MECHANICAL PROPERTIES AND MICROSTRUCTURE OF POLYPROPYLENE FIBRE-REINFORCED MORTAR

(Date received: 09.11.2023/Date accepted: 26.12.2023)

Lee Foo Wei

Department of Civil Engineering, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, 43000 Kajang, Selangor, Malaysia

Corresponding author: leefw@utar.edu.my

ABSTRACT

Polypropylene, a widely used thermoplastic, has significantly contributed to environmental waste due to its extensive production and the gradual degradation of its fibres. In order to address this critical issue, a comprehensive study was undertaken to investigate the impact of polypropylene fibre reinforcement in mortar. The study involved a battery of tests designed to evaluate the effectiveness of this approach. Results indicated that the optimal percentage of polypropylene fibres for achieving maximum compressive strength after 7 and 28 days was 0.4%. This percentage performed best within a specific water-to-cement ratio (w/c) range of 0.6 to 0.8. Additionally, the research revealed that the most effective combination for enhancing flexural strength was a water-to-cement ratio (w/c) in the range of 0.6 to 0.8, along with a 0.6% polypropylene fibre content. It's worth noting that this innovative technique promises to bolster the strength characteristics of mortar and offers a sustainable solution by reducing the environmental burden associated with polypropylene waste. These findings have significant implications for achieving commercial and engineering goals while addressing the limitations of traditional mortar practices. The study offers a promising path toward enhanced construction materials and reduced environmental impact.

Keywords: Compression, Fibre, Flexural, Mortar, Polypropylene

1.0 INTRODUCTION

A concise, accurate, but not exhaustive summary of current knowledge concerning the five most common construction materials used in the world: concrete, steel, wood, stone, and masonry. Concrete and steel are currently widely used as they are strong and durable construction materials. Brick masonry, as one of the oldest manufactured building materials in the world, has played an integral part in construction, as proven by the world's historical treasures such as the pyramids of Giza and the Roman Colosseum (Bagherzadeh *et al.,* 2012). Mortar was introduced as a bonding agent to hold different building units like brick, masonry, or concrete together. Mortar is a paste-like substance typically made by mixing cement, sand, and water. The weaknesses and limitations of mortar, such as poor strength, workability, toughness, impact resistance, and durability, have been slowly discovered over time (Alsadey, 2016). Fibre-reinforced mortar was introduced to overcome the limitations and weaknesses of traditional mortar. Fibre-reinforced mortar contains fibrous material added during mixing to improve its structural properties. Fibres made of synthetic, natural, mineral, and polypropylene are among the fibrous materials. The properties provided by each fibre might have some differences. Fibre-reinforced mortar is commonly used in building structures nowadays as it provides better mortar toughness, flexure strength, tensile strength, and impact strength, increasing the structure's life and reducing maintenance.

Polypropylene fibres are a popular option for use in several composite materials because of their lightweight, low cost, and vast availability advantage. The emergence of polypropylene-reinforced mortar has helped reduce plastic waste worldwide. Polypropylene is one inexpensive thermoplastic polymer plastic widely used worldwide in textiles, packaging, and automotive components. A small amount of polypropylene fibres (typically 0.1% to 0.5% by weight) was added to the mortar during the mixing process along with the cement, fine aggregate, and water to enhance its mechanical properties and durability. Evenly distributed polypropylene fibres in the mortar will act as a bridge between the cracks formed due to shrinkage and assist in distributing the stresses more evenly throughout the mortar matrix to reduce the possibility of cracks developing and spreading. The mortar particles will be held together by a network of fibres that prevents the mortar from disintegrating or degrading over time. The primary function of mortar is to bind individual building materials like masonry, bricks, and concrete blocks into one unit to provide a strong, durable, and cohesive bond between each of them. Besides that, mortar can also be used for sealing purposes to fill the gaps between masonry units to prevent infiltration and improve the stability of the structure by ensuring an evenly distributed distribution of loads across the surface of the masonry units. However, the compressive strength of the mortar is a vital characteristic to consider, as it will directly reflect its stability against external forces (wind and seismic forces) and the force itself. The strength of the mortar can affect the structure's durability, which leads to future maintenance costs. There is significant use of polypropylene fibre-reinforced mortar in the construction field. Polypropylene fibres are commonly added to concrete and mortar mixes to improve crack resistance, particularly in slabs and foundations, to safeguard the overall structural integrity.

Polypropylene fibre-reinforced mortar is commonly employed in waterproofing applications, such as below-grade constructions, swimming pools, and water tanks, due to its ability to diminish permeability and enhance resistance against water infiltration. Incorporating polypropylene fibre with mortar has been found to significantly improve the durability and resistance of industrial flooring. This reinforcement effectively minimises cracking, abrasion, and chemical exposure, which are significant in environments such as warehouses, manufacturing facilities, and chemical processing plants. Incorporating polypropylene fibres with mortar improves adhesion and flexibility, enhancing mortar's overall performance and durability in roadway and bridge repairs. This development is particularly beneficial in regions that experience freeze-thaw cycles and severe traffic loads, where using polypropylene fibre-reinforced mortar can significantly prolong the lifespan of the repaired structures.

1.1 Hypothesis

This study's hypothesis posits that incorporating polypropylene fibres into mortar can significantly enhance its mechanical properties, specifically compressive and flexural strength. The investigation aims to identify the optimal percentage of polypropylene fibres within a defined water-to-cement ratio range to maximise strength gains. It is hypothesised that the selected polypropylene fibre content will create a reinforcing network within the mortar matrix, leading to improved strength characteristics. Furthermore, the study anticipates that this innovative approach will contribute to enhanced construction materials and address the environmental challenges posed by polypropylene waste, aligning with sustainable and eco-friendly construction practices.

2.0 METHODOLOGY

2.1 Materials

The raw materials used to produce the polypropylene fibres reinforced mortar specimens are cement, fine aggregate, water, and polypropylene fibres. The raw materials used in cement production comply with Malaysian standards to maintain the quality of the final cement product. In order to ensure the quality of cement, it is compulsory to store it in a dry environment at all times, hence minimising any potential adverse effects caused by moisture. Ordinary Portland cement (OPC) is manufactured by YTL Cement (M) Sdn. Bhd. was chosen to be used in this research work. This ordinary Portland cement (OPC) was certified with the Malaysia standard of MS EN 197-1:2014 CEM I 52.5N. The sand utilised in this study was sourced from a quarry, which is natural sand. Polypropylene microfibres are added to the mortar mixture to create a reinforced mortar with polypropylene fibres. The length of the polypropylene fibres utilised in this study is restricted to 5 cm to maintain consistency.

2.2 Specimens

According to ASTM C109, the cube specimens should have dimensions of 50 mm x 50 mm x 50 mm for the compressive strength test and 40 mm x 40 mm x 160 mm for the flexural strength test. The specimens will be prepared in three different water-to-cement ratios: 0.60, 0.70, and 0.80. Six sets of mortar cube specimens will be prepared for each water-to-cement ratio, with varying percentages of polypropylene fibres at 0, 0.2, 0.4, 0.6, 0.8, and 1.0%. One hundred eight mortar cube specimens and 108 prism specimens will be constructed to investigate the impact of polypropylene fibres on compressive strength and flexural strength, respectively.

2.3 Preparation of Mortar Specimens

There are three stages for the preparation, which are the mixing, casting, and curing procedures. The mixing method adopted in this experiment is hand mixing. The cement and fine aggregate were poured and mixed in dry conditions. All the raw materials were added to the mixing bowl based on the design mixing proportion proposed and dried by hand until they were well mixed. The polypropylene fibres were tied off to ensure a random distribution of the fibres within the mixture to avoid fibre lumping. Dry-hand mixing was repeated until they were mixed well and uniformly. The water was added to the dry mixture of the raw material according to the W/C proposed. The density of fresh mortar will be determined using a beaker. The fresh mortar within the target density range will undergo a flow table test. Before starting the casting process, cleaning the mould was necessary to remove impurities. A layer of oil will be applied to the inner surface of the cube mould to facilitate the demoulding process afterward. The fresh mortar was carefully poured into the mould in two layers. The fresh mortar was compacted by applying 32 strokes per layer and then levelling the surface using a trowel. The mortar specimens were cured in the laboratory under controlled conditions with minimal air circulation to minimise excessive moisture evaporation from the fresh mortar's surface. The specimen will be demolished after 24 hours and labelled clearly accordingly. The specimens will be cured in the water for 7 days and 28 days at a temperature between 21 and 25 degrees Celsius, which is suggested by ASTM 192. After being cured, all the specimens undergo surface air drying by a blower gun.

3.0 EXPERIMENTAL SETUP

A flow table test examines mortar performances during the fresh stage before casting. The compression and flexural strength tests will be performed after being cured for 7 days and 28 days, respectively. The compression and flexural strength tests are destructive methods where the mortar cube specimen will undergo crushing. The interfacial transition zone (ITZ) of the crushed part of the destructed mortar will be observed under scanning electron microscopy (SEM).

3.1 Compression Strength Test

A total of 108 cube specimens with a 7- and 28-days curing period will undergo compressive strength testing using a compression test machine based on the standard of BS EN 12390–4. The entire surface of the specimens was dried using an air blower gun before proceeding to the weighing process. The cross-sectional area of the specimen on which the applied load will be acting will be determined before conducting the test. The specimen is centrally located on the plate of the compression test equipment—the rate at which the applied load was set at 1.0 mm/min. The test will start by applying loading on the mortar specimen and end when the cracking happens on the mortar specimen. The compressive strength of the specimen can be calculated by dividing the compressive strength by the cross-section area of the specimen. The formula is shown in Equation 1.

$$fc= P/A \quad (1)$$

Where fc is compressive strength, P is the peak load sustained by the specimen, and A is the cube ' 'specimen's cross-sectional area at which uniform load is applied.

3.2 Flexural Strength Test

One hundred eight prism specimens subjected to a curing period of 7 days and 28 days will undergo flexural strength testing. A 3- 3-point loading test was conducted to determine the flexural strength of the prism specimens. Prior to proceeding with the weighing stages, the entire surface of the specimens was dried using an air blower gun. The cross-sectional area of the specimen, on which the applied load will be measured before the test, will be determined. Both ends of the support are pinned and positioned 150mm apart. On the middle span of the specimen, a load was applied at a constant rate of 0.5 mm/min. Equation 3.2 shows the formula to obtain the modulus of rupture.

$$R = 3PL/2BD^2 \quad (2)$$

Where R is the modulus of rupture, P is the maximum applied load indicated by the testing machine, L is span length, B is the average width of the specimen, and D is the average depth of the specimen.

3.3 Scanning Electron Microscope

Partially crushed mortar specimens were used to observe the ITZ using SEM. To prevent water from vaporising in the vacuum, removing all water from the samples is essential. The specimen must be covered with a thin layer of conductive material using a sputter coater. Samples are mounted rigidly by the specimen holder on the specimen stage. The current and voltage are adjusted. The image was displaced on the monitor screen, and the magnification was adjusted until the ITZ could be observed.

4.0 RESULTS AND DISCUSSION

4.1 Compressive Strength

The destructive test was adopted to determine the compressive strength of polypropylene fibres reinforced mortar. The cured specimens until the target day were subjected to surface drying and afterward underwent a compressive strength test. The load was applied at a constant rate of 1.0mm/s until the specimen failed. Table 1 displays the average compressive strength over 7 and 28 days, respectively, varying with P.P. percentages and w/c ratios. Figure 1 shows the relationship between 7 days of compressive strength and the P.P. percentage of cube specimens with different w/c. Figure 2 shows the relationship between 28 days of compressive strength and the P.P. percentage of cube specimens with different w/c.

The graphical representations depicted in Figures 1 and 2 illustrate an increase in compressive strength as the percentage of P.P. (polypropylene) increases from 0% to 0.4%. However, it is observed that the compressive strength experiences a subsequent decline beyond the P.P. percentage of 0.4%. The graph in Figure 2 illustrates the changes in compressive strength over a curing age of 28 days for plain mortar. It is observed that the initial compressive strength of the plain mortar was 22 MPa. However, upon adding 0.2% of P.P., the compressive strength increased to 24.7 MPa. Adding 0.4% of polypropylene (P.P.) resulted in a notable increase in compressive strength, reaching a value of 25.8 MPa.

Table 1: Average 7 and 28 Days Compressive Strength of Mortar with different P.P. Percentages and W/C Ratios

W/C Ratios	PP Percentage (%)	Compressive Strength (MPa- 7 days)	Compressive Strength (MPa- 28 days)
0.6	0.0	19.3	22.0
	0.2	20.2	24.7
	0.4	22.6	25.8
	0.6	19.0	22.8
	0.8	18.2	21.3
	1.0	16.0	20.5
0.7	0.0	17.2	21.5
	0.2	19.0	22.5
	0.4	19.5	24.0
	0.6	16.8	20.9
	0.8	15.2	19.6
	1.0	14.4	18.8
0.8	0.0	16.2	18.1
	0.2	16.6	20.9
	0.4	17.4	22.9
	0.6	15.5	17.8
	0.8	14.3	17.1
	1.0	12.3	16.1

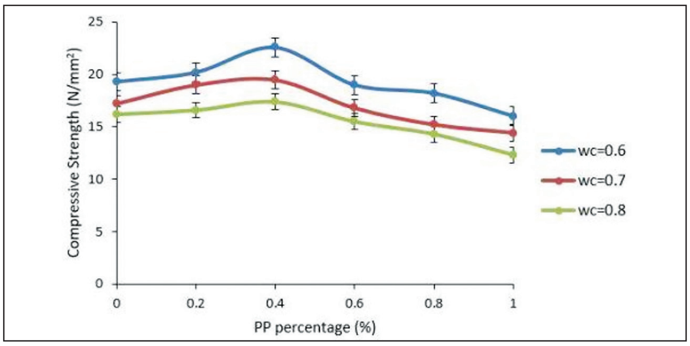


Figure 1: Relationship between 7 Days Compressive Strength and P.P. Percentage of Cube Specimens with different w/c

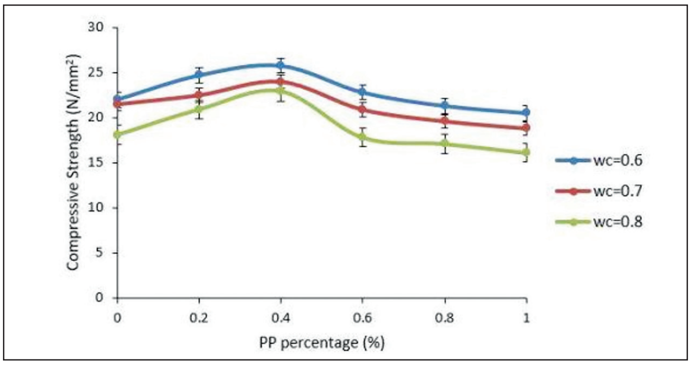


Figure 2: Relationship between 28 Days Compressive Strength and P.P. Percentage of Cube Specimens with different w/c

The findings indicate a significant decrease in compressive strength upon adding polypropylene fibres exceeding 0.4%. The compressive strength continuously declines as the percentage of P.P. increases, ultimately reaching a value of 1.0%. Thus, a P.P. percentage of 0.4% is the optimal percentage for polypropylene fibres reinforced mortar to achieve maximum compressive strength. Adding the optimum amount of polypropylene (P.P.) resulted in a 17.27% increase in compressive strength compared to the plain mortar. A similar trend was observed in the 7-day compressive strength of the specimens, as depicted in Figure 1, but with different values. The compressive strength of plain mortar with a w/c of 0.6 shows a compressive strength of 19.30 MPa. It achieved a compressive strength of 22.60 MPa when 0.4% of P.P. had been added, which is 17.1% greater than plain mortar. However, a decrease of 1.58% in compressive strength was noticed when the PP% reached 0.6% compared to the compressive strength of the control mortar. The compressive strength of mortar reinforced with 1.0% P.P. shows a drop of 20.63% in compressive strength as compared to the control sample.

The observed phenomenon can be attributed to the inherent properties of polypropylene fibres, which can retard the initiation of micro-cracks in the mortar and consequently restrict their propagation to a certain degree (Alsadey, 2016). The evenly distributed polypropylene fibres in the mortar will act as a bridge between the cracks formed to ensure the distribution of the applied stresses more evenly throughout the mortar matrix, especially in the ITZ zone. This bridge effect can potentially reduce the progression of cracks and prevent their propagation to adjacent regions. The polypropylene fibers network can hold the cement particles together to stop the mortar from disintegrating or degrading over time. Figure 3 shows the bridge effect caused by polypropylene fibres containing cement particles together. In addition to this, incorporating a network composed of polypropylene fibres inside the mortar matrix has been shown to enhance its compressive strength. However, the continuous drop in compressive strength after the optimum P.P. percentage is due to the discontinuous mortar structure where coherent matrixes fail to form (Dawood and Ghanim, 2020). The hydration process between water and cement will form calcium silicate hydrate (C-H-S) gel, the primary source of concrete strength. When polypropylene fibres are added at a dosage of not more than 0.4%, polypropylene fibres can effectively minimize pore formation.

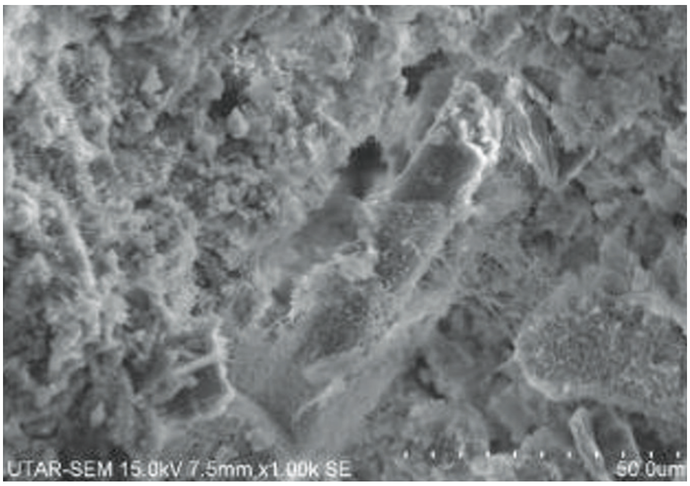


Figure 3: Bridge Effect

The polypropylene fibres are small enough to replace the pore, producing a more compact material with greater strength. When polypropylene fibres added exceed 0.4%, large amounts of cement will be substituted by polypropylene fibres, reducing the production of C-H-S gel. This resulted in a scenario where the compressive strength progressively decreased beyond the optimal percentage of P.P. According to the results presented in Figures 1 and 2, it can be observed that an increase in the water-to-cement ratio leads to a drop in compressive strength. The mortar with a water-to-cement ratio (w/c) of 0.6 demonstrates the highest compressive strength, whereas the mortar with a w/c of 0.8 exhibits the lowest compressive strength among the three different water-to-cement ratios. The graph exhibits similar trends across various water-to-cement ratios, indicating that a 0.4% P.P. percentage yields the highest compressive strength. An increased water content in fresh mortar will create more capillary pores and air voids. This condition will increase the porosity and reduce the density of the mortar, thus resulting in a reduction in the compressive strength. The presence of voids within hardened mortar will serve as the weakest initiation point for cracking. The increase in the water-to-cement ratio will reduce the cement content in the design mix, causing less cementitious material to form strong bonds.

4.2 Flexural Strength

The flexural strength test, also known as the modulus rupture test, assesses the bending resistance capability of polypropylene fibres reinforced mortar. The prism specimens were cured until the designated day and were surface-dried before the 3-point loading test. Figure 5 shows the cracking formed on prism mortar upon reaching its ultimate flexural strength. The load was applied to the prism ' 'specimen's specimen at a constant rate of 0.5 mm/s until the point of failure was reached. Table 2 shows the average 7 days and 28 days flexural strength of mortar with different P.P. percentages and w/c ratios. Figures 4 and 5 present a summary graph demonstrating the relationship between 7 days and 28 days flexural strength of specimens against different P.P. percentages with w/c of 0.6, 0.7, and 0.8.

The summary graphs depicted in Figures 4 and 5 show a continuous increase in flexural strength as the percentage of P.P. fibres increases from 0% to 0.6%. However, above this point, the flexural strength begins to decline. The graph depicting mortar with a water-to-cement ratio (w/c) of 0.6 indicates that the flexural strength of plain mortar at 28 days was recorded as 6.33 MPa. However, the addition of 0.2% of polypropylene (P.P.) resulted in an increase in flexural strength to 6.93 MPa. The flexural strength gradually increased, achieving the values of 7.21 MPa and 8.99 MPa upon adding 0.4% and 0.6% of polypropylene (P.P.), respectively. However, a significant decrease in flexural strength is observed after exceeding the optimum 6 PP%. The flexural strength of the specimen with 1.0 PP% is 3.77% lower than the plain prism specimen, with a water-to-cement ratio (w/c) of 0.6. A similar trend was observed in specimens' 7 days flexural strength across all water-to-cement ratios, as depicted in Figure 4. However, the recorded values varied. The initial flexural strength of the plain mortar is measured at 4.93 MPa after 7 days. Adding PP% at various amounts of 0.2%, 0.4%, and 0.6% results in a rise in flexural strength to 5.1 MPa, 5.62 MPa, and 6.52 MPa, respectively. After exceeding the optimum PP% of 0.6, the flexural strength decreases to 4.9 MPa and 4.53 MPa for 0.8%

and 1.0% of P.P., respectively. Compared to plain prism, there is a decrease of 8.83% in the flexural strength of prisms containing 1.0% polypropylene (P.P.). The results demonstrate a significant average increment of 42.28 % in overall 7 days flexural strength and a corresponding average increase of 35.79% for 28 days flexural strength when incorporating polypropylene fibres. These findings suggest that polypropylene fibres significantly impact flexural strength more than compressive strength.

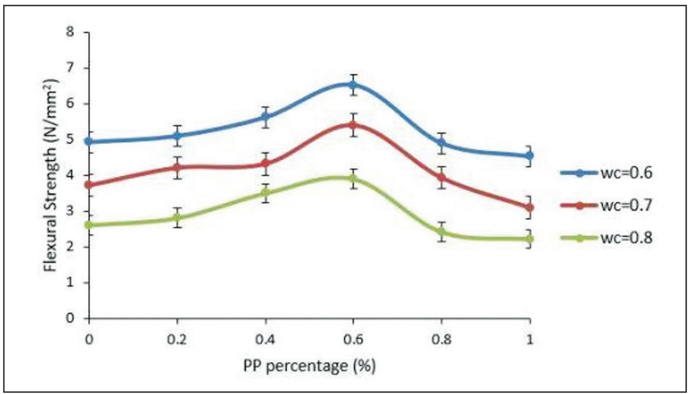


Figure 4: Relationship between 7 Days Flexural Strength and P.P. Percentage of Prism Spec

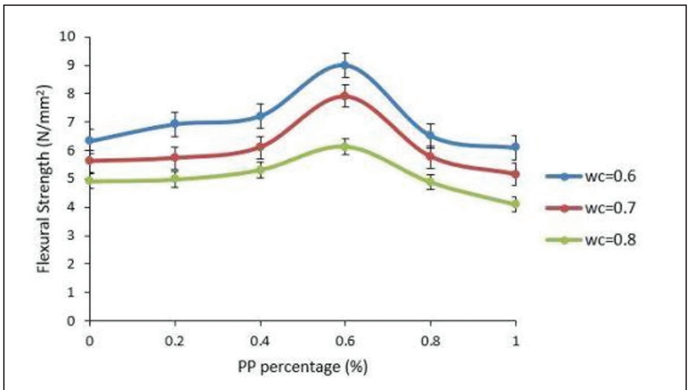


Figure 5: Relationship between 28 Days Flexural Strength and P.P. Percentage of Prism Specimens with different w/c

Adding polypropylene fibres into mortar was discovered to improve its ductility, hence enhancing its ability to withstand bending before failure. The polypropylene fibres reinforced mortar will undergo a deformation plastically before failure. As stated earlier, uniform dispersion of polypropylene fibres in the mortar will act as a bridge between the cracks to distribute the stresses more evenly throughout the mortar matrix. This condition is particularly effective in the ITZ region, leading to a prolonged resistance to failure under bending conditions. The holding effect by a network of fibres within the mortar matrix will prevent the mortar from disintegrating or degrading over time (Dawood and Ghanim, 2020). The bridge effect will reduce crack formation by delaying the time for cracking initiation. According to Alsadey (2016), including polypropylene fibres in mortar has been found to reduce shrinkage cracking efficiently. The volume reduction resulting from water evaporation during the hardening process can give rise to internal stress, ultimately leading to internal cracking. The tiny and discrete polypropylene fibres will disperse through the mortar and control and reduce the cracking. The strength of polypropylene fibre-reinforced mortar was maintained as it reduced the occurrence of internal cracking.

Table 2: Average 7 Days and 28 days Flexural Strength of Mortar with different P.P. Percentages and w/c Ratios

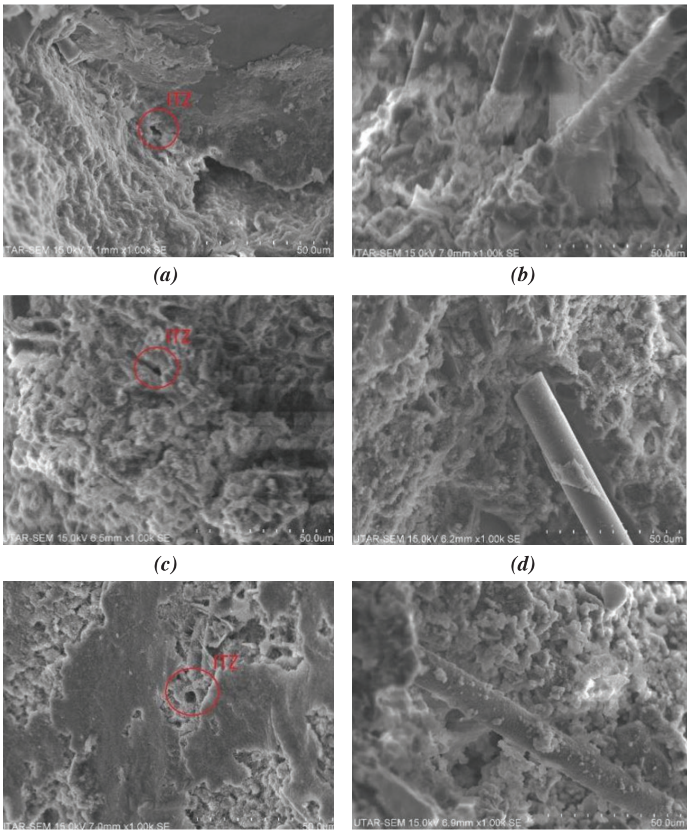
W/C Ratios	PP Percentage (%)	Flexural Strength (MPa- 7 days)	Flexural Strength (MPa- 28 days)
0.6	0.0	4.93	6.33
	0.2	5.10	6.93
	0.4	5.62	7.21
	0.6	6.52	8.99
	0.8	4.90	6.52
	1.0	4.53	6.10
0.7	0.0	3.72	5.62
	0.2	4.21	5.73
	0.4	4.32	6.11
	0.6	5.40	7.91
	0.8	3.93	5.77
	1.0	3.10	5.15
0.8	0.0	2.61	4.92
	0.2	2.81	4.98
	0.4	3.50	5.31
	0.6	3.90	6.13
	0.8	2.42	4.88
	1.0	2.22	4.10

The polypropylene fibres are tiny enough to minimize pore formation by replacing the pore capillary, forming a more compact material with greater strength. However, the progressive decrease in flexural strength after exceeding the optimum P.P. percentage is attributed to the identical factor: the mortar structure's discontinuity. The production of a coherent matrix is hindered when a significant quantity of polypropylene fibres is introduced, resulting in fewer cement particles in the mix, subsequently reducing the formation of C-H-S gel. These hairlines of high doses of polypropylene fibres induce the entrainment of air bubbles within the polypropylene fibres reinforced mortar prism (Jawad and Al-Haydari, 2022). The decrease in flexural strength is observed as the water-to-cement ratio increases, as depicted in Figures 4 and 5. Both graphs demonstrate that the flexural strength of mortar is highest when the water-to-cement ratio (w/c) is 0.6 and lowest when the w/c is 0.8 for the same percentage of polypropylene fibres among the three w/c ratios.

Nevertheless, the graph trends remain similar across all mortars with varying water-to-cement ratios, indicating that a P.P. % of 0.6 is optimal for achieving the highest flexural strength. The observed phenomenon can be attributed to the development of capillary pores and air voids within fresh mortar with high water content, resulting in reduced density and flexural strength. The presence of pores in the hardened mortar will serve as the weakest point where the initiation point for cracking.

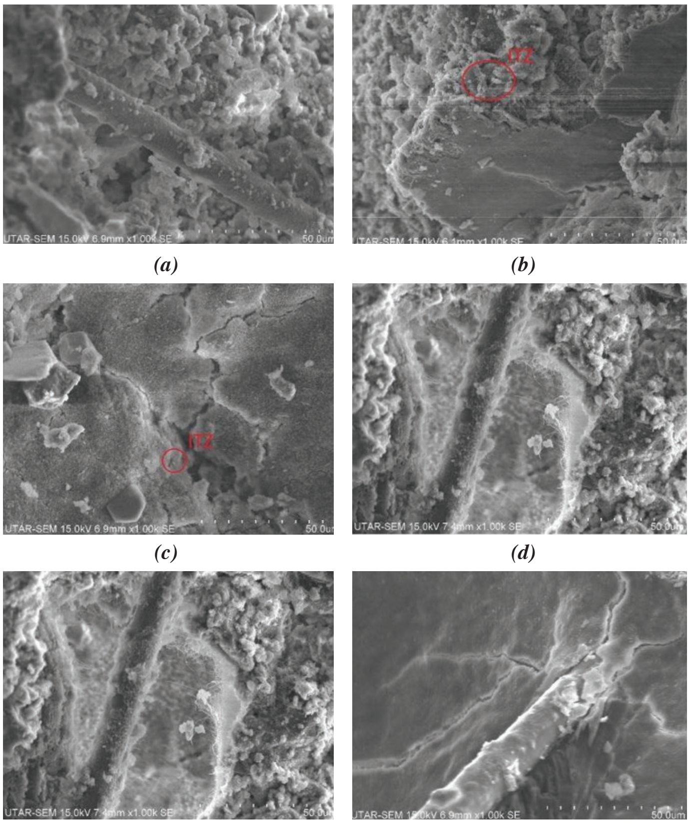
4.3 Image of Interfacial Transition Zone (ITZ)

The images presented under this subtopic were obtained through scanning electron microscopy (SEM) at a magnification level of 1,000x. These images aimed to investigate the interaction between polypropylene fibres and the ITZ. The figures corresponding to



(a) *(b)* *(c)* *(d)* *(e)* *(f)*

Figure 6: ITZ of Cube Mortar with (a) 0% P.P. with w/c of 0.6, (b) 0.4% P.P. with w/c of 0.6, (c) 0% P.P. with w/c of 0.7, (d) 0.4% P.P. with w/c of 0.7, (e) 0% P.P. with w/c of 0.8 and (f) 0.4 % P.P. with w/c of 0.8



(a) *(b)* *(c)* *(d)* *(e)* *(f)*

Figure 7: ITZ of Prism Mortar with (a) 0% P.P. with w/c of 0.6, (b) 0.4% P.P. with w/c of 0.6, (c) 0% P.P. with w/c of 0.7, (d) 0.4% P.P. with w/c of 0.7, (e) 0% P.P. with w/c of 0.8 and (f) 0.4 % P.P. with w/c of 0.8

odd numbers in this subtopic represent the pictures obtained from the control sample under scanning electron microscopy (SEM). In contrast, the figures corresponding to even numbers represent the images obtained from the sample treated with optimum polypropylene fibres percentage. Figures 6(a) to (f) depict the SEM-captured pictures of cube mortar, whereas Figures 7 (a) to (f) display the SEM-captured photos of prism mortar. ITZ is a crucial part of concrete or mortar, as it constitutes a highly porous and permeable region that directly impacts the performance and durability of the concrete construction. By referring to all the figures showing the ITZ zone of optimum P.P. percentage, it clearly showed that the polypropylene fibres had replaced the ITZ zone. Polypropylene fibres, including ITZ zone, are tiny enough to disperse throughout the mortar matrix, forming a bridge network to distribute the stress evenly. The holding effect by the polypropylene fibres will strengthen the ITZ zone. ITZ was one of the weakest points in concrete where cracking point initiation occurred. The presence of polypropylene fibres can control the cracking by limiting the cracking development. The total improvement will result in a rise in the durability of the mortar, as demonstrated by the results of the compressive strength test and flexural strength test.

5.0 CONCLUSION

In conclusion, the emergence of polypropylene-reinforced mortar significantly benefits the environment, research endeavours, and commercial construction projects. The research aims to investigate the effect of polypropylene fibre polymer treatment on polypropylene fibre reinforced mortar with different polypropylene fibre percentages. Several properties, such as compressive and flexural strengths, the interaction between polypropylene fibres and ITZ, and fresh mortar workability were evaluated. The first objective of this study is to study the influence of polypropylene fibres percentage on polypropylene fibre reinforced mortar's compressive and flexural strengths and determine the optimal percentage for maximum strengths. The finding shows that the addition of optimum P.P. percentage can increase the compressive and flexural strength of the mortar. The compressive strengths and flexural strength of mortar present an increasing trend until they reach the optimal percentage of polypropylene (P.P.) fibres, which are 0.4% and 0.6%, for water-to-cement ratios (w/c) of 0.6, 0.7, or 0.8. However, the compressive and flexural strength was continuously decreased as the PP% applied exceeded the optimum percentage. The second objective of this study is to study the effect on fibre or matrix ITZ of polypropylene fibres reinforced mortar with different polypropylene fibres percentages by using scanning electron microscopy (SEM). The polypropylene fibres, including ITZ zone, are tiny enough to disperse throughout the mortar matrix, forming a bridge network to distribute the stress evenly. The holding effect by the polypropylene fibres will strengthen the ITZ zone and control the cracking. Thus, the compressive and flexural strengths of mortar will be improved. However, the flow table test results show that increasing polypropylene fibres inside the mortar mixture will increase the viscosity of fresh mortar, thus reducing the workability. In addition, the enhanced properties of polypropylene fibre reinforced mortar suggest promising applications in diverse construction scenarios, such as the development of high-performance and durable structures.

Moving forward, further research could explore optimised mix designs, long-term durability assessments, and real-world application studies to refine the integration of polypropylene-reinforced mortar into mainstream construction practices. This ongoing investigation aims to bridge the gap between laboratory findings and practical implementations, paving the way for sustainable and resilient construction solutions in the future. ■

LIST OF NOTATIONS

v is the allowable vertical displacement
α is the coefficient of thermal expansion of concrete
T_2 is the slab bottom surface temperature
T_1 is the slab top surface temperature
L is the length of the longer span of the slab
l is the length of the shorter span of the slab
h is the effective depth of the slab, as given in BS EN1994-1-2
f_y is reinforcement yield stress
E is the elastic modulus of the reinforcement

REFERENCES

[1] American Society for Testing and Materials. (2016). Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-In. Or [50-Mm] Cube Specimens) (ASTM C109). ASTM International. https://Doi.Org/10.1520/C0109_C0109M-16

[2] American Society for Testing and Materials. (2015). Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-In. Or [50-Mm] Cube Specimens) (ASTM C192). ASTM International. https://Doi.Org/10.1520/C0192_C0192M-16

[3] Bagherzadeh, R., Sadeghi, A. H., and Latifi, M. (2012). Utilizing Polypropylene Fibres to Improve Physical and Mechanical Properties of Concrete. Textile Research Journal, 82(1), 88-96.

[4] British Standards Institution. (2019). BS EN 12390-4: Testing Hardened Concrete. Compressive Strength. Specification for Testing Machines. British Standards Institution.

[5] Dawood, E. T., and Ghanim, T. W. (2020). Mechanical Properties of Mortar Using Polypropylene Fibres. Journal of Civil Engineering Research and Technology, 2(1), 1-4.

[6] Jawad, H. S., and Al-Haydari, I. S. (2022). Sustainable Use of Polypropylene Fibres as a Cement Mortar Reinforcement. International Journal of Engineering, 35(8), 1494-1500.

[7] Malaysian Standards. (2014). MS EN 197-1:2014 Cement – Part 1: Composition, Specifications, and Conformity Criteria for Common Cements (CEM I) (4th Ed.). Department of Standards Malaysia.

PROFILE

LEE FOO WEI earned his Ph.D. in 2017, specialising in non-destructive testing, construction waste materials development, and soil stabilisation. With a keen focus on advancing these critical areas, Lee's research contributions have played a pivotal role in enhancing the safety, sustainability, and efficiency of the construction industry. His innovative work in non-destructive testing methods, sustainable materials development, and soil stabilisation techniques has left a lasting impact, establishing him as a respected authority and a driving force in the field of civil engineering and construction.
Email address: ah-foo3@hotmail.com