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Strength and Behavior of Polypropylene Fiber Reinforced Concrete Double Tee Beams

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Abstract: This investigation looks at the additive impact of polypropylene fibers to the concrete properties. The structural performance of polypropylene fibers concrete double tee beams was also inspected. Four-point bending tests were prepared with fiber content (0.5, 1.0, 1.5 and 2% by weight) to inspect the flexural strength and deflection of double tee beams. Additionally, the impact of PPF on the beams with various amounts of transverse steel reinforcement was explored. The outcomes demonstrate that fiber addition improved the concrete properties in general and enhanced the ductility and the load bearing capacity, control of cracking of the double tee beams remarkably. The highest increase in loading was 21.98%, at the same manner an increases were observed in the deflection values under the largest load compared to the control sample. Deflection was decreases with respect to the same loading stages with the increase of fiber contents, the highest recorded decrease was 21.47%. The polypropylene fiber can be used as a solution for the cases with stirrups congestion since the ultimate load was increases with the same spacing of stirrups. The polypropylene fiber usage was upheld as hopeful technics for the different problems of concrete cracking in destructive situations.

Key words: Double tee beam, polypropylene fiber, flexural strength, shear strength, technics, fiber

INTRODUCTION

The ability of durable construction to withstand weathering action and other debasement forms amid its existence with insignificant maintenance is similarly essential as the limit of a construction to oppose the loads applied on it. The idea of adding strands to enhance brittle material conduct is deep-rooted. For instance, Mesopotamians (present-day Iraq) utilized straw to reinforce sun-dried bricks (Campbell, 2010). This outdated innovation is as yet used to enhance concrete characteristics.

On one hand, concrete offers many favorable circumstances with respect to mechanical attributes and monetary parts of the development then again, the brittle conduct of the concrete residues the biggest disable for the dynamic and many applications where adaptable conduct is basically necessary.

The latter periods witnesses a rising attention in fibers usage of in ready-mixed, pre-cast concrete and shotcrete concrete. Intermittent fibers practice in concrete can be branded in different techniques.

Examination of fiber concrete utilizing steel fibers had just been kaput by a few studies from numerous interval past (Sneed and Ramirez, 2010; Zakaria *et al*., 2009; Ne'ma *et al*., 2011; Kakooei *et al*., 2012; Altoubat *et al*., 2009). It was demonstrated that steel fibers enhance the mechanical properties of concrete particularly in the modulus of rupture and the concrete tensile strength (Patel *et al*., 2011). Although, steel fibers have disadvantages for example, effortlessly to consume, higher weight, tendency to harm the blender, magnetic interferences and higher cost (Patel and Pandya, 2012). Consequently, another fiber material was produced and utilized as a part of concrete, for example, polypropylene fibers. Examination of fiber concrete utilizing polypropylene fiber was at that point done by several studies (Patel and Li, 2010; Patel and Pandya, 2010). It was demonstrated that polypropylene can enhanced the rigidity of concretes. Use of precast concrete is more common and quicker than typical concrete. Various endeavors was associated with the early presentation of FRC in precast concrete thought developing design procedures. For instance, PCI's GFRC advisory group built up an outline technique that is as yet utilized today. These plan hones have been approved with time and a many products have now been in benefit for over 40 years. However, study on enhancement precast concrete shear strength using polypropylene is still rare. Therefore, study on concrete shear strength using polypropylene is still needed.

Double tee beams are appropriate for basic suspend floors in many structures particularly in bigger business structures, auto parks and stores were expansive segment

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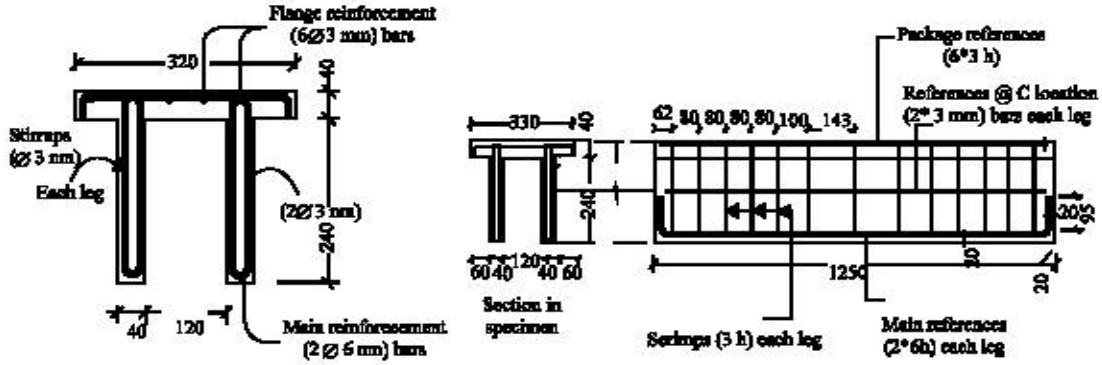

Fig. 1: Section and general layouts of double tee beams models

free spaces are required. For the most part, the double tee is an extensive precast solid segment that sensible for use in most kind of structures and can be cast with any sort of concrete. According to the researches, the increase of formability and bending strength are the extra advantages of adding the fibers to the concrete (Zheng and Feldman, 1995).

In the present research, the scientific objective were to evaluate the influence polypropylene fiber on the flexural and shear behavior of reinforced concrete double Tee Beams when subjected to practical load circumstances.

Experimental program: Nine reinforced concrete double tee beams under the influence of four point loading were tested. All the concrete double tee beams were reinforced by (4'8 mm) conventional steel bars of 420 MPa yield strength at bottom of the webs. The top flange was reinforced by 6'3 mm bars. Slightly shear reinforcement was used to certify all of specimens failure will be due to shear ('3 mm) steel bars were used as stirrups in the weds. The first group (DTB1-4) of the tested beams were made with stirrups spacing of d/3. To study the effect of transverse reinforcement amount with addition of PPF, the other beams (DTB5, DTB6) where reinforced with d/4, d/2, receptively in the same manner (CDTB2, CDTB3) where casted to be control beams. Therefore, the total number of PPF double tee beams where six with three control ones.

Specimen details: The scale of the tested beams model were a one-third scale, suitable for laboratory experiments (Fig. 1). Depending on scale the total height of the typical beam was chosen as 280 mm. The width of the both beam webs was selected to maintain adequate room for longitudinal reinforcement and provide 20 mm cover.

The double tee beams properties and reinforcement details are introduced in Table 1, Fig. 1 and 2, respectively. Each beam is assigned in an approach to demonstrate the double tee beam featured and its group. Along these lines, the beam (DTB3) is a double tee beam cast with polypropylene fiber, the beam that started with the letter C where the control one.

Fig. 2: Fibrillated polypropylene fibers used in present work

Table 1: Concrete blend proportions

	Concrete type				
Parameters	Normal				PPF
Water/cement ratio	0.52				0.52
Water (L)	156				156
Cement Portland type I (kg/m³)	300				300
Fine aggregate-sand with max. size 4.75 mm (kg/m³)	1127				1127
Coarse aggregate-crushed with max. size 20 mm (kg/m³)	752				752
Polypropylene fiber (kg/m³)	-	600	1200	1800	2400
Additive (%)	-	0.5	1.0	1.5	2.0
Unit weight (kg/m³)	2335	2335	2335	2335	2335

MATERIALS AND METHODS

All of experienced blend prepared with the same ingredients. gravel as coarse aggregate of max. size of 20 mm was consumed and Sand as fine aggregate.

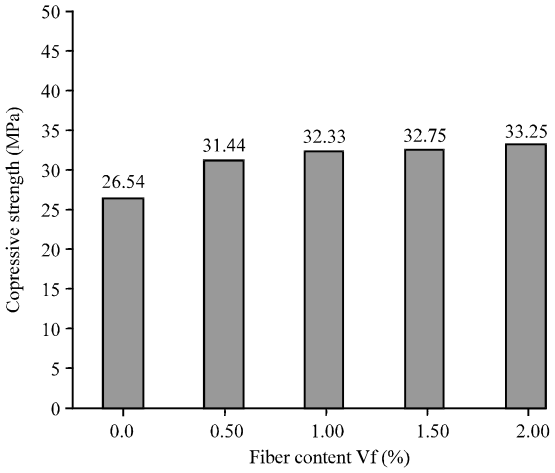

Fig. 3: Polypropylene fibers content effect on compressive strength

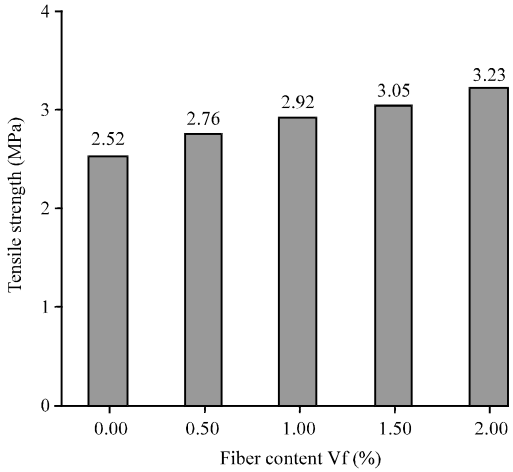

Fig. 4: Polypropylene fibers content effect on tensile strength

Table 2: Fibers characteristic

Types	Fibrillated
Modulus of elasticity (GPa)	3.5-7.5
Tensile strength (MPa)	547-658
Length (mm)	30-50
Diameter (mm)	0.30-0.35
Specific surface (m^2/kg)	91
Density (kg/cm^3)	0.91

Elongation, >20%; Appearance, White Fibrillated; Acid and salt resistance; Heavy-duty

The used fiber was fibrillated polypropylene that shown in Fig. 2. It had an typical length among 15-50 mm and width of 0.3-0.5 mm with a tensile strength of 547-658 MPa, also it had an elastic modulus of 3.50-7.50 GPa and a specific gravity of 0.9 (Table 2).

Polypropylene effect on compressive strength: The consequences of compressive quality for different PPF reinforced concrete mix are offered in Fig. 3. The 28 days strengths gained for cylinder samples vary from 26.54 MPa for ordinary reinforced concrete to 32.48 with PPF. The additive of polypropylene fiber of 0.5% by weight improved the compressive strength to 13.97% in the same way 1, 1.5, 2% variant of PPF compressive strength improved to 18.46, 21.81, 23.02%, respectively in association with the control cylinder (Fig. 4). it was obviously, the adding of 2% of fiber presented the most weighty result to cylinder compressive strength.

Polypropylene effect on tensile strength: The investigation of splitting strength for concrete with different polypropylene fiber contents are offered in Fig. 4. It was grasped that the cylinder splitting strength vary from 2.52-3.23 MPa. The additive of polypropylene fiber of 0.5% polypropylene fiber by weight improved the tensile strength up to 4.7% in the same way 1, 1.5, 2% variation of polypropylene fiber tensile strength improved by 9.5, 15.87, 28.17%, respectively. Fibers be apt to conduit micro cracks and impede the spread of it. When tensile stress is transmitted to fibers, the micro cracks are detained and thus increase the tensile strength.

RESULTS AND DISCUSSION

Double tee beams test results: The double tee beams was aligned and held on position and the above two loading was applied. The measuring instruments was situated secure in the desired locations. Load was applied in prearranged incremental then displacement consistent to every load were recorded. Development of cracks was detected throughout all loading procedure. Crack was striking when detected in the concrete face and the increment upon which crack was performed. All the applied load and measurements was documented in anticipation of the beam failure.

Figure 5-10 demonstration the typical experimental deflection curves for normal reinforced concrete double tee beam and the beams with polypropylene fibers with different ratios. Through the continuous increasing of load, cracks happened in the webs when load surpassed the cracking load. Therefore, flexural stiffness of double tee beam was considerably decreased and the curves were slightly softened.

Toward the start of the experiments, under moderately little loading level, few little flexural cracks there were began to create in the mid-span. Nonstop flexural cracks stay growing with the cumulative of loading. Merely one big crack in the shear span region developed as the practice of the test continued.

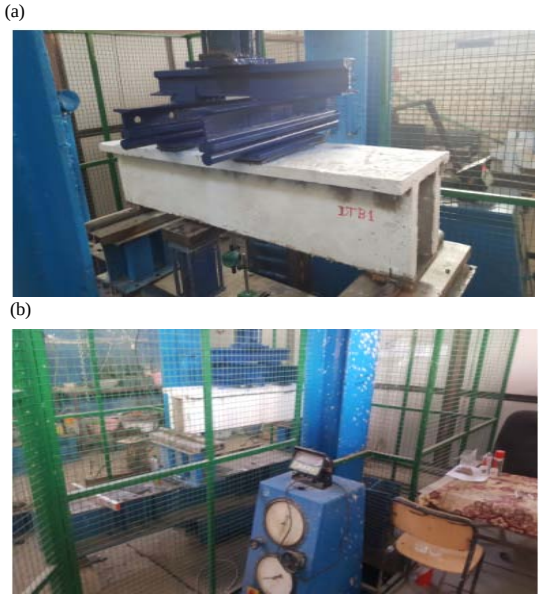

Fig. 5: a, b) Beam was positioned on the test form under the UTM with proper alliance

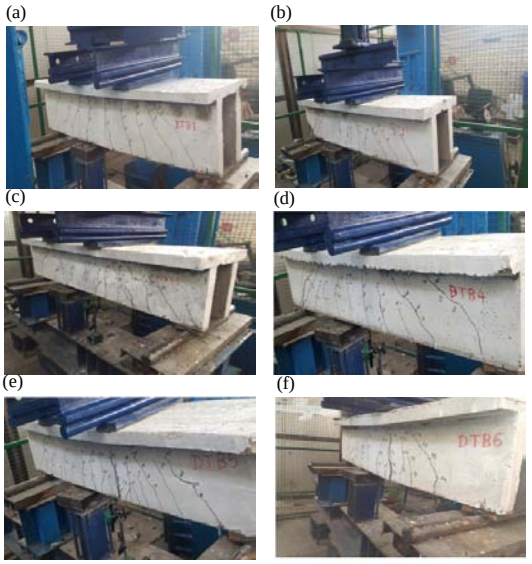

Fig. 6: a-f) Double tee beams with PPF after test

Comparable crack shapes can similarly be presence in literatures (Schumacher, 2006; Dancygier and Savir, 2006; Deluce and Vecchio, 2013). Associated to double tee beams without polypropylene, decreased deflection can be attained at the equivalent loading increments with the adding of polypropylene. The improved bond between the reinforcement and concrete produced via. restraining effect of the polypropylene could be the main reason (Chao and Naaman, 2006; Harajli *et al*., 2002; Ding *et al*., 2014).

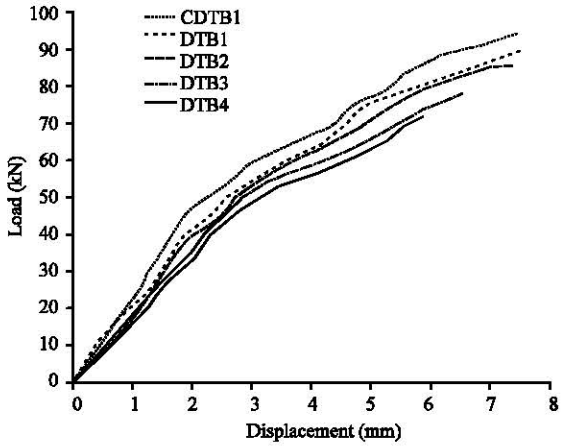

Fig. 7: Double tee beams with PPF and control load deflection curves

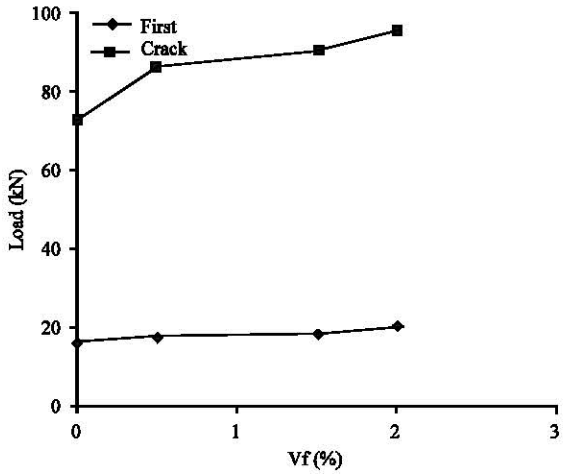

Fig. 8: Effect of PPF content on the first and ultimate load for double tee beams

Table 3: Test result for specemens with pp fiber vatriation ratios

Specimen ID	fc (MPa)	Cracking load (kN)	Ultimate load (kN)	Vf (%)	Puf/Pc (%)
CDTB1	26.54	17.5	75.31	0.5	1.0
DTB1	30.25	17.0	78.51	0.5	104.2
DTB2	31.44	18.0	78.52	1.0	114.5
DTB3	32.33	20.0	90.21	1.5	119.8
DTB4	33.65	21.5	95.10	2.0	126.3

Table 4: Test result for specemens with transvers reiforcement vatriation

Specimen ID	Spacing (mm)	Cracking load (kN)	Ultimate Load (kN)	Puf/Pc (%)
CDTB1	88	17.50	72.41	126.3
DTB4	88	17.00	95.10	
CDTB2	132	16.25	66.82	129.5
DTB5	132	18.00	86.53	
CDTB3	66	18.00	96.80	132.2
DTB6	66	22.00	128.00	

As presented in Table 3-4 and Fig. 6-7, per adding of polypropylene fibers, the ultimate loads and deflections

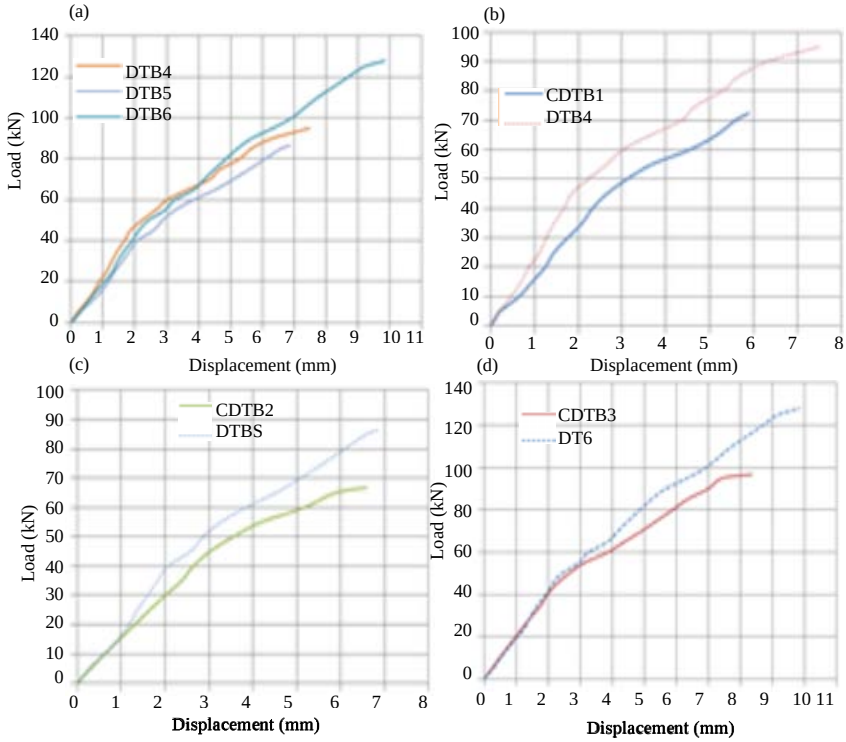

Fig. 9: a-d) Effect of PPF and shear reinforcement amount on the double tee beams behavior

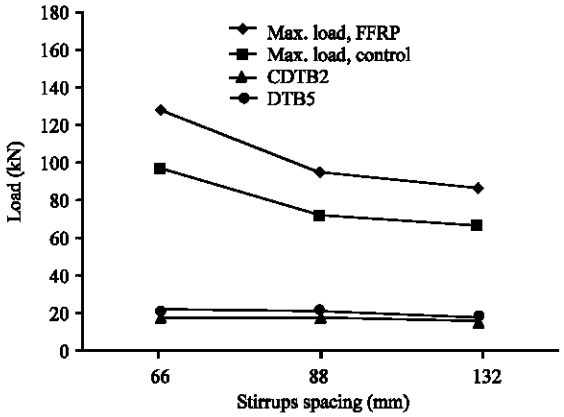

Fig. 10: Effect of PPF on the double tee beams with different transverse reinforcement

were increased. Normal double tee beams failed in a extra brittle way. Just at stage it reached capacity, the beam was cracked and the load fallen rapidly and aggressively. Polypropylene fiber beam failed in more ductile way as the load fallen more gently and smoothly.

The present of polypropylene fiber in concrete essentially impact the final load of the double tee beams and deflection at extreme capacity. Little variety in the maximum load was because of the adjustments in the concrete compressive strength due to presence of polypropylene fibers. Fundamentally little impact on the flexural strength before cracking. In any case, maximum deflection essentially increased by utilizing polypropylene fibers as a part of concrete in the double tee beams.

Double-tee beams permit the manufacture of car parks and industrial floors in a rapid besides profitable manner. According to the most practical imperative, the beam webs need to decrease the congestion of shear stirrups or even could be exclude it entirely from the beam webs. Although the elimination of stirrups involves excessive attention and more study of the design, so as to evade sudden failure of the narrow webbed beams (Al-Shather *et al*., 2017).

Figure 7 displays the load mid-span deflection curves for FFP fiber double tee beams per changed transverse steel spacing. Table 5 recaps the experimental results. The results show that the by adding of polypropylene fiber there's an increase in cracking and final loads of the double tee beams compared to conventional once.

For the change in transverse reinforcement spacing, comparable pattern of polypropylene fiber influence on the ultimate load of the double tee beams was watched but the influence of polypropylene decreases. Contrasted with reference beam CDTB1, it is noticed that by using stirrups spacing (d/3) with inclusion of 2% PPF enhances the ultimate capacity by 26.3%. For reference double tee

beams CDTB2, CDTB3 with stirrups spacing (d/2, d/4) polypropylene fiber increase the ultimate beam capacity by 29.5 and 32.2%, respectively.

From Table 5, first crack load was not meaningfully subjective through the polypropylene fiber adding. Since, the ratio is small, 2% in, first-crack strength and stiffness of the composite are almost equal to the plain concrete. Though, when the beam cracks continued, excessive alteration is detected owing to improved flexural and shear stiffness for double tee beams with the presence of polypropylene materials. Due to adding of polypropylene fibers to the beams there was tendency to the number of cracks growth and decrease in cracks width and distribution (Al-Shather *et al*., 2017). Polypropylene fibers link the crack and take on portion of unconstrained load via cracked concrete. Ultimate load were improved, although the mid-span deflection consistent to the ultimate load significantly increased with the addition of Polypropylene fibers amounts.

The permutation fiber practice besides customary reinforcement in concrete structure is a worthy choice (Chao and Naaman, 2006). From one perspective, reinforcement take on the foremost bearing capacity of the concrete element in flexure. Then again, the fibers bridge concrete paste cracks and provide a consistent post-cracking ductility.

CONCLUSION

The experimental program demonstrated that the addition of polypropylene fibers to the concrete was appropriate to enhance the fundamental of concrete featured and behavior. In view of the outcomes, the accompanying conclusions are drawn: The addition of polypropylene fibers at low values (0.5-0.2%) essentially advances the standard compressive strength up to 23%.

The tensile strength of concrete with PPF was increased about 9.5-28.17% in lieu of adding the PPF via. the range (0.5-0.2%) with respect to normal concrete strength.

For the tested double tee beams there is around (4-26%) improve in flexural strength by adding (0.5-0.2%) fibers in concrete. The test outcomes demonstrated that the deflection has been generally increased with the addition of polypropylene fibers. Moreover, double tee beams with fibers have greater final deflection past the ordinary concrete beams. The addition of polypropylene fiber gives greater malleability and flexible properties.

The concrete double tee beams shear strength was enhanced remarkably by adding polypropylene fibers, since, the presence of fibers ensure more positive performance at pre-cracking stage, there is no surprising enhancement in load capacity up to first crack shows up, and a better performance at the final loading stage. Double tee beams without fibers exhibited a typical brittle shear failure. The addition of polypropylene fibers can shift the kind of failure from a pure shear failure to a combined flexure-shear or pure flexural failure. It is also can settling that the suitable addition of polypropylene fibers to concrete beams could be an alternate strategy for diminishing the concentration of shear stirrups.

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