveness of Repair Material Using Polypropylene Fiber

Zafri Ayob¹, Sallehuddin Shah Ayop^{1*}

¹ Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author: sallehs@uthm.edu.my

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Abstract

The study investigated the impact of polypropylene fiber on the properties of SikaGrout®-215 mortar, focusing on compressive and flexural strength. Tests were conducted on mortar samples with a characteristic strength of 65-70 N/mm² at 28 days. Polypropylene fiber volume fractions of 0.1%, 0.3%, and 0.5% were examined, with a control mix having no fiber. Surprisingly, fiber addition had no positive effect on compressive strength but significantly increased flexural strength. The addition of fiber increased pore structure, permeability, and porosity, although these decreased with longer curing periods. Despite falling within the range of good quality, the optimal mixture design was observed with a 0.3% fiber combination.

1. Introduction

Polypropylene fiber, known for its strength and versatility, is emerging as a promising material for repair applications. Studies show that incorporating polypropylene fiber into materials such as mortar and concrete can enhance mechanical properties, thereby improving durability. Particularly used in repairing concrete structures affected by reinforcement corrosion, polypropylene fiber offers the potential for stronger, longer-lasting structures.

This study examines the efficacy of repair materials reinforced with polypropylene fiber, aiming to advance scientific understanding and provide valuable insights for builders seeking sustainable and resilient structural repair solutions. Mortar repair materials with low flexural strength may experience reduced bond strength with the existing concrete substrate, leading to delamination and failure of the repair. In addition, conventional mortar repair may have lower flexural and compressive strengths than high-performance grouting materials, such as Sika grout, which can lead to cracking and affect the durability and performance of the repair. The main purposes of the research are to evaluate the performance of different polypropylene fiber percentages as a repair material and to determine the compressive and flexural strengths of the repaired material at varying fiber percentages. To achieve these objectives, 3 mortars containing 0.1%, 0.3%, and 0.5% polypropylene fiber were mixed.

The objective of this study is to investigate the effects of polypropylene fiber on SikaGrout-215, with a focus on shrinkage cracking and impact resistance. Through a methodical assessment of the performance of these materials, the study aims to provide insights into how mortar formulations can be optimized to enhance structural durability and reliability. By delving into the nuances of material selection and interaction, we aim to advance construction methods and ensure that mortar applications, specifically SikaGrout-215 with polypropylene fiber, meet the most stringent requirements for durability and performance.

2. Literature Review

2.1 Polypropylene Fiber

Polypropylene fiber, known for its low density and moisture resistance, is employed in construction, specifically macro polypropylene fiber in this study. This high-strength fiber enhances concrete toughness, effectively mitigating plastic shrinkage cracking and regulating crack progression [1]. Notably, it serves as a cost-effective alternative to traditional steel fiber and fabric in construction engineering applications.

The impact of polypropylene fibers depends on factors such as fiber type, length, and volume fraction (refer to Table 1), as well as the mix design and the properties of the concrete materials used [2]. The overall findings indicate substantial improvements in permeability, abrasion resistance, and impact resistance upon incorporation of polypropylene fibers [1]. Large and robust fibers prevent the formation of significant cracks, whereas smaller and more flexible fibers regulate both the initiation and propagation of smaller cracks.

Because of its superior compressive, flexural, and tensile strengths, as well as its high modulus of elasticity, which yields lower strain under loading and therefore fewer fracture propagations, composite concrete, such as fiber-reinforced concrete, is frequently utilized in construction.

Table 1 Physical and mechanical properties of polypropylene fibers

Properties	Polypropylene fibers
Density (g/cm^3)	0.91
Diameter (μm)	34
Length (mm)	12
Modulus of elasticity (MPa)	3750
Geometry	Multifilament
Content	600-900 g/m^3

2.2 Sika Grout

Sika grout is a line of high-performance, non-shrink cementitious grouting materials developed by Sika, a prominent manufacturer of construction chemicals. These products are engineered to deliver robust, long-lasting, and precise grouting solutions for a variety of construction applications. Sika grout is formulated to resist shrinkage during curing, thereby maintaining its volume and forming a strong bond [3]. The sika grout range includes products such as SikaGrout-215, SikaGrout-111, SikaGrout-212, and SikaGrout-212.

Sika grout is a versatile range of non-shrink, cementitious grouts designed for various construction applications. It is available in different formulations to accommodate diverse project requirements. Some variants offer extended working times, adaptability to different ambient temperatures, or specialized properties for specific construction scenarios. As with any construction material, it is essential to adhere to proper handling, mixing, and application procedures outlined in the product's technical data sheet to ensure optimal performance.

2.3 Crack Mitigation

Polypropylene fibers are essential for mitigating mortar cracks because of their exceptional ability to reduce crack propagation. It is known for its ability to control and mitigate cracks in mortar. These fibers, an essential component of the mortar mixture, serve as a dispersed network that distributes stress throughout the material. This method of stress distribution is especially important for keeping large, potentially dangerous cracks from forming in the mortar. The use of polypropylene fibers actively absorbs and redistributes applied pressure in the mortar and serves as a physical barrier to crack propagation [4].

In the end, this crack control process helps to maintain the structural performance and longer lifespan of the restored parts by strengthening the mortar's integrity against outside forces and environmental variables. The inclusion of these fibers helps distribute stress and prevents the formation of large cracks, enhancing the overall durability of the repaired structures. The outcome is a strengthened mortar matrix that successfully prevents the growth of significant cracks, guaranteeing a strong and long-lasting repair and rehabilitation solution.

2.4 Flexural Strength

The addition of polypropylene fibers to mortar to increase its flexural strength represents a significant breakthrough in mortar technology. The capacity of a material to withstand bending stresses, also known as flexural strength, becomes crucial in repair applications where structural members are exposed to external forces,

changing weights and loads. Polypropylene fibers significantly increase the mortar matrix's ability to endure bending loads by adding a reinforcing network to it [5].

In addition, the increased flexural strength provided by polypropylene fibers enhances the overall structural performance of the restored components. Over time, the mortar reinforced with these fibers will be more resilient to changes in loads and external pressures, ensuring greater stability. This is especially important when repaired structures are subjected to harsh environments like seismic activity or high traffic volumes [6].

2.5 Compressive Strength

The increase in the compressive strength of polypropylene fiber mortar is an important development that will substantially affect the ability of repaired structures to support loads. One of the most important characteristics of building materials is its compressive strength, which determines how well the material can withstand compressive forces and resist axial loads. When it comes to this important feature, the addition of polypropylene fibers to cement used for structural rehabilitation makes a significant difference [7].

Polypropylene fiber mortar has a higher compressive strength, which makes it more resilient and able to support heavy loads. This improvement is essential to guaranteeing the stability and lifetime of restored structures, particularly in situations when structures are subjected to significant and fluctuating vertical stresses. With its increased compressive strength, the reinforced mortar provides a reliable, long-lasting solution that meets the rigorous specifications for load-bearing elements in the built environment [8].

In summary, the addition of polypropylene fibers to mortar results in a notable improvement in compressive strength, which is an important property for the load-bearing capacity of buildings that are being repaired. This enhancement greatly adds to the overall structural robustness and durability of the restored parts in addition to reinforcing the material against compressive stresses.

2.6 Patch Repair Process

This technique is used to repair spalled concrete. It is typically necessary to return the affected member to its original section and to adequately protect any reinforcement it may contain when some concrete is removed from a structure or has become loose to the point that it must be removed [9]. This process is known as patching reinforced concrete as shown on Figure 1. The removal of damaged concrete, preparation of the substrate and steel, and application of the repair materials make up the patch repair procedure. Figure 1 shows patch repair on a concrete structure.



Fig. 1 Patch repair on concrete structure [9]

2.7 Remolding The Flexure Beam and Pouring

A concrete beam can be repaired by applying the repair material to the prepared area while the beam is inverted. This method is used to apply repair material to the tension side efficiently and straightforwardly. The repair material can be pneumatically projected onto the prepared surface at high velocity while being transported through a hose under field circumstances. Because of the power with which it is propelled from the nozzle, this process will simultaneously deposit and compact the repair material [10]. Figure 2 shows the application of the primer and the repair material.



Fig. 2 Application of primer and repair material [10]

To repair the beams, the corresponding repair material primers were first coated on the beams. The mix was then poured into the properly enclosed pouring gap of the beam to be repaired using a scoop, and the material was uniformly tamped. After achieving the required filling, the repair material was smoothed-off on the surface by a trowel. Wet-burlap and plastic sheets were used to cover the beams to avoid any kind of moisture loss. The wooden enclosures of the repair section were removed after 24 hours, and the spray curing was started [10]. The moist curing was continued for 28 days, and later the beams were tested to ensure their structural integrity.

3. Methodology

This chapter outlines the methodology employed in the study, focusing on evaluating the performance of concrete with varying percentages (0%, 0.1%, 0.3%, and 0.5%) of polypropylene fiber mixed with SikaGrout®-215 as a repair material. The investigation aimed to identify the optimal polypropylene fiber weight percentage to achieve desirable flexural and compressive strengths in the mortar mix. Standard guidelines, specifically BS EN 12390-5:2000, were followed for the assessment of flexural and compressive strength. The compressive strengths of 50×50×50 mm cube specimens at 28 days were tested using a universal testing machine with a capacity of 1500 kN. The Sikagrout 215 mix design entails dividing the powder into water in accordance with the manufacturer's guidelines, which typically specify a powder-to-water ratio. For Polypropylene fiber (PP) in mortar, the design addition of fiber, which is 0%, 0.1%, 0.3%, and 0.5%, will assess. Water cement ratio of 0.72 is use in this study. By using proper machine for mixing such as cordless drill will obtain a better mix of samples.

3.1 Mix Design and Sample Preparation for Repair Beam

After mixing work done according to the mixing ratio that SikaGrout®-215 company provided, add the PP fibers to the mortar sample with three difference percentage which are 0.1%, 0.3% and 0.5% by the weight of the mortar sample. After that, pour the mortar sample into cube mold with dimensions of (50mm x 50mm x 50mm) for the compression test. At least three samples were analyzed for testing, and these samples came from separate batches. Table 2 shows the mix design of Sikagrout for flowable and pourable consistency.

Table 2 Mix design of Sikagrout mortar for flowable and pourable consistency

Flowable Consistency			
Sika	1.84 kg	25 kg	74 x 25 kg
Water	0.31 L	4.2 L	309 L
Volume mortar	1 L	13.6 L	1 m ³
Pourable Consistency			
Sika	1.90 kg	25 kg	76 x 25 kg
Water	0.3 L	4 L	303 L
Volume mortar	1 L	13.2 L	1 m ³

In the flexural test, four (4) defective reinforced concrete beams with a size of (150mm x 150mm x 600mm) were taken to repair, refer to Figure 3. After that, remove all the loose parts of the defective concrete until you find the bottom bar, which is a hardened part of the reinforced concrete beam. Before remolding and grouting the

defect area, cut the surface around the defect area so that the mortar and the reinforce concrete beam can bond effectively. Figure 3 shows removing loose concrete and shaping concrete surface.

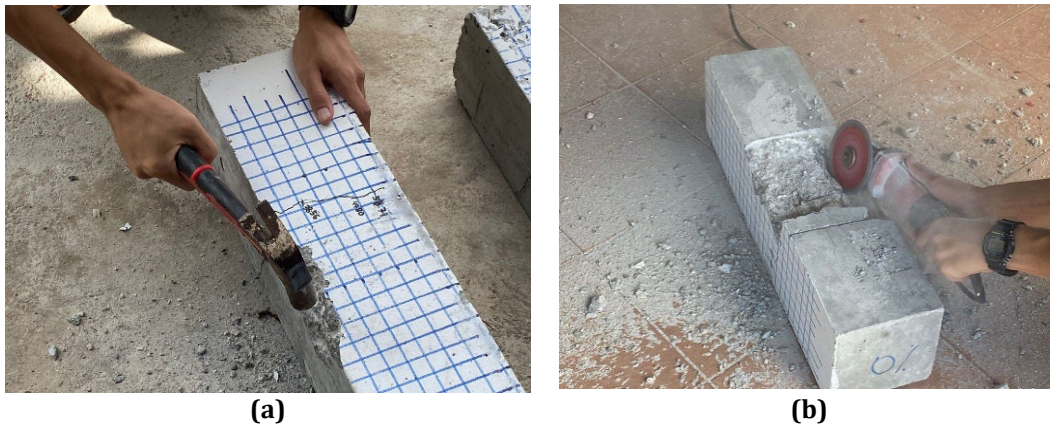


Fig. 3 (a) Remove loose concrete; (b) Shaping the concrete surface

To ensure an effective and long-lasting repair, the concrete area must be cleaned before beginning work. In order to improve adhesion and bonding with the repair materials, this stage cleans the surface of dirt and impurities. It also stops more impurities from being introduced during the repair process and permits a visual evaluation of the damage. In order to apply coatings and bonding chemicals correctly and increase the overall longevity of the restored structure, a clean surface is required. Figure 4 shows the process of cleaning repair area by water. Initially, formwork acts as a mold or template that establishes the size and shape of the concrete building that is being constructed. During the pouring and curing stages, it gives the wet concrete the support it needs. The shape, size, and surface finish of the concrete are guaranteed when formwork is built and planned correctly—Figure 5 shows remolding defect beam. After remodeling works, grout by pouring mortar mix PP 0%, 0.1%, 0.3% & 0.5% sample on the repair area. The procedure starts with careful surface preparation, grout selection, and cleaning. To guarantee a consistent grout mixture, mechanical mixers are frequently utilized. Grouting gives the restored structure strength, stability, and longevity, making it a flexible and efficient option for a range of concrete repair applications. The curing process for these materials is by dry curing for 24 hours. Figure 6 shows pouring mortar sample on defect area.



Fig. 4 Wash the defect area by water



Fig. 5 Remolding defect beams



Fig. 6 Grouting mortar mix sample

3.2 Cube Sample Preparation

Twelve (12) cubes, each 10 cm x 10 cm x 10 cm, were prepared using SikaGrout®-215, polypropylene, and water to measure the compressive strength of mortar. The cubes are well mixed and then allowed to cure in a controlled atmosphere for a predetermined amount of time for 28 days. These cubes were then subjected to a machine-assisted compressive strength test, in which the force is gradually increased until failure. Figure 7 illustrates the procedure for cube sample preparation using a steel mold measuring 10 cm x 10 cm x 10 cm, while Figure 8 shows the application of oil on the inner mold and the casting of the specimen in three layers

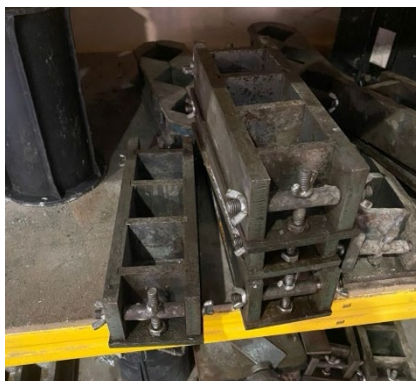


Fig. 7 Mortar cube mold

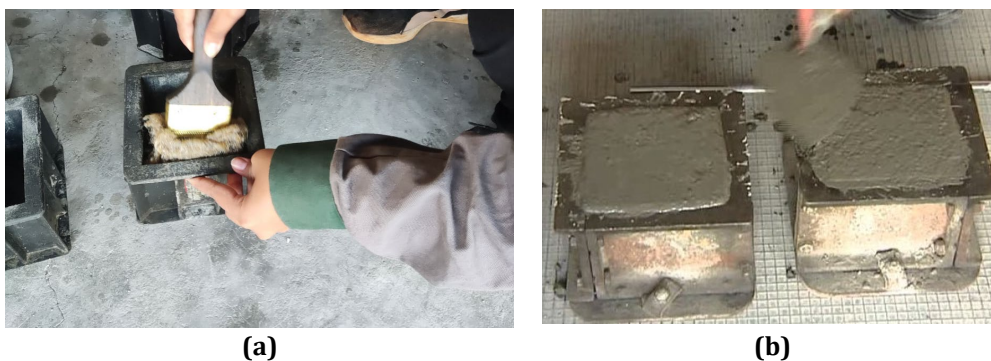


Fig. 8 Rub oil on the inner mold (a); and the specimen cast in 3 layer each (b)

The study's used curing technique was curing in water and it adhered to the BS ISO 1370-2013 standard. All of the cube samples were cured in the water tank for 28 days after the concrete had dried for 24 hours. In this study, compressive strength was measured on days 28 after curing, whereas the flexural strength for repaired beam will be tested right after curing for 24 hours. The purpose of the curing process is to manage the moisture level of the concrete while the hardening process is being done. Figure below shows curing sample for 28 days.



Fig. 9 Curing cube sample

3.3 Testing Method

As part of this investigation, a range of tests were conducted to examine the properties of concrete. The study encompassed assessments of compressive strength and flexural strength. To determine the maximum flexural strengths, a hydraulic compression and flexural machine will be used.

The flexural strength test will be carried out in accordance with the specifications outlined in BS EN 12390-5:2000. The test involves using $150 \times 150 \times 600$ mm beams subjected to four-point loading on a supported span measuring 400 mm. The load will be applied at a consistent rate within the range of 0.04 MPa/s ($\text{N}/\text{mm}^2/\text{s}$) to 0.06 MPa/s ($\text{N}/\text{mm}^2/\text{s}$). The load application was free from sudden impact and increased steadily at the chosen constant rate, with a permissible deviation of $\pm 1\%$, until the maximum sustainable load was reached. In line with the BS EN 12390-5:2000 standard, the interpretation of the flexural strength test results involved calculating the flexural stress as follows:

$$R = PL/bd^2 \quad (1)$$

Where: R is flexural strength (modulus of rupture), P is maximum indicated load, L is span length, b is width of specimen, and d is depth of specimen.



Fig. 10 Flexural strength test apparatus

The assessment of the compressive strength of hardened concrete was conducted in accordance with the guidelines outlined in EN 12390-3:2000 (2000). This evaluation was crucial to verify whether the concrete mixture fulfilled the specified strength requirements. Once the concrete reached its peak compressive strength, the average of three test results obtained from each concrete batch was utilized for research. The testing of cubes was performed using a hydraulic compression machine with a capacity of 2000kN, as depicted in Figure 11. The strength determination was carried out using the formula presented in equation below

$$\sigma = \frac{F}{A} \quad (2)$$

Where: σ is compressive strength, F is force (N) and A is area of specimen (mm^2)

**Fig. 11** Compressive strength test

4. Result and Discussion

The results were obtained to identify the most favorable outcome. The result discusses comply with the objective in this study which are to evaluate the performance of polypropylene fiber as a repair materials and to determine the effectiveness mortar sample repair on flexural failure. The chapter concludes with a discussion of the results.

4.1 Compressive Strength Test

Overall, the strength of the repair material is higher than that of concrete containing polypropylene fibers. The highest average compressive-strength of mortar sample with spent garnet falls to specimen 0.5% with 78.6MPa and followed by specimen 0.3% with 72.3MPa and specimen 0.1% with 68.2 MPa. Overall, in compressive strength the result shows the specimen of 0% to 0.1% are constant. Meanwhile, after the increment of 0.3% PP fibers, the strength increase to 72.5MPa. Its strength is found that has higher 6.6% than the control specimen. Table 3 shows Compressive strength of mortar sample at the curing period of 28 days.

Figure 12 shows a bar chart is used to show the specimens' compressive strengths as well as the goal strength line. Compared with the control and other fiber percentages, the addition of mortar up to 0.5% by weight yields the highest strength. Strength rose from 0.3% to 0.5% over the target strength at 28 days when the amount of polypropylene used as a repair material was increased. The target strengths have only a 0.3% difference in compressive strength with the control mortar sample when 0.1% PP fibres are included in the mortar sample.

The results of compressive strength for the highest specimens of the repair material give 19.84% above the target strength of 65 MPa for 0.5% of PP fiber.

Table 3 *Compressive strength of mortar sample at the curing period of 28 days*

	Sample	Compressive strength (MPa)
Controlled	1	68.1
	2	68.2
	3	67.8
	Average	68.0
0.10%	1	68.1
	2	67.9
	3	68.5
	Average	68.2
0.3%	1	71.9
	2	72.6
	3	72.3
	Average	72.3
0.5%	1	78.5
	2	78.4
	3	78.9
	Average	78.6

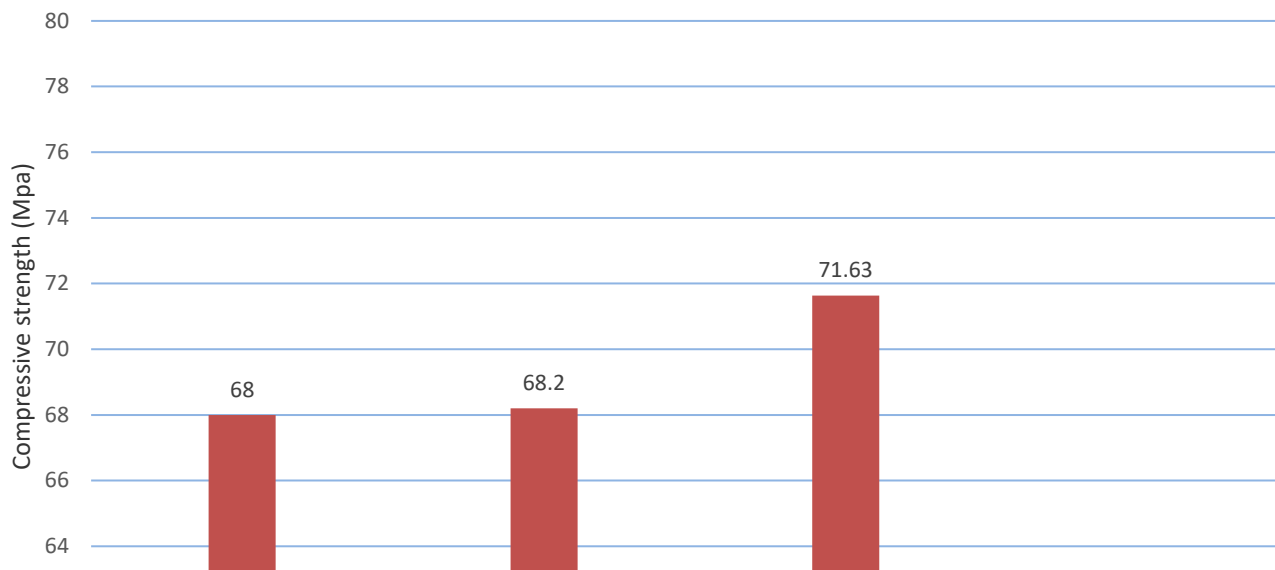


Fig. 12 *Average compressive strength of concrete specimens at age of 28 days*

4.2 Flexural Strength Test

Flexural strength is the capacity of an unreinforced concrete slab or beam to resist the bending brought on by an applied load. Concrete specimens' flexural strength has been calculated using a formula that depends on the maximum load applied, which is compiled in Table 4.

Table 4 Maximum load applied and the corresponding flexural strength

Specimen	Max loading(kN)	Flexural Strength (MPa)
S 1 (0%)	51.96	7.0
S 2(0.1%)	61.24	9.17
S 3(0.3%)	77.96	10.4
S 4(0.5%)	69.04	9.2

Figure 13 displays the results of the flexural strength tests on mortar specimens at 28 days of age. The flexural strength of the control specimen is 7.0 Mpa. The flexural strength of polypropylene fiber at 0.3% was 10.4 MPa, 0.5% was 9.2 MPa, and 0.1% was 9.17 MPa. It was discovered that 0.3% of PP fiber had the ideal strength, which differs from the mortar control sample by 48%. The strength of 0.5% PP fiber is less than 0.3% of PP fiber, as evidenced by the existence of polypropylene fiber. This is due to the possibility that an increase in the volume occupied by PP fibers will raise the total porosity as the fraction of PP fiber increased. Increased porosity can weaken the concrete matrix's resistance to applied stresses and risk its continuation [11]. A high fiber content may have a negative effect on the binding between the base layer and the grout, perhaps contributing to weak interfaces and void development [12]. The total flexural strength may be compromised by weak interfacial bonding, which can also lower the load transfer capacity throughout the repaired region.

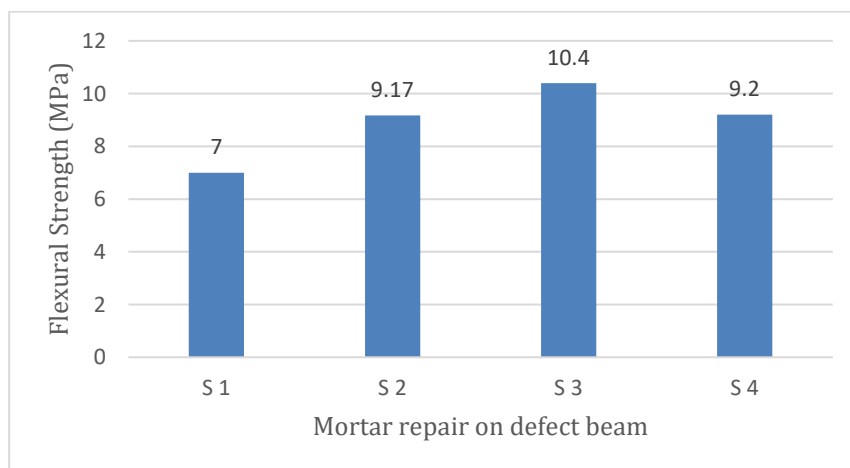


Fig. 13 The results of the flexural strength tests on mortar specimens at 28 days

5. Conclusion

This research focuses on the performance of a repair material which consists of Polypropylene fiber and SikaGrout®-215 by adding different percentages of PP fibers. The mechanical properties of repair material affected by the presence of PP fiber were investigated through the laboratory tests complied with the standard requirement. The performances of concrete were evaluated in terms of the compressive and flexural strength.

Compressive strength is a crucial property for mortar and concrete, representing their resistance to axial loading.

The study found that mortar repair with polypropylene (PP) fiber exhibited overall stronger compressive strength. Notably, the presence of 0.5% PP fiber, the highest percentage tested, generated optimum strength at 28 days. The increased amount of PP fiber significantly contributed to this strength improvement by reducing retraction and contraction cracks, enhancing energy absorption, and distributing concrete load more efficiently. Moreover, PP fibers played a role in preventing moisture transfer, minimizing risks of cracking or spalling, and overall augmenting concrete strength, leading to greater compressive strength [13].

Excessive polypropylene fiber percentages exceeding 0.3% contribute to a significant reduction in flexural strength. This is attributed to the propensity for high fiber content to cause clustering, impeding proper fiber-matrix bonding and resulting in decreased strength. However, within optimal limits, polypropylene fibers

enhance flexural strength by absorbing energy and efficiently distributing the concrete load. In summary, the judicious use of polypropylene fibers in mortar improves mechanical properties, specifically enhancing flexural strength.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Zafri Ayob; **data collection:** Zafri Ayob; **analysis and interpretation of results:** Zafri Ayob, Sallehuddin Shah Ayop; **draft manuscript preparation:** Zafri Ayob. All authors reviewed the results and approved the final version of the manuscript.

References

- [1] Azandariani, M. G., Kazemi, M., & Madandoust, R. (2023). Mechanical properties of polyolefin and polypropylene fiber-reinforced concrete. *Composites Part C: Open Access*, 10, 100312. <https://doi.org/10.1016/j.jcomc.2022.100312>
- [2] Tahwia, A. M., El-Attar, M. M., & Diab, A. M. (2023). Optimizing characteristics of high-performance concrete incorporating hybrid polypropylene fibers. *Innovative Infrastructure Solutions*, 8(2), 64. <https://doi.org/10.1007/s41062-023-00976-3>
- [3] Sika AG. (2018). *SikaGrout®-215 product data sheet*. Sika Malaysia.
- [4] Zhu, K., Chen, B., & Zhou, J. (2021). Effect of polypropylene fiber on strength and drying shrinkage cracking of mortar with coal gangue aggregate. *Advances in Materials Science and Engineering*, 2021, 1–10. <https://doi.org/10.1155/2021/5534219>
- [5] Sukkarak, R., & Prasittisopin, L. (2019). Effect of polypropylene fiber on flexural strength of lightweight foam mixed soil. *Advances in Materials Science and Engineering*, 2019, 1–9. <https://doi.org/10.1155/2019/3932874>
- [6] Mugahed, A., Amran, M., & Murali, G. (2022). Performance of polypropylene fiber-reinforced cementitious composites under flexural loading. *Case Studies in Construction Materials*, 17, e01123. <https://doi.org/10.1016/j.cscm.2022.e01123>
- [7] Amran, M., Fediuk, R., Murali, G., Avudaiappan, S., Ozbakkaloglu, T., & Klyuev, S. (2022). Properties and performance of polypropylene fiber-reinforced high-strength concrete: A review. *Case Studies in Construction Materials*, 16, e00947. <https://doi.org/10.1016/j.cscm.2022.e00947>
- [8] Song, M., Li, Z., & Wang, Y. (2022). Mechanical properties of polypropylene-fiber-reinforced high-performance concrete based on response surface methodology. *Advances in Materials Science and Engineering*, 2022, 1–12. <https://doi.org/10.1155/2022/9463821>
- [9] Jumaat, M. Z., Rahman, A. B. A., & Rahman, M. M. (2006). A review of the repair of reinforced concrete beams. *Journal of Applied Sciences*, 6(10), 2300–2305. <https://doi.org/10.3923/jas.2006.2300.2305>
- [10] Al-Salloum, Y. A. (2006). Flexural performance of reinforced concrete beams repaired with commercial repair materials. *Construction and Building Materials*, 20(8), 534–544. <https://doi.org/10.1016/j.conbuildmat.2005.01.032>
- [11] Zhang, Y., Li, V. C., & Liu, J. (2019). Effects of geometry and fraction of polypropylene fibers on permeability of ultra-high-performance concrete after heat exposure. *Cement and Concrete Research*, 116, 168–178. <https://doi.org/10.1016/j.cemconres.2018.11.011>
- [12] Chen, Y., Zhang, Y., & Leung, C. K. Y. (2022). A review of printing strategies, sustainable cementitious materials and characterization methods in extrusion-based 3D concrete printing. *Journal of Building Engineering*, 45, 103487. <https://doi.org/10.1016/j.jobbe.2021.103487>

- [13] Salahaldeen Alsadey. (2016). Effect of polypropylene fiber on properties of mortar. *International Journal of Civil Engineering and Technology*, 7(2), 96–104.