The Shear Behavior of Reinforced Concrete I – Beams With Polypropylene Fibers

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Abstract

This research submits theoretical and experimental realization of shear behavior of RC I-beams with polypropylene fiber with different volume fraction of plastic fiber as additive. The enhance of the sustainability of structural elements through the development of its mechanical performance by adding new materials such as plastic raw materials has become more important in the current period , particularly I-beams that was used in the long spans structure to become more environmentally-friendly. Seven specimens were tested in this study and only the amount of fiber volume fraction was varied. Experimental results showed that the ultimate strengths are increased in range (**4.4% to 35.27%**) that of control IB-1 for the tested beams containing Polypropylene Fiber Reinforced Concrete (PPFRC) with varied amount percentage of fiber material. Crack arrest mechanism of polypropylene fibers, and compressive strength of concrete increased in range (**7.42% to 29.3%**) that of plain concrete, and improved the tensile response in range (**8.36% to 92.7%**) that of plain concrete, limited crack propagation. So, improved behavior was obtained.

ANSYS 11, Finite Element models software are used to emulate two tested I-beams. 3D -nonlinear solid elements was utilized to model the concrete, while, the steel reinforcement was demonstrated by spar element. It was found that the general practices of the FE models demonstrated acceptable concurrence with perceptions and information from the experimental tests.

Keywords*:* Concrete, I-Beam, Polypropylene Fiber, (PPFRC), Finite Element.

1 Introduction

The conventional objectives of engineers are the design of economic and safe structures. However, there is a developing sympathy toward sustainability about the need to ensure the environment. Presently, like never before, engineers ought to pick environmentally-friendly materials by adding appropriate material to improving the mechanical properties, for example, plastic raw material (PPFRC). In this setting, the Beams with I-shaped cross sections are utilized broadly as a part of long traverse and pre-stressed concrete structures. The wide flange does not just allow a large compressive force to grow however it likewise amplifies the arm of the internal couple by situating the resultant of the compressive stress close to the compression surface, [Roger Yuan Xu. (2011)] [1]. This paper depicts the advancement of shearing stress of reinforced concrete I-beams connected to one target capacity; to be specific the change in its conduct against shear stress comes up short and creates the economic cost. For the configuration of a simply supported concrete I-Beam, one variable were utilized (percentage of polypropylene fiber added to admixture of concrete). The conventional concrete with same compressive strength were be utilized. The minimization of concrete from the tension zone, where only the steel reinforcement is viable in carrying tension, diminishes the dead weight and allows the configuration of littler and lighter members. Moreover, the narrow web of I-shaped cross is more powerful to convey shear stress, [Xie. L. (2009)] [2]. This paper demonstrates an audit of the effect of polypropylene (PP) fibers on shear properties of concrete in hardened. The piece of fibers in crack anticipation has additionally been discussed. Exploratory studies indicate that the addition of polypropylene fibers to the concrete in beams without increasing shear reinforcement (stirrups) may fundamentally increase the ultimate shear strength [Cladera, A. at all (2005)] [3]. The expansion in shear strength owing to the fibers relies on upon the amount of fibers (fiber volume fraction (V_f)). Fibers are compelling after the formation of cracks and keep on resisting large tension until the fibers yield or pull out.

2 Layout of the Study

The case scrutinized was a simply supported RC I-beam (**Fig.1**). The problem was formulated with seven specimens. Each specimen having the same geometry: the depth (h = 350 mm), the width of flange (b_f = 160 mm), the thickness of the flange (t_f = 50 mm), the web thickness (t_w = 60 mm) and the concrete cover (c = 15 mm). All specimens establish the same properties of concrete mix with different percentage of PPF material (0.0% for control specimen until content of fiber 0.6%). The applied load and setup configurations of beams and their corresponding shear force and bending moment diagrams are shown in **Fig. 2**.

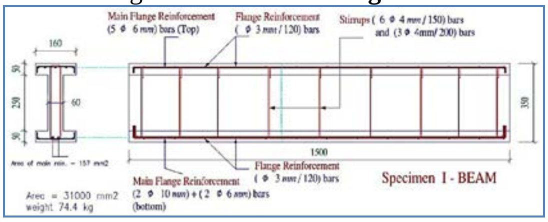


Figure 1: Geometry and Sectional Dimensions of the I-section Reinforced Concrete Beam (units: mm)

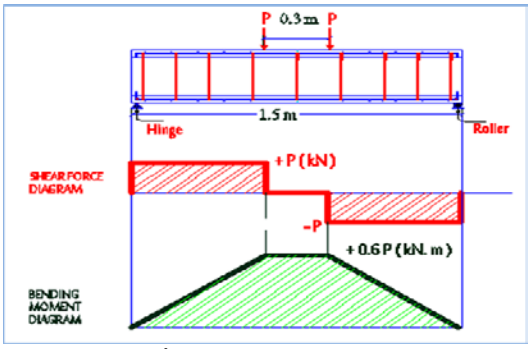


Figure 2: shear force and bending moment diagrams.

2.1 Reinforcement Layout

The seven specimens have transverse reinforcement stirrups (3 Ø 4 mm). Each beam had the less of maximum amount of shear reinforcement allowed by [Committee 318, A. C. I. (2011)] [9]. These ratios were initially calculated based on a specified concrete strength of 30 MPa (standard cube) and stirrup yield strength of 416 MPa. Using the specified cross sectional dimensions, the maximum shear reinforcement ratio given by ACI 318-11 was 1.238%. With a web width of 60 mm, the cross section of every beam had only two legs (Ø 4 mm) stirrup in order to maintain adequate clear cover. The spacing of stirrups for the specified shear reinforcement was 150 mm for shear zone and 200 mm for mid space. The stirrups were all the more closely dispersed in the outer I-sections of each beam to guarantee that the shear failure would first happen in the test area. The fortification design of each beam was symmetrical about the mid-span. The longitudinal reinforcements in the two flanges of each beam were intended to give adequate flexural capacity to keep flexural failure from happening before the beam fails in shear. [Lee, J. Y. at all. (2010)] [11]

2.2 Formwork

The formwork was developed to permit every one of the seven specimens to be thrown immediately. The base was made by two layers of intertwining plywood with four openings screwed onto it. Every space was isolated by a divider made of two layers of marine plywood with a 50 mm by 100 mm wood in the middle. Considering that the formwork may be utilized for more than a single cast, marine plywood was picked rather than regular plywood with a specific end goal to minimize the damages done by concrete during casting and curing. The curing done by covering concrete surfaces with wetted gunny bags for keeping the surface wet for several days, ASTM C192 (1990) [5]. (Fig. 3).

Figure 3: Preparing Specimens for Casting.

2.3 Material Properties

2.3.1 Concrete

All specimens were casted at the same time utilizing ready mixed with a specified strength of 30 MPa. Regular concrete couldn't be utilized because the poker vibrators were not able to fit into the dense reinforcement cages. The casting procedure was done in under an hour and a half. The concrete strength was measured utilizing standard cube compression test. Two cubes and one standard cylinder with 150 mm diameter and 300 mm in height were tested for each example to measure the concrete compressive and splitting strength ASTM C496 (1990) [9] at a particular age. The cubes and cylinders strength were resolved on 28 days after the cast beam test, ASTM C39 (1993) [7]. Table 1 lists the materials of concrete and its amount in mixture. The cylinder (150 x 300) mm tested for splitting strength of concrete according to ASTM standard requirements while the cube (150) mm used to measure the compressive strength according to BS1881-116 (1983) [8] of concrete by converted its magnitude to American standard by using convert factor (0.88) for normal strength level and water cured , Zabihi and O. Eren (2014) [10] , Table 1 and 2.

Table 1: Conversion factors for normal strength concrete and water cured.

Water cured	**Cylinder (100 x 200)**	**Cylinder (150 x 300)**	**100^3**	**150^3**	**200^3**
Cylinder (100 x 200)	1.00	1.18	1.16	1.35	1.38
Cylinder (150 x 300)	0.84	1.00	0.98	1.14	1.17
100^3	0.86	1.02	1.00	1.16	1.19
150^3	0.74	**0.88**	0.86	1.00	1.02
200^3	0.72	0.86	0.84	0.98	1.00

Table 2: Concrete Mixture and Descriptions.

Material	Descriptions	Content in Mix. (kg)
Cement	Ordinary Portland with specific gravity of 3.15.	384.30
Coarse aggregate	Crushed blue granite was passed through 10 mm sieve. The apparent specific gravity is 2.95 and fineness modulus is 7.1.	572.50
Fine aggregate:	Natural river sand with fineness modulus of 2.64. Its gradation meets zone II of IS 383 (1970) requirements. Specific gravity is 2.63.	1162.50
Water	Potable water	192.0
Ratio of Mixture :		(1:1.5:3 : 0.5)

2.3.2 Polypropylene Fiber

The polypropylene raw material (Figure 4) is gotten from absolutely hydrocarbon. Its method of polymerization, its high atomic weight and the way it is handled into fibers join to give polypropylene fibers extremely valuable properties as clarified beneath: [Bruce, P. (2004) [9], Hananth, D. J. (1998)] [14]· Table 3,4.and 5.

- The hydrophobic surface not being wet by cement glue keeps hacked fibers from balling impact amid blending like different fibers.
- The water interest is nil for polypropylene fibers.
- The introduction leaves the film powerless in the horizontal course which facilitates fibrillations. The matrix of cement can hence enter in the mesh structure between the personage fibrils and make a mechanical bond property between the cement matrix and fiber. Henager, C.N.(1976) [11].

Figure 4: Polypropylene Fiber used in study.

Table 3: Properties of polypropylene fibers used in present work

Fiber type	Length (mm)	Dia. (mm)	Tensile strength (MPa)	Modulus of elasticity (GPa)	Specific surface (m2/kg)	Density (kg/cm3)
monofilament	30-50	0.30-0.35	547-658	3.50-7.50	91	0.91
Elongation At Break %:	Appearance				Frost Resistance (Acid and salt resistance)	
>20	White Or White Pencil Monofilament				Strong	

Table 4: The Modules of elasticity of concrete with and without fiber adopted in FE models.

Concrete Type	Equation	Note
Normal Concrete	$EC = 4700 \sqrt{f'c}$	ACI-318 -11
Concrete with Polypropylene Fiber	EC = E f Vf + (1- Vf) Em	Rahul Jain at all (2011) [14]

Table 5: Volume Fraction of Fiber and other Parameters Values for Verification Program.

Specimen	Vf %	Fcu N/mm2	f_x N/mm2	Ec according to Table 6	Efp GPa	Fiber size mm
IB-1	0.0	25.6	2.63	23,780	3.5	5
IB-2	0.2	27.5	2.85	24,647	3.5	5

3 Experimental Works

3.1 Compressive Strength of Concrete

The compressive strength of test cubes was measured for PPFRC cubes after 28 days of moist curing. The average compressive strength values observed after 28 days are given in Table 6. The strength increment was directly proportional to increasing amount of fibers in concrete. The maximum 28 days average cube compressive strength for Mixes was 25.6 (no fiber), 27.5, 28.2, 29, 29.5, 31.7 and 33.1 MPa respectively, all corresponding to a conventional concrete (control) volume fraction of 0.0%. The increase in compressive strength was about 7.42% ,10.15%., 13.28%, 15.23%, 23.82% and 29.3% respectively that of plain concrete. During test it was observed that the pieces of concrete did not spall off severely as they were held intact by the fibers. The incorporation of the fibers in the concrete had, in general no significant effect on the compression strengths, although there were a few exceptions. [B.S.I., (1983)] [13].

Table 6: Experimental Results of PPFRC.

Specimen	Volume Fraction of Fiber, V_f %	Compressive Strength (MPa) - Cube	Splitting Tensile Strength (MPa) – Cylinder
IB-1 (control)	0.0	25.6	2.63
IB-2	0.2	27.5	2.85
IB-3	0.3	28.2	3.12
IB-4	0.4	29.0	3.35
IB-5	0.5	29.5	3.65
IB-6	0.55	31.7	4.61
IB-7	0.6	33.1	5.07

3.2 Splitting Tensile Strength of Concrete

The splitting tensile strengths for various concrete mixtures adopted by tested cylinders under compression machine in lab. The strength in this case was similar to that of the cubes. The increase in strength for Mixes was about 8.36%, 18.63%, 27.37%, 38.78%, 75.28% and 92.7% respectively that of plain concrete. A possible reason for this difference is that the fiber content is more effect in tensile behavior of concrete. In the specimens containing fibers the split half of the cylinders were held together showing that the tensile strength and binding of fibers to concrete is superior. The results of the experiments are listed in Table 7. [ASTM C496 (1990)] [6].

Table 7: The experimental results of tested specimens.

Specimens	Vf %	Fcu (MPa)	f_t (MPa)	First Crack Load (kN)	Failure load (kN)	Ultimate displacement mm	Failure mode
IB-1	0.0	25.6	2.63	15.20	27.50	3.75	**Shear**
IB-2	0.2	27.5	2.85	15.34	28.31	3.42	**Shear**
IB-3	0.3	28.2	3.12	15.68	30.0	3.28	**Shear**
IB-4	0.4	29.0	3.35	17.50	31.4	3.18	**Shear**
IB-5	0.5	29.5	3.65	18.20	32.5	3.15	**Shear**
IB-6	0.55	31.7	4.61	20.0	35.0	3	**Shear**
IB-7	0.6	33.1	5.07	22.50	37.5	2.78	**Shear**

3.3 Specimens under Test

I-Beams of the main size (160 mm×350 mm×1500 mm) were tested under two point loading. Fig. (5-A), demonstrate the specimens under test machine. Fig.(5-B) demonstrates the crack patterns of the beams tested in the present work. The control beams (without fibers) fizzled by shear at the initiate cracks from the shear zone into the compression zone. Every one of the cracks showed up between the point loads straight forward to the support at start of beam. The experimental results indicates increase in strength because of utilization of fiber material in concrete, these increase in strength was around 4.4%, 9.1%, 12.7%, 17.82%, 27.2%, and 35.27% respectively that of control IB-1. In other hand the deflection at mid span of beam lessened marginally in view of the impact of fiber on the cracks in the concrete as it is to resist the widening cracks and its continuity. The experimental results of tested specimens are shown in Table 4. The load step in experimental work was 2.5 KN up to failure. Fig. 6.

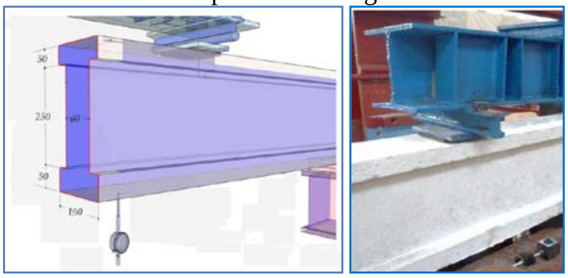


Figure (5-A): Reinforced Concrete I-beam under Test Machine

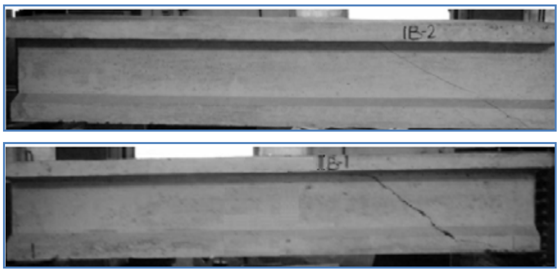


Figure (5-B): The crack patterns of the beams tested in the present work.

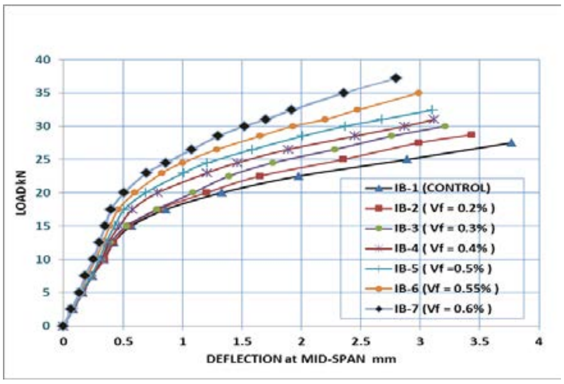


Figure 6: Load – Deflection curves for experimental work.

4 Verification of Experimental Works by Theoretical Study

The FE models are made utilizing the Finite Element (FE) software ANSYS 11. The models have the same geometry, dimensions, and boundary conditions of the tested I-section reinforced concrete I-beam specimen. The target of this section is to examine the conceivable outcomes of discovering best model in practical use for I-section reinforced concrete with PPFRP. It reports the results of some analyses performed utilizing the reinforced concrete models of the broadly useful FE software ANSYS, [ANSYS, (2007)] [15].

4.1 ANSYS Finite Element Model

The idealization of I-beam for finite element program is shown in Table by using 3-D elements. Table 8.

1- Solid 65 for concrete.
2- Link 8 for rebar.
3- Solid 45 for steel bearing load (supports and load).

The I-section RC (PPFRC) beam and control was demonstrated by generating nodes and elements through nodes. Then elements properties were assigned for both steel and concrete. By taking benefit from the symmetry of the tested beam, a half of the full model was utilized for demonstrating. This approach diminished time of computational significantly. Half of the whole model is appeared in Fig. (7-a, b). Link 8 elements were utilized to represent the flexural and shear reinforcement. [ANSYS, (2007)] [15].The load step in finite element model was chosen 1 KN for all specimen simulation.

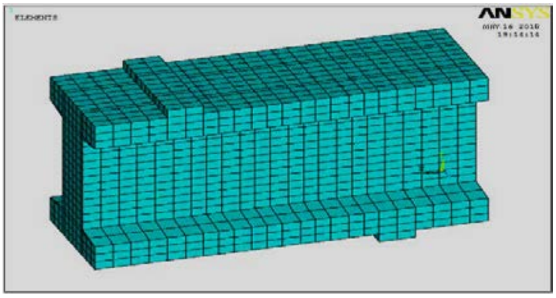


Figure (7, a): Typical half symmetry finite element model.

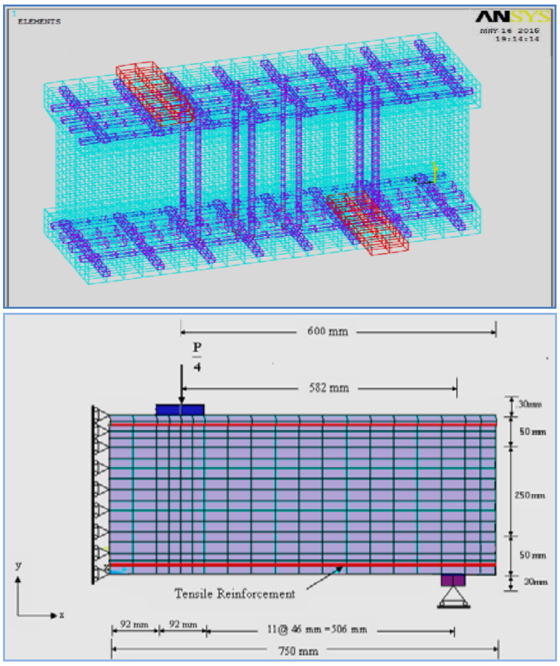
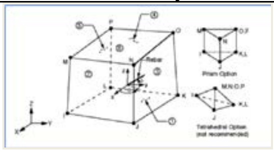
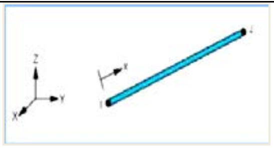
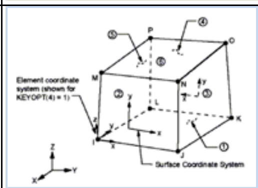


Figure (7, b): Typical half symmetry finite element model with dimensions (rollers as a supports at mid. Span to allow the y – direction displacement).

Table 8: The Elements Used to Idealization of Finite Element Program.

Element	Description	Geometry
SOLD65	This element is utilized to represent to concrete material.	
LINK8	Spar (or truss) element which might be utilized to represent reinforcement bars.	
SOLD45	This element is utilized to represent steel bearing plates located at supports and under the applied loads.	

4.2 Loads at Failure

The ultimate loads for experimental and the finite element compares at Table 8. As a rule, the anticipated ultimate loads got by ANSYS give satisfactory concurrence with experimental results. ANSYS overestimates the strength of the tested beams by around (3.9%-5.8%). One explanation behind the inconsistency is that the crack faces toughening may likewise somewhat expand the failures of the specimen before the final collapse.

4.3 Crack Patterns

The FE software yields the crack pattern at each load step application. As a rule, the first cracks that yields were flexural cracks happen right on time at mid-span. The vertical flexural cracks spread as the applied load increase at the shear span, the central flexural cracks continue drawing until it reaches the compression zone of the beam cross section. Diagonal cracks also happen at the beam web at higher loads. Compressive cracks finally, show up at the end of load application time. Figures (8 and 9) demonstrate the advancement of crack patterns for the model of four beams as were recorded in ANSYS program.

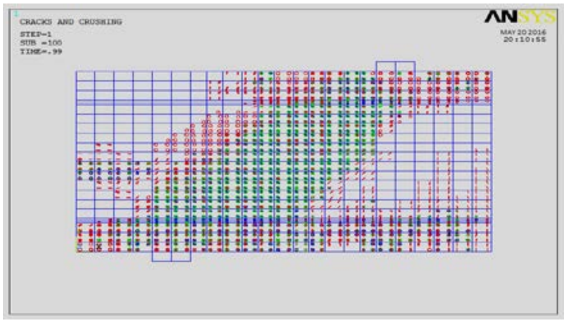


Figure 8: Crack Pattern of PPFRC IB-1 (ANSYS 11)

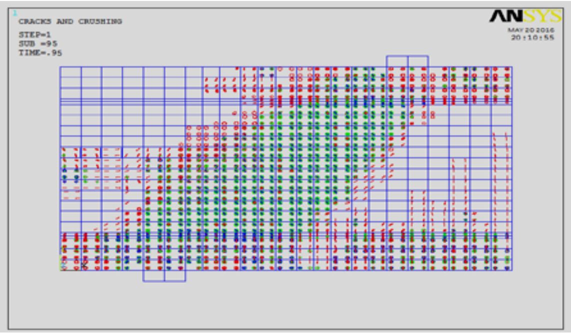
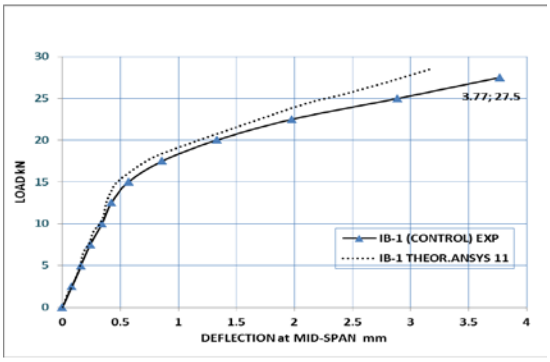


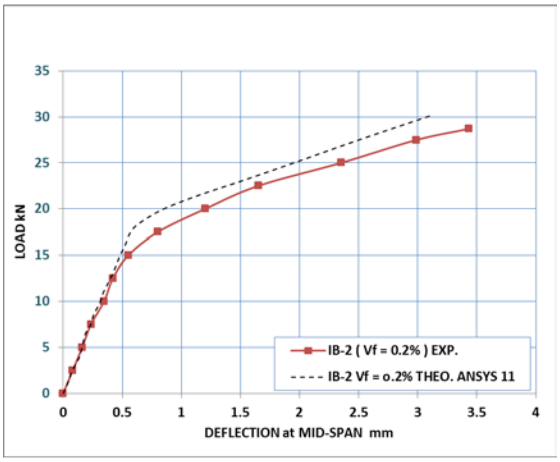
Figure 9: Crack Pattern of PPFRC IB-2 (ANSYS 11).

4.4 Load-Deflection Curves

The I- beam load - deflection were acquired at mid-span. For both experimental and FE application, Figs. (10 and 11) demonstrate the load-deflection plots from numerical and experimental results. Satisfactory understanding was seen amongst numerical and experimental results for I-B1 and IB-2 beam.



Figures (10): Comparison between Theoretical and Experimental work (load-deflection curves) at mid span for IB-1.



Figures (11): Comparison between Theoretical and Experimental work (load-deflection curves) at mid span IB-2.

5 Conclusions:

In light of the outcomes obtained from the experimental work and by finite element analysis for the reinforced concrete beams with PPFRP under two concentrated loading, the following conclusions can be drawn:-

1) The compressive strength of concrete increased in range (7.42% to 23.82%) to the plain concrete, and splitting strength of concrete increased in range (8.36% to 92.7%) to plain concrete because of impact of fiber substance (PPFRP) to concrete mix.

2) The increase in the ultimate load of the tested beams ranged strength was around (4.4% to 35.27%) that of control IB-1, and deflection reduced marginally because of utilization of fiber material (PPFRP) in concrete.

3) According to the perceptions through the beams test, the presence of PPFRP in the concrete mixture of the tested beams. The presence of fibers was delayed and restrained cracking spread which brought on increase in load carrying limits before the first cracking and the initial shear cracks appear at higher loads in case of fibred beams..

4) The observed load – deflection behavior of I – beam with PPFRC material was stiffer respond than the normal concrete I – beam (IB-1).

5) The finite element simulation represented by the load-deflection curves yields satisfactory concurrence with experimental curves. In any case, the finite element models demonstrate a somewhat close reaction in the linear parts and generally stiffer reaction at the nonlinear parts, this distinction is because of the fiber material balled inside the concrete mix and non-optimal distribution of fiber in experimental models.

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7 Notation and Abbreviations

Ec = modulus of elasticity of concrete;
Ef = modulus of elasticity of steel fiber;
Em= modulus of elasticity of plain concrete (matrix);
Fcu = cube compressive strength of concrete;
ft = tensile strength (from splitting tensile strength);
V_f = steel fiber volume fraction;
ACI = American Concrete Institute;
ASTM = American Society for Testing and Materials;
ASCE = American Society of Civil Engineering;
ANSYS = Analysis System Program (package);
F.E.M = Finite Element Method; and
PPFRC = Polypropylene Fiber Reinforced Concrete.

سلوك القص للعتبات ذات المقطع (I) والمصنوع من الخرسانة المسلحة والمعزز بمادة الفايبر بروبلين

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جامعة الكوفة – كلية الهندسة

الخلاصة:

يقدم هذا البحث التحقيق التجريبية والنظرية للسلوك القص للعتبات ذات المقطع (I) والمصنوع من الخرسانة المسلحة والمعزز بمادة الفايبر بروبلين مع نسب مختلفة من الألياف البلاستيكية المضافة. تعزيز استدامة العناصر الهيكلية من خلال تطوير أدائها الميكانيكية عن طريق إضافة المواد الجديدة مثل المواد الخام البلاستيكية قد أصبحت أكثر أهمية في الفترة الحالية، العتبات الخرسانية لا سيما مع المقاطع على شكل (I) والذي تم استخدامه على نطاق واسع في هيكل خرسانية يمتد لمسافة طويلة لتصبح أكثر صديقة للبيئة. تم اختبار النماذج الخرسانية السبعة في هذا التحقيق وقد تباينت فقط مقدار المحتوى الحجمي للألياف البلاستيكية. وأظهرت النتائج التجريبية أن نقاط القوة في المقاومة في نهاية المطاف هو زيادة في النطاق (4.4 % إلى 35.27%) بالنسبة للنموذج الذي لا يحوي على الالياف IB-1 . أن عمل هذه الالياف يكون واضحا في تأخير تشكل التشققات في الخرسانة وتقوم كذلك بتقييد استمراريتها مما يؤدي الى زيادة في مقاومة الانضغاط للخرسانة بمدى يتراوح ما بين (7.42% الى 29.3%) بالنسبة للخرسانة العادية, وكذلك تعزيز قابلية الشد الضعيفة لها (8.36% الى 92.7%) بالنسبة للخرسانة العادية. تم استخدام طريقة المحددة عن طريق استخدام برنامج الحاسوب (ANSYS 11) لتمحيص النتائج العملية لعتبتين باستخدام عناصر ثلاثية الابعاد لتمثيل موديل العتبات وصفيحة المساند والتحميل وعنصر ثالث لتمثيل حديد التسليح, وقد وجدت نتائج مقاربة ومقبولة بين البرنامج النظري والنتائج العملية في هذا البحث.