sciendo

Civil and Environmental Engineering
Vol. 19, Issue 1, 206-217, DOI: 10.2478/cee-2023-0018

SHEAR AND FLEXURAL BEHAVIOR OF LIGHT-WEIGHT CONCRETE BEAMS CONTAINING HYBRID FIBERS

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Abstract

Due to the low density of lightweight concrete, work has been done in this research to develop it by adding fibers of more than one type to improve its properties. Basic tests were conducted to determine the properties of concrete before and after the addition of fibers. The variables of the models were beams in two groups (shear and flexural). The variables of these two groups included the type of fibers (steel and polypropylene) and the size of the added fibers 0 %, 0.05 %, 0.1 % for polypropylene fibers 0 %, 0.75 %, 1 % for steel fibers. This study presented an examination of 18 beam specimens and discussed the results, which included mechanical properties (air dry density, slump test, compressive strength, modulus of elasticity, flexural strength, and splitting tensile strength). The results showed that the addition of fibers had an effective effect on the compressive strength, and this led to an increase in the resistance to shear forces and flexural forces, as the highest load capacity was shown by adding polypropylene fibers at a rate of 0.1 % in both groups, and the fibers played an important role in reducing the width of cracks and controlling their spread due to modulus of elasticity of the fiber.

Keywords:

Reinforced concrete beams;
Flexural behavior;
Shear behavior;
Lightweight aggregate;
Hybrid fibers.

1 Introduction

A rise in the population necessitates a rise in the production of building materials, particularly concrete. Lightweight aggregate with high performance and strength has been used to replace the softer part of ordinary concrete, or lightweight foam has been introduced to reduce the structure's dead load and provide better thermal and acoustic insulation than normal concrete. These developments have been made because concrete is such an important part of construction [1].

Lightweight concrete's low density, often between 1350 and 1900 kg/m^3, and compressive strength, typically at least 17 MPa, is its most distinctive characteristics ACI 213R, 2003, [2]. Density reduction results in smaller element sizes, giving the designer more leeway in customizing the design and bringing down the cost [3].

Widodo et al. 2012 [4] the researcher experimentally verified the addition of polypropylene fibers and steel fibers in a hybrid manner to some of the properties of lightweight aggregate concrete, where the density, compressive strength, modulus of elasticity, and tensile strength of cleavage were examined. With high improvements in mechanical properties, the compressive strength of lightweight concrete can be raised proportionally up to 22.44 %, the modulus of elasticity can be increased per the addition of hybrid fiber up to 24.71 % and the modulus of rupture of lightweight concrete samples can be improved proportionally up to 187.46 %.

Bindiganavile et al. 2015 [5] studied the shear behavior of lightweight concrete members containing steel fibers at a rate of 1% without using stirrups. The ratio of depth to shear was 3 for each beam. The results showed an increase in compressive Strength and tensile Strength, which led to an increase in the bearing strength of the element for the loads applied during the test.

Khalil et al. 2015 [6] this research aims, through experimental work, to study some of the properties of high-strength (lightweight) porcelain aggregates reinforced with monofilament and hybrid

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fibers, including steel fibers, polypropylene fibers, and carbon fibers with different dimensions and types single and hybrid fibers. The results of this study showed that the fibers, whether mono or hybrid, have an increase in tensile and flexural strength compared to mixtures that do not contain fibers.

Satheesh et al. 2017 [7] studied the impact of adding polypropylene fibers to the mixture and contrasting them with regular fibers. The test was conducted utilizing two different 12, and 24 mm lengths, with an added percentage of 0.5 from the model's weight. Tensile strength is impacted by the inclusion of this kind of fiber, and an increase in tensile strength prevents cracking and micro-cracks. The outcomes demonstrated that the fibers greatly increased flexural strength as well.

Sldozian et al. 2017 [8] studied the preparation of lightweight concrete by the chemical method, using aluminum powder to obtain bubbles within the concrete mixture. The fine aggregate was replaced with (Cenosphere) powder known as a ceramic powder 25 %, 50 %, 75 %, and 100 %. In more than one percentage, glass fibers were added in different proportions 1 %, 1.5 %, and 2 %, as the results showed that the cenosphere samples had higher compressive strength and tensile strength than the samples containing fine aggregates. The ratio of glass fibers is 1.5 %. Also, it was observed that the higher the percentage of bubbles, the lower the density.

Singh et al. 2018 [9] studied the behavior of the two types of polypropylene and steel fibers, also the effect of hybrid fibers on concrete mixtures, where a significant difference was observed in the properties of concrete. The presence of high-strength fibers increases the durability of the mixture, and low-strength fibers enhance the performance of concrete behavior in a short period. and where the inclusion of fibers in the mixture increases the pressure area at the first flats, and the presence of steel fibers helps to stop large cracks and reduce their size. As for the polypropylene fibers, they control the micro-cracks.

Infant et al. 2019 [10] investigated the flexural behavior of lightweight concrete containing steel fibers in three ratios 0.5, 1, and 1.5 for two types of LWAC and NWC beams produced with similar compressive strength to compare the behavior of their two kinds. Energy absorption, control of crack development, an increase in load-bearing capacity of 28 %, and an increase in ductility by 85 % or more.

Shanmugam et al. 2020 [11] in a study to replace materials with aggregates to reduce weight and use distributed fibers, as well as to compare its properties with conventional concrete, it was found that mixtures containing fibers had higher tensile strength and four compressive strengths, bending strengths, and tensile strengths when tested on samples aged 7 and 28 days.

Ismael et al. 2021 [12] aim is to study the properties of lightweight concrete containing fibers of more than one type and different proportions. The experimental work was done with mono and hybrid fibers and depending on glass fibers, polypropylene fibers, hooks, and straighteners, where the results mixed fibers have an advanced effect on the properties of solid concrete and showed that the best results in terms of mechanical properties are the mixtures containing straight, hook, polyolefin, and glass, where the results were achieved at 14.18 %, 91.97 %, and 36.70 % for compressive strength f_c', splitting tensile strength f_t, and modulus of elasticity E_c respectively.

Rafal et al. 2021 [13] two types of concrete, NWC, and LWC were studied, and the aim was to increase the strength of lightweight concrete due to its low fragility. The experimental work was to improve the properties of the lightweight mixture using fibers, where more than one type (Hook-end steel, polypropylene, and polyolefin) was used in more than one proportion. It was found that the best types are steel and polypropylene. The results showed an ideal texture for the mixture with a density of 1800 and a compressive strength of 40 MPa, similar to There is a noticeable increase in the mechanical properties in terms of rupture modulus, tensile strength, and splitting strength.

Yang et al. 2022 [14] studied the effect of adding many types of steel fibers in different proportions on the mechanical properties and improving the ductility of lightweight aggregates, where three types of fibers were used (hooked-end macro steel fibers H, straight fibers S, crimp-shaped C, and hooked-end fibers H). Types H in terms of enhanced tensile strength, as the results showed a compressive strength of approximately 40 MPa.

Zhou et al. 2022 [15] studied mixing polypropylene fibers and basalt fibers in lightweight aggregate concrete. The aim was to test the static compressive strength and compressive performance of lightweight concrete. The results showed that there is an effect of basalt fibers and polypropylene fibers on the stress-strain relationship. Fiber size mixed with 0.2 % then increases (strength, modulus of elasticity, peak stress, and final strain) and is increased by 61.9 %, 23.57 %, 32.81 %, and 45.14 %. These results were compared with those of models that did not contain fibers, and a comparison was made between models with and without fibers, where it was found from a

microscopic point of view that fibers affect improving the strength and durability of lightweight aggregate concrete.

Kumar et al. 2022 [16] experimental work was done to verify the operability and strength characteristics of the lightweight aggregate by replacing conventionally hard broken stone with lightweight aggregate by more than a ratio. The pressure test (hammer test) and compressive strength were performed. The results found that the higher the quantity of replaced aggregate, the greater its water absorption, which gives better performance to structural concrete.

Hrabová et al. 2022 [17] concrete beams were studied to verify the properties of the concrete mixture with steel fibers of two different types and lengths, where it was found necessary to add fibers because they carry loads after micro-cracks, and the smaller the fibers, the more effective they are cross sections, but with the opposite of shear properties. It was found that the length of the fibers was bigger the more effective.

All the previous studies for lightweight concrete containing hybrid or single fibers are not comprehensive for all types of tests, especially the load test for the shear and flexural strengths of the beams.

The paper aims to obtain lightweight concrete containing polypropylene fibers (P.P) and hook steel fibers (S.F) through experimental work, lightweight concrete suitable for use in structural elements by testing 18 beams and discussing the results.

2 Experimental methodology

To achieve the objectives of this work, eighteen beams of lightweight, flexural, and shear-reinforced concrete were cast and tested. Lightweight aggregate (LECA) was added as an alternative to coarse aggregate (gravel), polypropylene fibers, and steel fibers, both singly and in hybrid form.

2.1 Materials

- Materials used in this experimental work.
- Ordinary Portland Cement (Maas) conforming to Iraq standard specification No. 45-1984[18].
- Fine aggregate (sand) from the area of (Al-Ukhaidher) conforming to the Iraqi specifications I.Q.S. No. 45, 1984 [19].
- The lightweight aggregate manufactured in Tehran was used with gradations 0–8 mm, which conforms to the specifications and standards (ASTM Standards C 330–04) [20].
- Tap water for aggregate washing, concrete mixing, and curing of specimens.
- Hooked ends of the steel fibers are commercially known as sika. The lengths used in this research are 30, and 3 mm fibers, as shown in Fig. 1 and Table 1. Showed the properties of hook steel fiber.
- High-performance monofilament polypropylene fibers were used in this investigation, as shown in Fig. 1 and Table 2. Indicates the typical properties of the used polypropylene fibers (aspect ratio *L*/*D* = 667).
- Steel reinforcement: Ø 12 mm (deformed) with a yield strength of 678 MPa for tension Also, Ø 6 mm smooth bars were used at the top to hold stirrups in positions.
- The superplasticizer used in this work was PCE 600, which has been primarily developed for applications in the precast, lightweight, and aerated concrete industries.



Fig. 1: Shape of hook steel fibers, and polypropylene fibers.

Table 1: Hook steel fibers properties by sika factory.

Product code	Length [mm]	Diameter [mm]	Aspect ratio	Tensile strength [MPa]	Density [kg/m^2]
KF65/35	35	0.55	64	> 1000	7850
KF60/30	30	0.50	60	> 1000	7800

Table 2: Polypropylene fiber properties by sika factory.

Chemical base	100 % polypropylene
Appearance / Color	Transparent fibers
Dimensions	Diameter: 18 microns / Length: 12 mm
Density	0.91 g/cm^3
Tensile strength	Min. 350 MPa
Technical information	Thermal Conductivity / Low Electrical Conductivity Low / Acid Resistance High
Melting point	160 °C
Storage conditions	Storage temperatures are between (+5 °C and +30 °C). Store in a dry / covered place / protected from moisture/ direct sunlight / frost
Shelf life	Two years from the date of opening the box

2.2 Concrete mixes

In order to obtain the most suitable mixtures for lightweight concrete, several concrete tests have been carried out. The mixing of all proportions is listed in Table 3. In this work, the proportions of cement, gravel, and lightweight aggregate (LECA) were constant, and the differences were mainly about the type and proportions of fiber addition.

Table 3: Proportions of concrete mixes.

Group No.	Trail mix No.	Cement content [kg/m^3]	Sand content [kg/m^3]	LECA content [kg/m^3]	W/C	Super. [%] by wt. of cement	Hook S.F [%]	P.P fiber [%]	Slump [mm]	f_{cu}/7 days [MPa]	f_{cu}/28 days [MPa]	Dry density [kg/m^3]	Splitting tensile strength [MPa]
G1: without super and fibers	1	550	550	500	0.4	0	0	0	45	20.6	30.8	1752.6	2.3
G2: without fibers	2	550	550	500	0.33	0.85	0	0	135	32.8	38.8	1785.8	3
G3: Polypropylene fiber	3	550	550	500	0.3	0.58	0	0.05	40	32.0	37.2	1781.8	2.963
	4	550	550	500	0.38	1.1	0	0.1	150	35.9	38.2	1684.7	1.806
G4: S.F [3.5 mm / 3 mm]	5	550	550	500	0.33	0.825	0.75 (3.5 mm)	0	55	49.7	55.3	1855.2	4.79
	6	550	550	500	0.33	0.825	1 (3.5 mm)	0	110	44.3	29.2	1898.6	7
	7	550	550	500	0.3	0.825	0.75 (3 mm)	0	90	39.3	46.7	1817.9	3.691
	8	550	550	500	0.3	0.825	1 (3 mm)	0	115	42.2	49.5	1913.7	4.91
G5: S,F [3.5mm] / P.P fiber	9	550	550	500	0.34	0.825	0.75	0.05	55	37.24	44.1	1822	2.62/5
	10	550	550	500	0.33	0.825	1	0.05	90	40.2	40.3	1825.4	4.849
	11	550	550	500	0.33	0.825	0.75	0.1	65	40.14	47.73	1808.8	3.987
	12	550	550	500	0.38	0.825	1	0.1	110	40.7	51.4	1847,5	4.177
G6: S,F [3 mm] / P.P fiber	13	550	550	500	0.3	0.825	0.75	0.05	140	41.1	48.2	1896.7	4.120
	14	550	550	500	0.33	0.7	1	0.05	30	42.9	48.6	1844.9	3.205
	14	550	550	500	0.33	0.825	1	0.1	30	41.7	50.5	1883.8	4.499
	15	550	550	500	0.3	0.825	0.75	0.1	120	46.6	46.5	1889	4.7

P.P: Polypropylene fiber %, Hook S.F: Hook Steel fiber %, and Super: Superplasticizer (PCE 600).

2.3 Mixing and casting

The work was done using a horizontal laboratory rotary mixer to mix the concrete. Cement and sand were mixed for two minutes, and then LECA aggregate was added in a dry, saturated surface condition to the dry ingredients and mixed for three minutes or more, then water and superplasticizer PC-600 were added until the mixture became homogeneous. Fibers were added in a slow manner to ensure Non-clumping, and after homogenizing the mixture, the molds were prepared by oiling their

inner surfaces, and reinforcing steel were placed in the molds. The beams were cast in three layers and pressed using the vibrating table for one minute to prevent stagnation of the fibers.

Three cubes 150 x 150 x 150 mm, three cylinders 150 x 300 mm, and a prism 100 x 100 x 400 mm were cast with each mix to determine compressive, flexural, and splitting tensile strengths, respectively. After 24 hours, all specimens were demolded and cured in water until the age of 28 days; all stages are shown in Fig. 2.

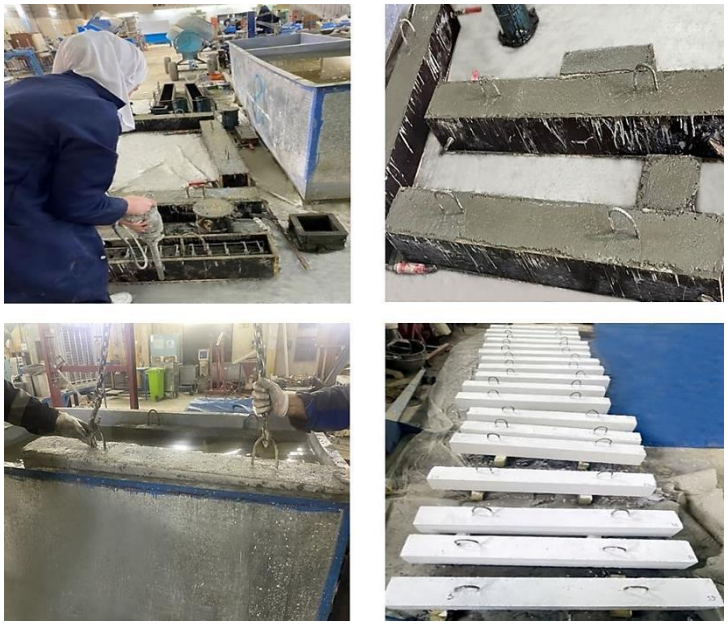


Fig. 2: Casting, curing method, and beam specimens.

2.4 Designation and details of beams

The beams of the first group A were tested for flexural strength using more than one concrete mixture, as shown in the variables in Table 4. The second group B was a shear test. It was tested with the same variables as the first group; the beams BS1 and BF1 were the control beams without fibers. Fig. 3 explains the design of the beam for each rebar reinforcement in each group.

Table 4: Geometry and parametric study of experimental work.

Spe. No.	Group No.	Specimen symbols	Compressive strength [MPa]	Steel fiber	Polypropylene fiber
1	A	BF1	f_{cu}	…….	…….
2		BF2		0.75 %	…….
3		BF3		1 %	…….
4		BF4		…….	0.05 %
5		BF5		…….	0.1 %
6		BF6		0.75 %	0.05 %
7		BF7		0.75 %	0.1 %
8		BF8		1 %	0.05 %
9		BF9		1 %	0.1 %
10	B	BS1		…….	…….
11		BS2		0.75 %	…….
12		BS3		1 %	…….
13		BS4		…….	0.05 %
14		BS5		…….	0.1 %
15		BS6		0.75 %	0.05 %
16		BS7		0.75 %	0.1 %
17		BS8		1 %	0.05 %
18		BS9		1 %	0.1 %

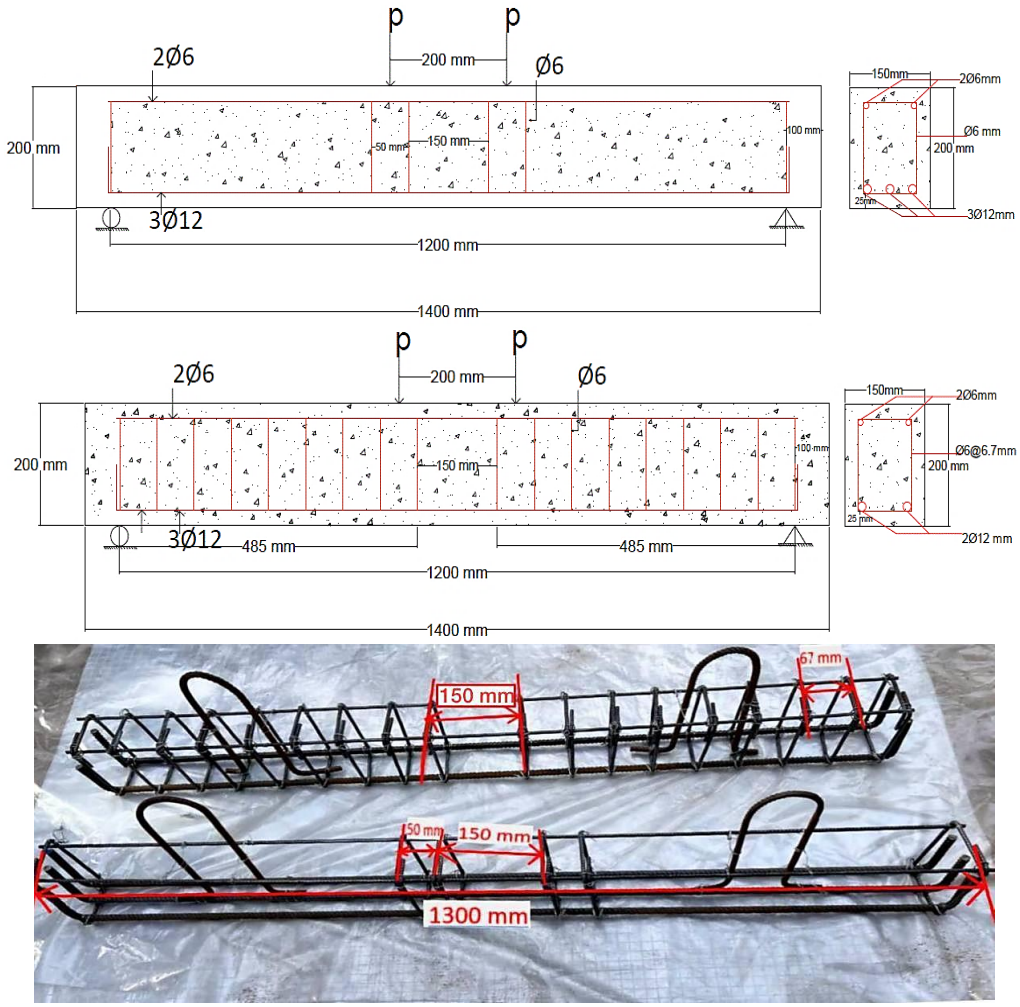


Fig. 3: Reinforcement details for beams for shear and flexural.

2.5 Testing setup

Tested in a hydraulic test machine with a maximum capacity of 2000 KN. All beams were tested with it, as shown in Fig. 4. All beams were loaded under monotonous loading. The load is applied from one upper point, and then the load is divided equally into two points through two arms connected from the steel plate to the specimen. The initial and maximum load deflection values are recorded for each beam until the model fails and the load value decreases, and then the width of the cracks and the distribution of their spread is measured.

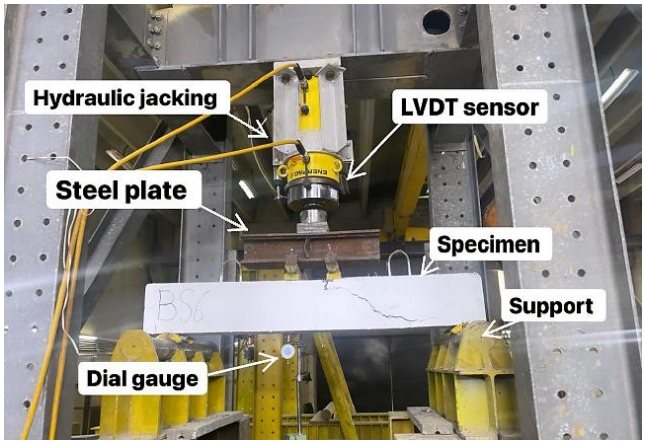


Fig. 4: Test setup for beam.

3 Test results

3.1 Mechanical properties

Cubes 150 × 150 × 150 mm were tested according to BS EN 12390-3:2019 [21] and cylinders 150 × 150 mm were tested according to ASTM C496/C496M-11 [22] to determine compressive strengths and splitting tensile strengths at 7, and 28 days using a digital universal hydraulic device (ELE-Digital Elect 2000). In addition, the slump test was to measure the workability of all mixes, which was carried out in accordance with the procedure described in ASTM C143-01a [23]. The results are shown in Table 5 The 28-day compressive, dry density, and splitting tensile strength tests are the maximum for group 5 containing hybrid fibers (Hook steel fibers 3.5 mm by 1 % and polypropylene fibers by 0.1 %), which were found to be 51.49 N/mm^2, 1847.5 kg/m^3, and 5.177 N/mm^2, respectively. Because hybrid fibers enhance the behavior of mechanical properties and resist tensile loads compared to models that do not contain fiber, there is a wide difference in the results of the tests due to their ability to enhance the matrix bonding mechanism [24]. The results of the slump test revealed that hook steel fiber has a significant impact on concrete workability. The workability of the concrete decreased as the percentage of steel fibers where the lowest value for the highest percentage of hybrid fibers in group 5. All of the above results agree with the previous findings [4, 6, 12, 13, 14, and 16].

Table 5: Results of compressive and tensile strengths.

Group No.	Trail mix No.	Slump [mm]	fcu/7-days [MPa]	fcu/28-days [MPa]	Dry density [kg/m^3]	Splitting tensile strength [MPa]
G1: Without Superplasticizer and fibers	1	50	20.68	28.8	1752.6	2.3
G2: without fibers	2	135	29.87	33.81	1785.8	3
G 3: Polypropylene fiber	3	90	32.04	37.2	1781.8	3.963
	4	84	35.92	39.26	1684.7	3.806
G 4: Steel fiber (3.5 mm/3 mm)	5	65	41.76	45.3	1855.2	4.79
	6	78	43.32	48.21	1898.6	5
	7	73	39.31	44.71	1817.92	4.691
	8	82	42.23	47.52	1913.77	4.91
G 5:Steel fiber (3.5mm)/ Polypropylene fiber	9	68	37.24	45.1	1822	5
	10	69	40.25	48.30	1825.47	4.849
	11	56	44.14	50.73	1808.86	3.987
	12	43	43.75	51.49	1847.5	5.177
G6:Steel fiber (3 mm)/ Polypropylene fiber	13	71	40.12	44.27	1896.79	4.120
	14	67	42.97	47.65	1844.90	4.405
	15	66	41.77	48.59	1883.86	4.899
	16	46	44.69	49.58	1889	4.7

3.2 Testing and results beams

The models were tested and divided into two groups, the first group contained 9 beams that were subjected to flexural testing, and the second group contained 9 beams that were subjected to shear testing. The test was carried out using a hydraulic test device with a capacity of 3000 KN for a monotonically increased static load and by gradually increasing the load in small increments. The deviation is measured from the dial gauge and also monitored, and also monitoring the development of the spread of cracks by measuring their width.

The results for cracking loads P_{cr}, ultimate loads P_u, mid-span deflection at first cracking D_{cr}, and ultimate deflection D_u are shown in Table 6.

Table 6: Results of the trial mix for LWC samples.

G1.Name for sample	*fc* for 7 days	Density	P.P fiber	Steel fiber	P_{cr}	P_u	D_{cr}	D_u	P_{cr} / P_u [%]	Min C. width	Max. C. width
BF1	30	1752	0	0	14.61	97.5	1.65	15.6	14.98	0.3	2.3
BF2	32	1800	0.05 %	0	18.02	111.1	0.43	15.2	16.27	0.2	4.5
BF3	35	1815	0.10 %	0	18.02	108.3	1.3	14.33	16.65	0.1	2
BF4	38	1830	0	0.75 %	25.4	116.2	1.3	13.64	21.85	0.3	3.4
BF5	39	1844	0	1 %	16.88	125.3	0.695	15.03	13.469	0.3	3
BF6	41	1865	0.05 %	0.75 %	29.37	115.7	2.25	13.72	25.4	0.2	1.9
BF7	42	1870	0.10 %	0.75 %	35	116.2	2.86	17.28	30.12	0.1	1.8
BF8	43	1873	0.05 %	1 %	29.37	124.2	2.25	18.24	23.65	0.2	2.3
BF9	41	1898	0.10 %	1 %	33.9	124.5	2.69	16.5	27.22	0.1	3.6
G2.Name for sample	**f_c for 7 days**	**Density**	**P.P fiber**	**Steel fiber**	**P_{cr}**	**P_u**	**D_{cr}**	**D_{cr}**	**P_{cr} / P_u [%]**	**Min C. width**	**Max. C. width**
BS1	30	1752	0	0	13.48	108.29	0.09	10.51	12.44	0.3	9
BS2	32	1800	0.05 %	0	19.16	114.53	1.56	12.16	16.73	0.2	9
BS3	35	1815	0.10 %	0	17.45	98.63	1.129	9.2	17.7	0.1	6
BS4	38	1830	0	0.75 %	37.33	169.61	3.13	16.16	22	0.1	2.1
BS5	39	1844	0	1 %	37.89	170.17	2.69	15.37	22.27	0.1	1.5
BS6	41	1865	0.05 %	0.75 %	41.86	163.92	3.12	14.94	25.54	0.1	2.2
BS7	42	1870	0.10 %	0.75 %	39	163.92	2.78	13.11	23.8	0.1	1.8
BS8	43	1873	0.05 %	1 %	37.32	166.5	3.38	15.55	22.4	0.2	2.2
BS9	41	1898	0.10 %	1 %	43	169.9	3.38	17.7	25.3	0.1	1.2

3.3 Structural behavior, cracking pattern, and failure mode

Observed during the examination, the structural behavior of the beams of the first group, including the beams BF1-BF9, showed cracks that began at the bottom and continued to rise to the top, centered in the middle, and spread on the sides. As for the second group that includes beams BS1-BS9, a difference was observed. The spread of cracks from the first group, where the cracks were at the point of the support continuous at an angle of approximately 45 degrees to the high point of the support, distribution, and failure occurred suddenly and without warning through small cracks. However, the presence of fibers relatively reduced the cracks' width, as agreed with [7, 9, 10], as shown in Fig. 5, and 6.



Fig. 5: Failure modes.

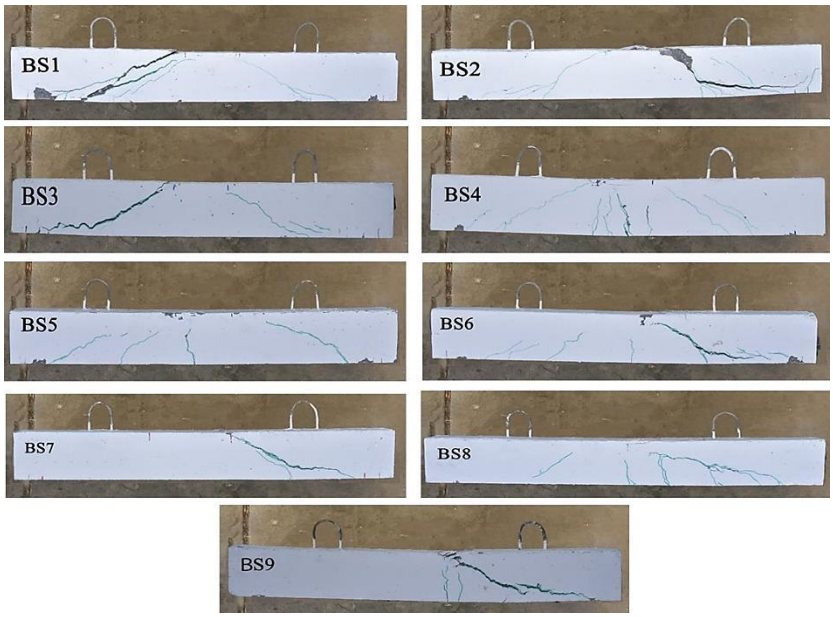


Fig. 6: Failure modes.

3.4 Structural behavior, cracking pattern, and failure mode

Fig. 7 shows the final failure of the first group A samples, which were hard to resist flexural failure. Where the results showed for the beams, there is a significant increase for the samples reinforced with fibers compared to the control sample. Where it was found that the highest percentage of resistance is 27.7 % for beams containing polypropylene fiber with 0.1 % because of its high porosity after that, the beams with hybrids fibers rose by 27 %. While the lowest percentage for steel fiber increased by 1 % is 10.7, all of the above results agree with the previous finding [7, 9, 10].

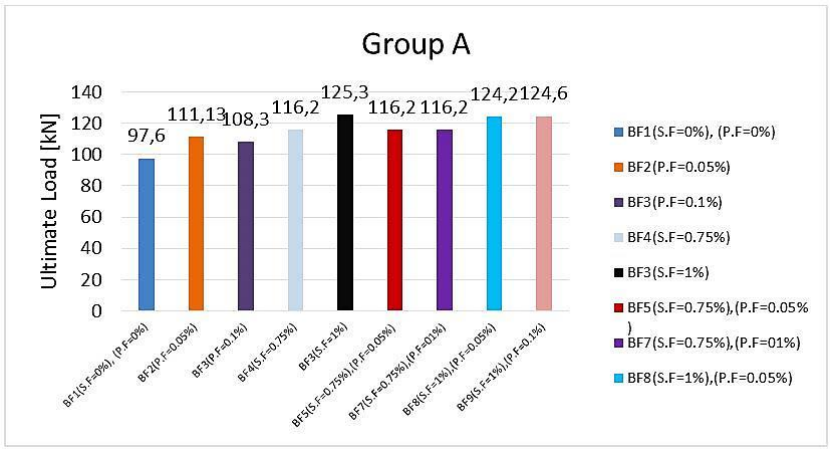


Fig. 7: Ultimate load for group A.

Fig. 8 shows the final load failure data for the second group B, which was designed to resist shear failure, it is shown in Fig. 3, and all results were compared for beams without fibers. The highest percentage of resistance was found for the sample that contained a polypropylene percentage of 0.1 %, which is 61.9 % after that, the beams with hybrid fibers increased by 61.6 %. While the lowest percentage for steel fiber decreased by 1 % is 9.7 %, all of the above results agree with the previous finding [5].

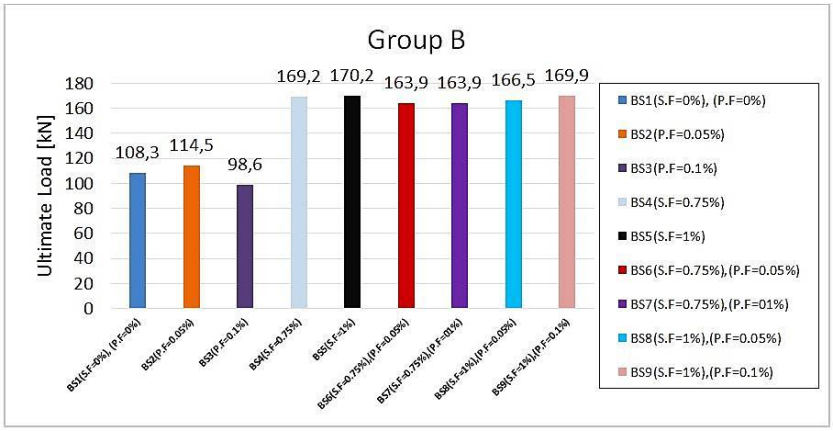


Fig. 8: Ultimate load for group B.

3.5 Load-deflection behavior

Fig. 9 and 10, all the curves in the second group showed similar behavior, which led to a sudden decrease in the load in the shear failure samples of the beams. As for the samples of the second group, their behavior was different, as there was an increase in the linear deflection with the load and the flexural failure was more flexible. It was noted from this that the failure was gradual for the beams of this group.

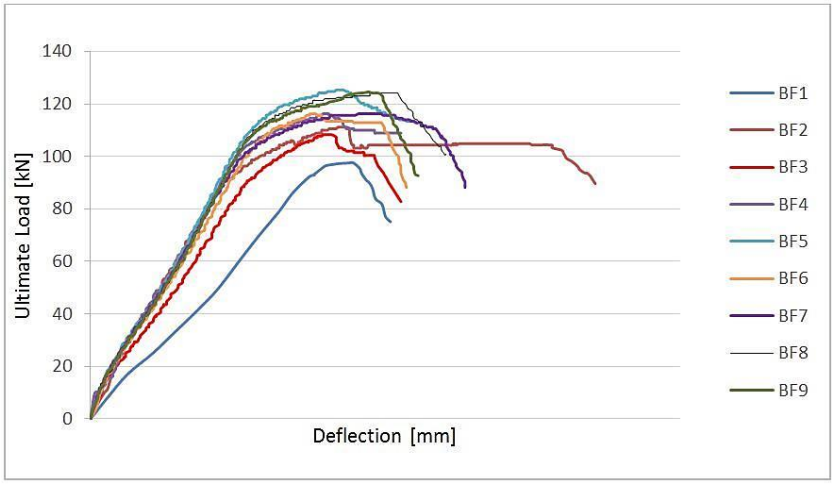


Fig. 9: Curve of load-deflection for group A.

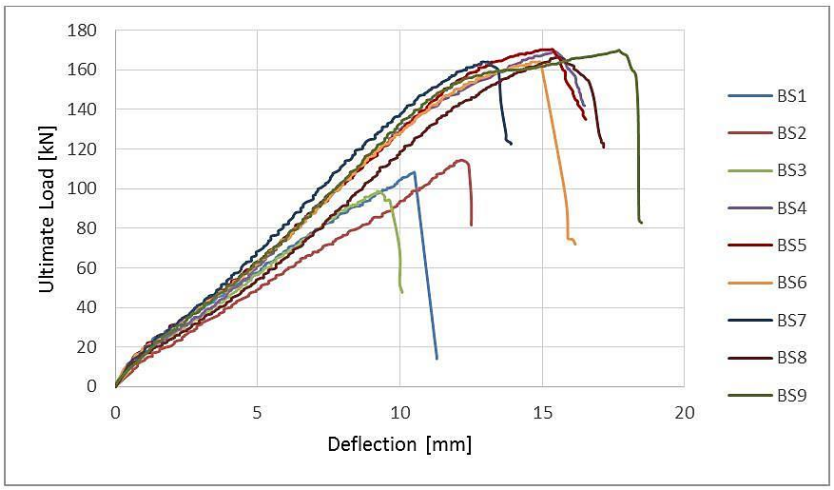


Fig. 10: Curve of load-deflection for group B.

4 Conclusions

From the results of the work to know the behavior of lightweight concrete containing single or hybrid fibers, a number of points were stated:

1) When testing the oven-dry density, an increase in the density values was observed when steel fibers were added singly or in a hybrid form, while a slight decrease in the density ratio was noticed when polypropylene fibers were added.

2) The workability of the concrete decreased with the increase in the percentage of steel fibers, as the higher the percentage of fibers, the more rigid the mixture.

3) Lightweight, high-strength concrete was produced without fibers, as it reached a compressive strength f_{cu}, 38 MPa at the age of 28.

4) When comparing steel fibers with a length of 3, and 3.5 mm, it was found that there is a slight effect on the results of the mechanical properties.

5) The presence of fibers improves the compressive strength of the samples containing hybrid fibers, of P.P. by 0.1 % and S.F. by 1 %, and single S.F. by 1 %, with an increase of 30.1 % and 27.5 %, respectively. As for the effect of the mixtures on the tensile strength of the split, it had the highest effect when adding S.F. with the highest rate of 63.6 %, unlike when adding P.P. with the highest percentage of 0.1 %, the tensile strength of the split was decreased by 39.8 with a volume of 0.1 %, for S.F. by 1 %, and P.P. by 0.1 %, with an increase of 73.6 %, and 60 %, respectively.

6) The highest effect of the ultimate load and corresponding deflection value of resistance to flexural failure was when adding single S.F. with a volume of 1 % or hybrid with P.P for BF4, BF8, and BF9, compared to the control beam increased by a percentage of 28.51 %, 27.69 %, 27.38 %, respectively. The increase was slightly less when adding S.F. by 0.75 %, the increase for BF4, BF6, and BF7 was 19.17 %, 18.67 %, and 19.18 %, respectively. However, the least increase in the ultimate load was when polypropylene fibers were added P.P. in BF2, and BF3.

7) The first crack, which was a flexure crack, was found in the central region of the lower half of the box beam. This crack is expected to appear at between 14 and 30 % of the box beam's ultimate load.

8) The failure mode for beams (group A) and concrete crushing was the control beams' flexural failure samples. Failure was predictably a failure.

9) There was a high impact of the fibers to resist the ultimate shear failure was increased ratios between 51.37 and 57.14 for BS4, BS5, BS5, BS6, BS7, BS8, and BS9. While the polypropylene fibers had a very slight effect at the ratio of 0.05 % in BS2, and it was observed that when the ratio was increased to 0.1 % in BS3, it had an opposite effect on the decrease in shear strength compared to the control beam.

10) The first crack, which was a shear crack, was found in the support zone of the lower half of the beam. This crack is expected to appear at between 12.5 % and 25.5 % of the ultimate load for the beams.

11) The mode of failure for beams (group B) and concrete crushing was the control box beams' shear failure samples. The failure occurred without any alarm alerts.

12) An effective effect of resisting shear and flexural strength was found for the single S.F. to be higher than when combined with another type of fiber (hybrid fiber).

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