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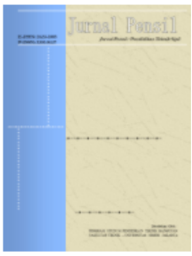

EXPERIMENTAL INVESTIGATION OF FLEXURAL AND CRACKING BEHAVIOR OF POLYPROPYLENE FIBER REINFORCED LIGHTWEIGHT CONCRETE BEAMS

I.G.A. Neny Purnawirati[1*], *Fajar Surya Herlambang*[2]
[1] Politeknik Negeri Bali, Kampus Bukit Jimbaran, Kuta Selatan, Badung, Bali 80364, Indonesia
[2] Politeknik Negeri Semarang, Jl. Prof. H. Soedarto, S.H. Tembalang, Semarang, 50275, Indonesia
[*1]nenypw26@gmail.com, [2]fajarjtspnb@gmail.com

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Abstract

This study experimentally evaluates the effect of polypropylene fiber incorporation on the flexural performance and cracking behavior of structural lightweight concrete beams. The lightweight concrete was produced using locally available lightweight aggregates with a target compressive strength of 25 MPa and a water-cement ratio of 0.41. Polypropylene fibers were added at a dosage of 0.45% by volume of concrete. The experimental program included compressive strength, splitting tensile strength, flexural strength, and crack width tests. A total of 10 cylindrical specimens and 6 reinforced lightweight concrete beam specimens measuring 200 × 300 × 1800 mm were prepared and tested. All specimens were water-cured for 28 days before testing. The results showed that polypropylene fibers improved the mechanical and cracking performance of structural lightweight concrete. The compressive strength increased from 23.73 MPa to 24.81 MPa, while the splitting tensile strength increased from 2.09 MPa to 2.31 MPa. In addition, the flexural strength increased from 3.28 MPa to 3.51 MPa. The addition of polypropylene fibers also reduced the maximum crack width from 0.75 mm to 0.47 mm and produced narrower and more uniformly distributed cracks along the beam span, indicating improved crack resistance and post-cracking behavior. The novelty of this study lies in the experimental investigation of crack propagation and flexural behavior of structural lightweight concrete beams incorporating polypropylene fibers using locally sourced lightweight aggregates under three-point loading conditions.

Keywords: Polypropylene Fiber, Lightweight Concrete, Flexural Behavior, Crack Width, Structural Lightweight Concrete Beam

Introduction

Cracking in concrete refers to the formation of discontinuities or openings within concrete members that occur when internal stresses surpass the tensile resistance of the material. Although concrete possesses relatively high compressive capacity, its resistance to tensile forces is comparatively limited; therefore, cracking typically initiates under tensile stress conditions, particularly in the tension zone at the underside of beams subjected to bending moments. Cracking is widely recognized as one of the most frequently encountered forms of deterioration in reinforced concrete structures.

Cracking in reinforced concrete structures commonly occurs when the tensile stress developed within the concrete exceeds its tensile capacity. Structural cracks are generally associated with excessive loading, large deformation, poor construction practices, or inadequate structural design, which may reduce the load-carrying capacity and serviceability of structural members. In contrast, non-structural cracks do not directly threaten structural safety; however, they may still affect durability, permeability, and the long-term performance of concrete structures (ACI 224R-01, 2001). Because concrete possesses relatively low tensile strength, cracks frequently develop in the tensile zone of beams subjected to flexural loading. Therefore, effective crack control is essential to improve the durability and service life of reinforced concrete structures (Ahmad et al., 2022).

Fibre Reinforced Concrete (FRC) is a type of concrete composite in which discrete fibres are incorporated into the cementitious matrix to improve mechanical performance, crack resistance, and durability characteristics (ACI 544.1R-96, 2002). The randomly distributed fibres help control crack propagation by enhancing stress transfer within the concrete matrix. Among various fibre types, polypropylene fibre (PPF) is widely used in concrete technology due to its low density, corrosion resistance, chemical stability, and good compatibility with cement-based materials (Ahmad et al., 2022; Blazy et al., 2022). Previous studies have demonstrated that polypropylene fibres are capable of reducing crack propagation and improving post-cracking behavior in concrete structures. Microstructural observations using Scanning Electron Microscope (SEM) analysis revealed that polypropylene fibres can bridge microcracks within the cement matrix, thereby enhancing tensile performance and durability while reducing shrinkage-induced cracking (Ahmad et al., 2022). In addition, polypropylene fibres have been reported to improve flexural performance, toughness, and energy absorption capacity of lightweight concrete elements subjected to flexural loading (Zhang et al., 2021). Due to their favorable mechanical and durability characteristics, polypropylene fibres have increasingly been utilized as reinforcement materials in structural lightweight concrete applications. Several studies also reported that the incorporation of polypropylene fibres can improve crack control and reduce brittle failure behavior in lightweight concrete members (Ngo et al., 2022; Nguyen et al., 2024).

In terms of physical characteristics, polypropylene fibres possess a relatively low specific gravity of approximately 0.91 g/cm^3, which contributes to their lightweight characteristics when incorporated into concrete mixtures. The mechanical properties of micro polypropylene fibres generally exhibit tensile strength values ranging from 300 to 450 MPa, with an elastic modulus between approximately 3.8 and 7.0 GPa (Newihy et al., 2018). In comparison, macro polypropylene fibres demonstrate higher mechanical capacity, with tensile strength values ranging from 400 to 760 MPa and an elastic modulus varying from approximately 3.5 to 12.0 GPa (Blazy & Blazy, 2022). Based on their geometrical configuration, polypropylene fibres can be classified into monofilament and fibrillated types. Monofilament fibres are commonly used to reduce plastic shrinkage cracking during the early stages of cement hydration and hardening, whereas fibrillated fibres are considered more effective for controlling crack propagation in concrete elements subjected to higher structural loading conditions (Blazy & Blazy, 2022). Previous studies also demonstrated that the incorporation of polypropylene fibres can improve the mechanical performance, toughness, and crack resistance of lightweight concrete materials (Ramalingam et al., 2023).

From the perspective of mechanical performance, previous studies reported that the optimum polypropylene fibre content for concrete is generally around 0.4%. Higher fibre contents beyond this level may lead to a reduction in strength due to fibre agglomeration and stress concentration effects occurring at the fibre ends within the cementitious matrix. A similar trend has also been observed in splitting tensile strength performance, where fibre contents of approximately 0.4% provide more favorable structural behavior (Tiwari et al., 2025). In terms of durability characteristics, the incorporation of polypropylene fibres has been reported to improve the resistance of concrete against environmental deterioration. Such improvements are reflected in reduced water absorption, increased resistance to acidic environments, and lower carbonation penetration depth. In general, the inclusion of polypropylene fibres contributes positively to the overall mechanical and durability performance of concrete materials (Tiwari et al., 2025). Furthermore, polypropylene fibres are recognized for their ability to improve flexural capacity and crack resistance in lightweight concrete members. Mohammed and Nimat (2026) investigated the influence of polypropylene fibre incorporation on failure patterns, stress–strain response, and crack development in lightweight concrete. Their findings demonstrated that the presence of polypropylene fibres significantly enhanced toughness, crack resistance, and energy absorption capacity, resulting in more ductile and resilient concrete behavior. These improvements are particularly beneficial for structural applications requiring reduced self-weight and enhanced durability performance.

Wang et al. (2026) developed a theoretical formulation to estimate the average spacing between cracks and the maximum crack width in reinforced concrete beams containing polypropylene fibres, employing an equivalent flexural strength method. Nevertheless, the proposed model was primarily derived from experimental observations on high-strength concrete and a restricted range of beam geometries, resulting in limited consideration of geometric variables in influencing crack patterns and post-cracking response. In practical structural applications, beam dimensions particularly. These parameters directly affect the initiation, propagation, and configuration of cracks that develop under loading conditions. Therefore, the present study carried out an extended experimental investigation. The experimental program focused on beams produced with normal-strength concrete while maintaining a constant fibre dosage, in order to more clearly identify the role of polypropylene fibres in controlling crack development.

Research Methods

This study employed an experimental research method to evaluate the effect of polypropylene fibre incorporation on the mechanical performance and cracking behavior of structural lightweight concrete beams. The research framework consisted of material characterization, concrete mix preparation, specimen casting, curing, and mechanical testing stages. The materials used in this investigation included Portland Composite Cement (PCC), locally sourced fine aggregate in the form of sand obtained from Karangasem, Bali, lightweight coarse aggregate originating from Gianyar, Bali, mixing water, a superplasticizer admixture identified as SIKA ViscoCrete-3115 N, and polypropylene fibres manufactured by SIKA. The polypropylene fibres used in this study had an approximate length of 12 mm, a specific gravity of about 0.91 g/cm^3, tensile strength ranging from 300 to 440 MPa, and an elastic modulus between 3.5 and 7.0 GPa (Newihy et al., 2018). Two concrete mixture variations were prepared to evaluate the influence of fibre incorporation, namely a control mixture without fibres (0%) and a fibre-reinforced mixture containing polypropylene fibres at a dosage of 0.45% by volume of concrete. The target compressive strength of the concrete was 25 MPa with a water-cement ratio of 0.41. The specimens consisted of cylindrical concrete specimens for compressive and splitting tensile strength tests and reinforced lightweight concrete beam specimens measuring 200 mm × 300 mm × 1800 mm for flexural and crack width evaluation. A total of 10 cylindrical specimens and 6 beam specimens were prepared. Concrete mixing was performed using a mechanical mixer to ensure uniform distribution of polypropylene fibres throughout the mixture. Beam moulds made of steel formwork were used during the casting process. After casting, all specimens remained in the moulds for approximately 24 hours before demoulding. Subsequently, the specimens were submerged in water for 28 days as the curing method prior to testing. Mechanical testing included compressive strength testing, splitting tensile strength testing, flexural strength testing using a three-point loading configuration, and crack width observation. Flexural testing was conducted using a Universal Testing Machine (UTM) in accordance with ASTM C78/C78M-18, while crack development and beam deflection were monitored during loading.

The study commenced with the preparation of the constituent materials, which consisted of cement, sand serving as fine aggregate, coarse aggregate, mixing water, a superplasticiser admixture, and polypropylene fibres with an approximate length of 12 mm. Prior to utilization, all materials underwent preliminary testing to identify their fundamental characteristics, including aggregate gradation, specific gravity, bulk density, silt or mud content, and moisture content. These evaluations were conducted to verify that the materials met the required quality standards and were suitable for producing structural lightweight concrete.

The assessment of material properties included tests for specific gravity, water absorption, and particle size distribution SNI 2834:2002. The results obtained from these laboratory tests served as the primary reference for developing the mix design of structural lightweight concrete incorporating polypropylene fibres. Concrete mixing was performed using a mechanical mixer to achieve uniform consistency and ensure proper dispersion of the polypropylene fibres throughout the mixture. The mixing procedure was implemented through several sequential stages. Initially, the aggregates were blended by combining the fine aggregate (sand) and coarse aggregate for approximately one minute to obtain an evenly distributed base mixture. Subsequently, cement was introduced and the materials were mixed for about two minutes. The mixing process continued. Finally, the superplasticiser, which had been partially diluted in water, was introduced together with the remaining.

Polypropylene fibres were incorporated into the concrete mixture in a gradual manner while. This controlled addition was intended to minimize the risk of fibre agglomeration, commonly referred to as the balling effect. Upon completion of the mixing stage, a visual inspection was performed to verify that the concrete exhibited a uniform texture and that no fibre clusters were present within the mixture. The testing procedure followed the guidelines specified in SNI 4431:2011. During the test, the slump cone was filled without the application of vibration or mechanical compaction. After the cone was carefully lifted in a vertical direction, the spread concrete along axes. Resulting slump value served as an indicator of the mixture's flowability and was used to confirm that the concrete possessed adequate workability prior to placement into cylindrical and beam moulds.

Structural lightweight concrete to resist bending loads while simultaneously examining the development and characteristics of cracking during loading. The specimens used in this test were reinforced concrete. The testing procedure followed the provisions specified in ASTM C78/C78M, which applies a three-point loading method for determining flexural performance. During testing, each beam specimen was positioned on two simple of approximately 1800 mm. Two concentrated loads were applied symmetrically at distances of 600 mm at the midspan section. The applied load was increased gradually using a Universal Testing Machine (UTM) to ensure controlled loading conditions. Beam deflection was monitored at the midspan using a dial gauge to record displacement throughout the loading process. The initiation of the first visible crack was identified through direct visual observation, after which loading was continued until the specimen reached its ultimate load capacity. The flexural strength of the beam was then determined based on the maximum load recorded during testing and the corresponding loading configuration. After casting, the fresh concrete was compacted using a mechanical vibrator to ensure adequate consolidation and to minimize the risk of segregation within the concrete mixture. The specimens were then kept in the moulds for approximately 24 hours before demoulding. Subsequently, all specimens were submerged in water for a curing period of 28 days prior to mechanical testing. The curing process was conducted to ensure proper cement hydration and to achieve the designated concrete strength before testing.

Table 1. Concrete Mix Composition (Mix Design) per m^3

No.	Material	0% Polypropilene (kg/m^3)	0.45% polypropilene (kg/m^3)
1	Portland cement	430	430
2	Fine aggregate	668	668
3	Pumice	531	531
4	Water	176	176
5	Superplasticizer	1% of the weight of cement	1% of the weight of cement
6	Polypropilene	0	4.1

Research Results and Discussion

Composition was determined using a lightweight concrete mix design procedure based on the guidelines outlined in SNI 03-2834, with necessary modifications made according to the specific characteristics of the constituent materials. The mix design process was initiated by defining the target compressive strength and the required slump flow value for the concrete. The outcomes of the concrete mechanical property tests obtained from the experimental program are presented in Table 2.

Table 2. Fine aggregate

No.	Type of fine aggregate	Test results
1	Mud content	3.61%
2	Loose bulk density	1.33 gr/m^3
3	Dense bulk density	1.49 gr/m^3
4	Water absorption	2.26%
5	Oven dry specific gravity	2.28
6	Saturated surface dry specific gravity	2.18
7	Apparent specific gravity	2.32
8	Fineness modulus	2.31%

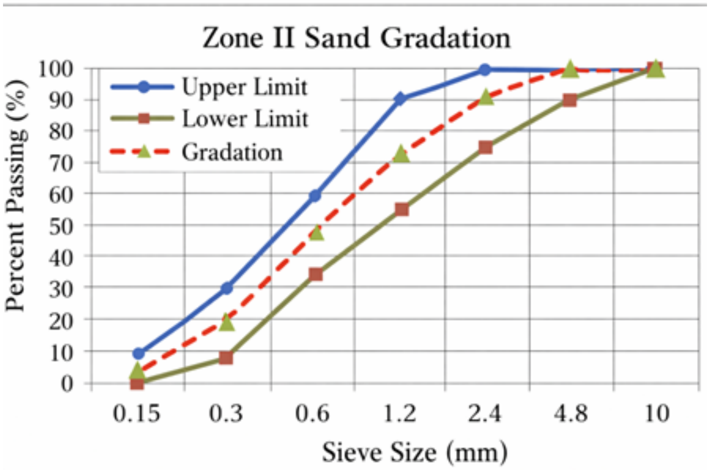

Figure 1. Fine Aggregate Gradation

Table 3. Coarse Aggregate Test Results

No.	Type of pumice	Test results
1	Mud content	0.39%
2	Loose bulk density	1.29 gr/m^3
3	Dense bulk density	1.41 gr/m^3
4	Water absorption	2.28%
5	Oven dry specific gravity	2.43
6	Saturated surface dry specific gravity	2.72
7	apparent specific gravity	2.68
8	Fineness modulus	27.30%

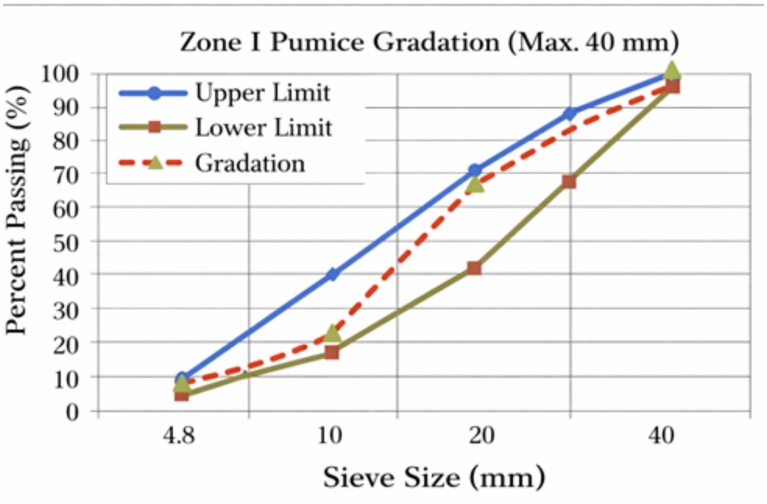

Figure 2. Pumice gradation

Pumice aggregate was utilized as the coarse aggregate because of its lightweight characteristics, porous structure, and ability to reduce the overall density of concrete while maintaining adequate mechanical performance for structural lightweight concrete applications. The specific gravity of lightweight aggregates is used to determine the proportion of aggregates in the mixture so that it meets the density requirements for structural lightweight concrete.

Polypropylene fibres were introduced into the concrete mixture in a controlled and gradual manner to minimize the risk of fibre agglomeration, commonly referred to as the balling effect of the fresh concrete and maintaining mixture consistency even after the fibres were fully dispersed. Upon completion of the mixing stage, a visual examination was performed to confirm that the mixture exhibited a consistent texture and that no clustering of fibres had occurred Beam moulds measuring 200 mm × 300 mm × 1800 mm were used for flexural performance evaluation. Flexural performance testing was conducted using beam specimens 200 x 300 x 1800 mm. Evaluate capacity structural lightweight to resist bending forces as well as to examine the development and characteristics of cracking under flexural loading conditions.

Table 4. Concrete strength in compression tested at 28 days.

No.	Variations	Number of specimens	Compressive strength (MPa)	Splitting tensile strength (MPa)	Flexural strength (MPa)	Maximum crack width (mm)
1.	Control (0% polypropilene)	5	23.73	2.09	3.28	0.75
2.	PP 0.45%	5	24.81	2.31	3.51	0.47

In comparison, the lightweight concrete mixture incorporating polypropylene fibres at a dosage of 0.45% by volume exhibited a slightly higher average compressive strength of 24.81 MPa compared to the control mixture, which achieved an average compressive strength of 23.73 MPa. This result indicates an increase of approximately 1.08 MPa or about 4.55% due to the incorporation of polypropylene fibres. The observed improvement in compressive strength may be attributed to the ability of polypropylene fibres to restrain microcrack propagation within the concrete matrix, thereby improving stress distribution and delaying crack development under compressive loading. In addition, the presence of fibres contributed to better integrity of the concrete matrix and enhanced post-cracking behavior of the lightweight concrete.

Polypropylene fibres do not always produce a significant increase in compressive strength. In some cases, the irregular distribution of fibres within the concrete matrix may create internal voids and reduce the bonding effectiveness between the cement paste and aggregates, which can negatively influence the compressive strength of lightweight concrete. Similarly, Li et al. (2024) reported that non-uniform dispersion of polypropylene fibres may reduce the density and compactness of the concrete matrix, ultimately affecting its compressive performance. In another study, Yaqin et al. (2024) developed macro polypropylene fibres (macro-PPF) with a bonded configuration and textured surface to improve the mechanical interlocking between the fibres and the surrounding cement matrix. Their findings demonstrated that the modified fibre geometry enhanced the bonding performance and crack resistance of concrete materials.Gaayathri et al. (2022) investigated the effect of polypropylene fibre incorporation on expanded clay-based structural lightweight concrete. The study reported that the addition of polypropylene fibres significantly improved the mechanical properties and crack resistance behavior of lightweight concrete. Similarly, Bhogone et al. (2021) observed that fibre reinforcement, particularly steel fibres and hybrid polypropylene fibres, enhanced early-age tensile strength, crack resistance, and fracture performance of concrete. The improvements became more pronounced with increasing concrete age, indicating the positive contribution of fibre reinforcement to the long-term performance of concrete structures.

Previous studies have reported that the incorporation of polypropylene fibres can significantly influence the mechanical and cracking behavior of lightweight concrete. Zeyad et al. (2020) investigated high-strength concrete reinforced with polypropylene fibres at volume fractions of 0.2%, 0.3%, and 0.5%, and reported that fibre incorporation affected workability and water absorption characteristics of the concrete mixture. The study also indicated that excessive fibre content may reduce concrete compactness due to fibre agglomeration within the cement matrix. Similarly, Chajec and Sadowski (2020) explained that different types and proportions of fibres produce varying effects on both fresh-state properties and hardened concrete performance. In general, improvements in tensile strength, crack resistance, and post-cracking behavior are more pronounced than improvements in compressive strength. Zhou et al. (2023) and Chen et al. (2023) also observed that polypropylene fibre incorporation contributed significantly to tensile and flexural performance enhancement, while the increase in compressive strength remained relatively limited. Research conducted by Gaayathri et al. (2022) and Savio et al. (2023) further demonstrated that polypropylene fibre reinforcement improved toughness, residual strength, and crack control performance in lightweight concrete systems. These findings are consistent with the results obtained in the present study, where the incorporation of 0.45% polypropylene fibres improved crack distribution and reduced crack width while producing a slight increase in compressive and flexural strength of structural lightweight concrete beams. Gusti et al. (2025) reported that the incorporation of polypropylene fibres in self-compacting lightweight concrete improved crack resistance, flexural performance, and ductility behavior, particularly under flexural loading conditions.

Splitting tensile strength testing was performed to assess the capacity of concrete to resist indirect tensile stresses generated by compressive forces applied along the diametrical axis of the cylindrical specimen. The experimental findings indicated that of polypropylene lightweight concrete. The control mixture without fibre reinforcement exhibited 2.09 MPa, whereas the concrete mixture containing 0.45% polypropylene fibres achieved a higher average value of 2.31 MPa. This improvement of approximately 10.53% in tensile capacity that develop within the tensile zone of the concrete matrix. By providing crack-bridging action, the fibres contribute to delaying crack propagation and enhancing when subjected to indirect tensile loading conditions.

Previous studies on expanded polystyrene (EPS) lightweight concrete have demonstrated that the incorporation of polypropylene fibres enhances the interaction between the cementitious matrix and lightweight aggregates, thereby improving ductility and overall mechanical performance (Maryani & Lisantono, 2024). The bridging effect provided by polypropylene fibres contributes to delaying crack initiation and restricting crack propagation within the concrete matrix. This mechanism improves post-cracking behaviour and reduces the tendency of brittle failure commonly observed in lightweight concrete. However, maintaining an optimum fibre dosage is essential to preserve concrete performance, since excessive fibre content may negatively affect workability, fibre dispersion, and bonding characteristics within the matrix. Poor fibre distribution can create voids and weak zones that reduce mechanical properties. Microscopic observations obtained from Scanning Electron Microscope (SEM) analysis further confirm that polypropylene fibres are capable of controlling microcrack development and improving crack resistance within the cementitious matrix (Ahmad et al., 2022). In addition, the inclusion of polypropylene fibres has been reported to significantly reduce shrinkage-related cracking due to the fibres' ability to distribute tensile stresses more uniformly throughout the concrete.

Studies on porous concrete containing different proportions of polypropylene fibres have also shown that fibre inclusion produces a more significant improvement in flexural performance than in compressive strength (Huy et al., 2025). This phenomenon occurs because polypropylene fibres mainly contribute to tensile stress transfer and crack-bridging mechanisms rather than increasing the load-carrying capacity under compression. Huy et al. (2025) reported an increase in flexural strength of approximately 7.01% after fibre incorporation, indicating that polypropylene fibres are more effective in enhancing tensile and flexural behaviour. Furthermore, the relatively low density of polypropylene fibres contributes to a slight reduction in concrete unit weight, which may be advantageous for lightweight concrete applications. Polypropylene fibre (PPF) is widely utilized in concrete technology because of its ability to improve toughness, ductility, and crack resistance. In addition, the extensive use of polypropylene materials in the textile industry generates significant amounts of polypropylene waste annually, making recycled polypropylene fibres a potentially sustainable alternative for concrete reinforcement (Qin et al., 2022). Therefore, the incorporation of polypropylene fibres not only improves the mechanical performance of concrete but also contributes to environmental sustainability through waste utilization.

Polypropylene fibres developed a greater number of cracks that were generally narrower and more evenly distributed along the span, resulting in a reduced maximum crack width. These findings suggest that polypropylene fibres not only enhance flexural strength but also contribute to improved ductility and increased energy absorption capacity, commonly referred to as toughness, in structural concrete members. Furthermore, flexural testing results indicate that lightweight concrete reinforced with polypropylene fibres demonstrates superior post-cracking performance. Reflected in enhanced resistance to crack propagation which is primarily associated with the fibre-bridging mechanism (Zhang et al., 2021). Dwianto et al. (2025) also reported that polypropylene on the splitting tensile is closely related to the proportion of fibre volume incorporated into the mixture. The use of fibre reinforcement represents one practical approach to improving the flexural performance of concrete materials. In related research, efforts have been made to utilize recycled concrete waste in combination with denim fabric fibres to enhance both compressive and flexural strength. In related research, recycled concrete waste combined with denim fabric fibres has been utilized to improve concrete mechanical properties. The fibres were incorporated at dosage levels of 1% and 2% to evaluate their effects on compressive and flexural performance.

Table 5. Maximum crack width in beams

No.	Variations	Number of test specimens	Maximum crack width (mm)
1.	Control (0% serat)	2	0.75
2.	PP 0.45%	2	0.47

The experimental observations indicated that, in the control beam without polypropylene fibre reinforcement, the initial crack approximately 65%. The maximum crack width recorded for this specimen was about 0.75 mm, and the crack propagated rapidly as the load increased until the beam approached failure. Mortagi et al. (2023) reported incorporation of 0.2% polypropylene fibres could enhance both the by about 11.7% and 17.6%, respectively. These results suggest that combining steel fibres with polypropylene fibres may significantly improve the structural performance of lightweight concrete, particularly in terms of delaying crack initiation, controlling crack propagation, and enhancing the ductility of flexural members. Polypropylene fibers help control shrinkage, reduce cracking, and enhance the durability of structural elements (Singer et al., 2025).

Rashid (2020) also demonstrated that the inclusion of polypropylene at proportions of 0.4% and 0.6% in prestressed concrete beams exposed to normal environmental conditions over a three-year period resulted in reductions in water absorption of approximately 3% and 8%, respectively, when compared to conventional concrete. Similarly, Yuan et al. (2025) examined of polypropylene fibre addition at 0.45%, 0.90%, and 1.35% on the water absorption characteristics of concrete. Their findings revealed that a fibre dosage of 0.45% was effective in reducing water absorption, whereas higher fibre contents tended to increase the absorption values. The incorporation of polypropylene fibres into concrete has been shown to effectively control crack propagation through the formation of fibre bridging mechanisms and modifications to the pore structure, which in turn enhances the resistance of concrete to water and gas permeability (Abdulkareem et al., 2022). In the present context, the addition of polypropylene fibre (PPF) to lightweight concrete containing pumice aggregate was found to significantly improve and splitting, while producing at fibre contents ranging from 1% to 1.5%. This improvement is primarily associated with the ability of PPF to bridge microcracks within the cementitious matrix (Aziz & Mulla., 2025). Blended micro and macro polypropylene fibers demonstrate higher resistance to cracking and pullout than macro polypropylene fibers (Liu et al., 2021). In addition, the study identified 1.0% PP fiber as the optimum level for manufacturing LFC (Ngo et al., 2022)

Similarly, Nguyen et al. (2024) polypropylene with different geometrical characteristics in ultralightweight concrete had a substantial influence on both the microstructural features and the mechanical behaviour of the material. From an economic perspective, fibre-reinforced concrete systems incorporating glass fibres or polypropylene fibres have been shown to provide more cost-effective pavement solutions compared to steel fibre-reinforced concrete as well as conventional plain concrete, while maintaining comparable structural performance (Hussain et al., 2020). Research conducted by Smarzewski (2019) examined the toughness. The study revealed that under flexural loading conditions, the toughness of temperature approached approximately 800 °C, indicating the sensitivity of polypropylene fibres to high-temperature environments. Furthermore, microstructural investigations by Elkatatny et al. (2020) incorporation of polypropylene contributed to a reduction in the porosity and permeability. Improvement was pore-filling effect fibre particles within the concrete microstructure, which resulted in a denser internal structure and enhanced durability characteristics. Polypropylene fiber inclusion contributed to better crack control and improved flexural performance in reinforced concrete beams (Harahap et al., 2025).

Conclusion

This study investigated the effect of 0.45% polypropylene fibre incorporation on the mechanical behaviour and crack characteristics of lightweight concrete beams. The experimental results demonstrated that the addition of polypropylene fibres contributed to an improvement in compressive strength compared to the control specimens without fibre reinforcement. In flexural performance evaluation, fibre-reinforced beams exhibited reduced crack width and improved resistance to crack propagation during the post-cracking stage. The crack pattern observed in polypropylene fibre-reinforced specimens was characterized by a greater number of finer and more uniformly distributed cracks along the constant moment region. This behaviour indicates the presence of a fibre-bridging mechanism that delayed crack propagation and enhanced ductility. However, at a fibre dosage of 0.45%, the improvement in mechanical performance was still relatively limited and not yet dominant. The novelty of this research lies in the investigation of crack behaviour and flexural response of lightweight concrete beams reinforced with a relatively low dosage of polypropylene fibre under flexural loading conditions. The findings provide additional insight into the effectiveness of polypropylene fibre in controlling crack distribution and improving post-cracking performance in lightweight concrete applications. Based on the obtained results, a polypropylene fibre dosage of 0.45% can reduce crack width and improve crack distribution characteristics, although higher fibre contents may be required to achieve more significant mechanical enhancement. Therefore, future studies are recommended to investigate wider fibre dosage variations, such as 0.8% to 1.2%, as well as the potential use of hybrid additives to optimize the mechanical and durability performance of lightweight concrete.

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