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Flexural and Deflection Behavior of Polypropylene Fiber-Reinforced Concrete with Plasticizer at Different Ratios

İlker Bekir Topçu[1], Hasan Baylavli[2]
[1]Eskisehir Osmangazi University/Civil Engineering
Batı Meselik Yerleskesi, 26480, Eskisehir/Turkey
ilkerbt@ogu.edu.tr
[2]Hitit University/Vocational School of Technical Sciences
Cevre Yolu Bulvarı, 19030, Corum/Turkey
hasanbaylavli@hitit.edu.tr

***Abstract* -** This study examines the effect of polypropylene fibers with different characteristics on the flexural strength and deflection value of concrete. Hyperplasticizer was used in all mixtures. As the amount of fiber in the mixtures increased, the amount of hyperplasticizer was increased as well. Slump value of the fresh concrete ranged from 150 to 190 mm. No lump or segregation was observed in the fresh concrete. The effect of the amount of plasticizer on the flexural behavior and amount of deflection was investigated. Beam specimens (150x150x550 mm) were used to test flexural strength. Four point flexural test was conducted on the specimens. Deflection values at the moment of exerting the largest load and breaking were measured. The changes in the flexural strength in 7 and 28 days were recorded. Flexural strength of some specimens in a period of 7 days were found to be higher than their flexural strength in a period of 28 days. Flexural strengths ranged from 4.43 MPa to 6.29 MPa. Increases and decreases were observed in the flexural behavior compared to the control sample. The highest decrease was 15.46% and the highest increase was 21.98%. Increases and decreases were observed in the deflection values under the largest load compared to the control sample. The highest decrease was 21.47% and the highest increase was 43.42%. Increases and decreases were observed in the deflection values at the moment of breaking compared to the control sample. The highest decrease was 23.24% and the highest increase was 47.21%. Furthermore, the compressive strength of the specimens were examined. The effect of the change in compressive strength on flexural strength and deflection values was investigated.

***Keywords*:** Polypropylene Fiber, plasticizer, flexural strength, deflection, compressive strength.

1. Introduction

At the time immemorial, fibres were used to strengthen fragile materials. Effect of fibres over concrete varies according to type, kind, shape, size and features of other materials [2]. It is stated that fibre-reinforced concretes having the weight of 3.5 kg/m^3 have been productive and low cost solutions especially for roads within tunnels [1]. Admixture of carbon fibre with the volume of 1% and 1,5% ratio did not have much effect over concrete's compressive strength [3]. Admixture of polypropylene fibre with the volume of 1% and 2% decreased the three points flexural strength of concrete respectively 15.9% and 28% [4]. Admixture of polypropylene fibre with volume of 0.7% to mortar decreased the compressive strength by 5%. It increased deflection value under maximum load together with the deflection value of the broken moment at Three points flexural strength experiment [5]. Bars produced by concrete with polypropylene admixture having weights of 0.5, 0.7, 0.9, 1.5, 2.0 and 4.0 kg decreased the compressive strength by 8.8% and increased the flexural strength by 10% [6]. Natural pumice, hybrid fibre-reinforced light aggregated concrete's compressive strength increased by proportion of fibre with 0.2% volume and decreased by 0.4% proportion of fibre. Flexural strength increased in these two volumes [7]. It is stated that admixture of grain and polypropylene fibre improves concrete's compressive strength [8-15]. Admixture of 910 g/m^3 weighted polypropylene fibre increased concrete's flexural strength by 9.3% and 13.4% [12]. Cement mixture with fibre admixed by volumes of 0.5%, 0.75% and 1.0% with high performance improved the compressive and flexural strengths according to the ratio of fibre [13]. Chalk waste within mortar and and admixture of polypropylene fibre with volumes of 0.5%, 1%, 2% and 4% increased the flexural strength by an important ratio. When the amount of fibre is over 2%, it is observed that specimen is not totally broken with regard to flexural strength [14]. With silica fume and admixture of polypropylene fibre with volume of 0.5% increased splitting tensile strength and flexural strength of concrete by an important ratio [15]. Admixture of fibres obtained from recycled plastic bottles with the volume of 1% increased the flexural strength [16]. Concrete with admixture of 12 mm-length polypropylene fibre with metachlonium and pumice increased the flexural strength of the amount of deflection [17]. Ribbed polymer reinforced, and admixture of polypropylene fibre with volume of 0.5% increased concrete's flexural strength by 30% [18]. It is stated that admixture of polypropylene and steel fibre to the concrete with fibre of oil palm hulls improved the concrete's mechanic aspects and silica fume within the mixture limited the micro cracks [19]. Admixture of polypropylene fibre with weights of 0.45 kg/m^3, 0.90 kg/m^3 and 1.80 kg/m^3 decreased the concrete's compressive strength and young's modules [20]. Admixture of polypropylene fibre with volumes of 0.1% and 0.5% decreased the concrete's compressive and flexural strength [21]. Admixture of polypropylene fibre derived high unit of deformation especially on low strength concrete. Admixture of polypropylene fibre increased ductility of concrete [22]. This research analyses the effect of polypropylene fibres with different features on concrete's flexural strength and value of deflection. Effect of wetter admixture of mixtures on compressive strength, flexural strength and value of deflection is analysed.

2. Materials and Specimens

Type of cement used at mixtures is CEM I 42,5 R. Eight types of polypropylene fibre were used. (Figure 1) Polypropylene fibres were used with three different ratios. Technical features of polypropylene fibre is given at Table 1. Ratio of fibre is 600 g/m^3, 1200 g/m^3 and 1800 g/m^3. 25 serials of concrete were produced including the control concrete without polypropylene (K).

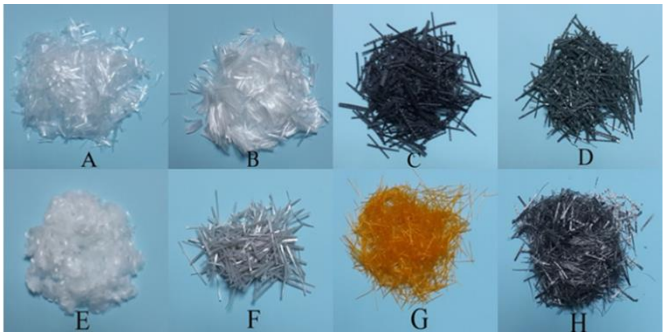

Fig. 1: Polypropylene fibers.

Polypropylene fibres were shown as A, B, C, D, E, F, G, H. For instance A6 shows A fibre with admixture of 600 g/m^3, B12; shows B fibre with 1200 g/m^3, C18; shows C fibre with 1800 g/m^3. Water-cement ratio was constant in mixtures. Wetter admixture was used to increase fluidity of fresh concrete. As the ratio of fibre increase in mixture, ratio of wetter admixture is increased as well. Ratio of mixtures were given at Table 2. For compressive test, 15 cm cubes and for flexural test 15x15x15 cm beam specimens were used.

Table 1: Technical properties of polypropylene fibers.

Fiber	Length (mm)	Width (mm)	Thickness (mm)	Shape
A	12	0.48	0.30	Circular
B	19	0.48	0.30	Circular
C	30	1.20	0.30	Ribbed
D	30	1.20	0.45	Double Hook
E	30	0.48	0.30	Circular
F	40	0.433	0.433	Flat
G	18	0.3	0.50	Circular
H	20	0.6/1.3	0.18/0.22	Flat

Table 2: Ratios and amounts of materials used within the source concretes.

Ingredients		**K**	**Fiber mixtures**		
			600 gr/m³	**1200 gr/m³**	**1800 gr/m³**
Sand (0-4 mm)	(kg/m³)	1127	1127	1127	1127
Crushed Stone (7-15 mm)	(kg/m³)	451	451	451	451
Crushed Stone (16-22,4 mm)	(kg/m³)	301	301	301	301
Water	(kg/m³)	156	156	156	156
Cement	(kg/m³)	300	300	300	300
Polypropylene Fiber	g/m³	-	600	1200	1800
Additive	%	0,6	0,8	0,9	1,1
Water-cement ratio	W/C	0.52	0,52	0,52	0,52
Unit weight	(kg/m³)	2335	2335	2335	2335

3. Test Results and Findings

Compressive strengths were done at the end of the 28th day. Flexural strengths were done at the end of the 7th and 28th day. $f_{c(28)}$; shows compressive strength of cube (28 days), $f_{f\text{-}s(7)}$; shows 4 points strength (7 days), δ_{max}; shows deflection under maximum load (28 days), δ_b; shows deflection at the breaking moment (28 days) (Table 3).

Table 3: Compressive strength, flexural strength, deflection and slump values.

Mixtures	f_c **(MPa)**	$f_{f\text{-}s(7)}$ **(MPa)**	$f_{f\text{-}s(28)}$ **(MPa)**	δ_{max} **(28 day)**	δ_b **(28 day)**	δ_b- δ_{max} **(mm)**	**Slump**
K	55.72	4.05	5.24	0.532	0.519	**-0.013**	**17**
A6	48.94	4.18	4.87	0.574	0.572	**-0.002**	17
A12	52.13	3.87	5.58	0.614	0.622	0.008	18
A18	52.09	3.59	5.18	0.763	0.764	0.001	16
B6	48.26	4.63	4.60	0.422	0.437	*0.015*	16
B12	48.53	4.02	4.53	0.442	0.442	0.000	17
B18	48.95	3.60	4.53	0.462	0.468	0.006	15
C6	49.87	4.34	4.99	0.459	0.470	*0.011*	16
C12	52.97	4.94	5.62	0.538	0.540	0.002	19
C18	55.51	4.61	5.28	0.472	0.476	0.004	17
D6	51.31	4.68	5.45	0.467	0.479	*0.012*	17
D12	52.30	3.94	5.32	0.518	0.520	0.002	17
D18	52.95	3.93	5.55	0.510	0.514	0.004	17
E6	53.34	4.76	5.41	0.517	0.519	0.002	17
E12	53.87	4.57	6.09	0.703	0.703	0.000	16
E18	48.19	3.76	4.51	0.486	0.475	**-0.011**	15
F6	47.81	3.75	4.64	0.446	0.456	0.010	15
F12	48.76	4.90	5.09	0.604	0.604	0.000	17
F18	47.58	4.57	4.43	0.538	0.548	0.010	17
G6	46.08	4.61	5.61	0.649	0.636	**-0.013**	16
G12	51.34	4.76	5.36	0.757	0.760	0.003	17
G18	47.64	4.33	4.58	0.604	0.610	0.006	18
H6	48.68	3.97	5.63	0.611	0.606	**-0.005**	18
H12	46.31	4.06	5.77	0.621	0.621	0.000	19
H18	51.68	4.25	6.29	0.625	0.627	0.002	19

3.1. Compressive Strength

Polypropylene fibres decreased concrete's cube compressive strength in all mixtures. Control specimen's compressive strength was 55.72 MPa and it decreased by 17.3% (Figure 2). Compressive strength of B18, E18 and F6 mixtures having the lowest slump value (150 mm) decreased respectively 12.15%, 13.51% and 14.2%. Compressive strength of H12 and H18 mixtures having the highest slump value decreased respectively 16.89% and 7.25%. The biggest compressive strength is C18 having 170 mm slump value. Compressive strength of C18 mixture is equivalent to compressive strength of control specimen.

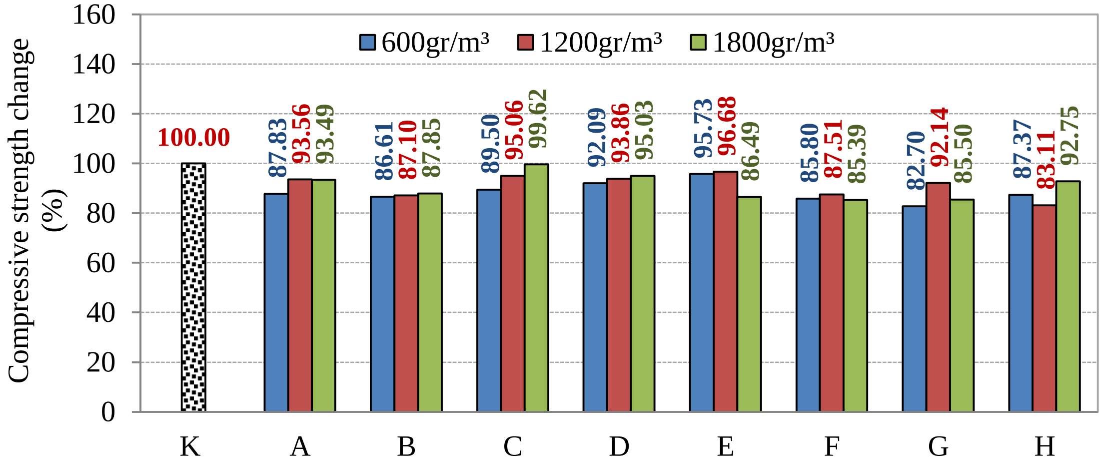

Fig. 2: Changes on the compressive strength of cube (28 days).

3.2. Flexural Strength

Four point flexural test was conducted on the specimens. Flexural strength is decreased at B and F fibred mixtures in comparison with the control specimen. At H fibred mixtures, flexural strength increased while ratio of fibre increased. In H18 mixture, flexural strength increased by 20% in comparison with the control specimen (Figure 3). Flexural strength of the specimen with the lowest compressive strength (G6) increased by 7%. Flexural strength of the specimen with the highest compressive strength (C18) is equivalent with control specimen. In fibred mixtures, while compressive strength increases, flexural strength decreased. Flexural strengths of B18, E 18 and F6 mixtures with the lowest slump value (150 mm) decreased.

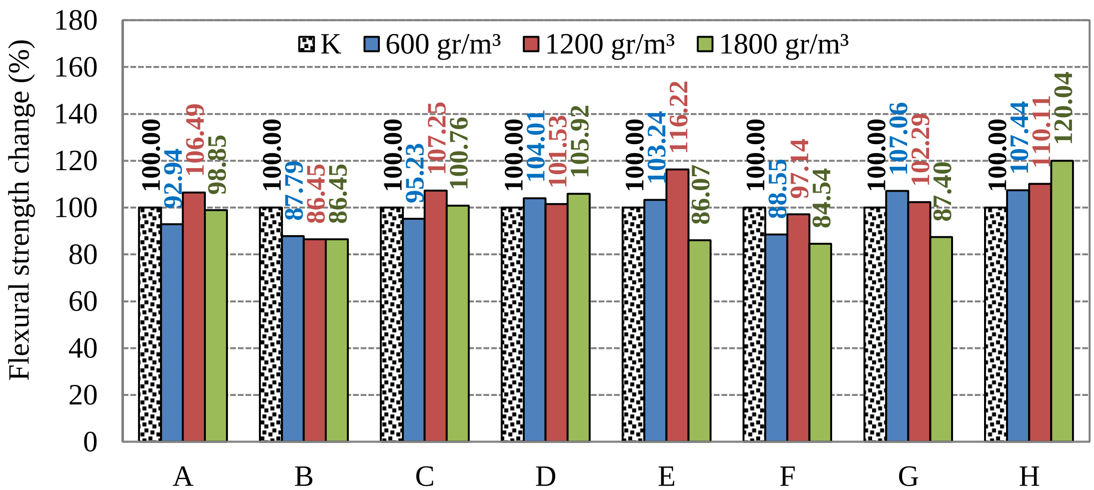

Fig. 3: Changes on four points flexural strength (28 days).

Flexural strengths of H12 and H18 mixtures with the highest slump value increased respectively by 10% and 20%. Increase of wetter within H12 and H18 mixtures effected flexural strength in a positive way. Same could be argues for A12, C12 and E12 mixtures as well. Flexural strength of some specimens in a period of 7 days were found to be higher than their flexural strength in a period of 28 days (B6 and F18).

3.3. Deflection Tests:

Deflection values under the maximum load increased at A, G and H fibred mixtures. It decreased at B, C and D fibred mixtures It increased in E12 and F12 mixtures. While flexural strength of A18 mixture decreased by 6.5% in comparison with the control specimen, increased by 43.42% for deflection value under the maximum load. While flexural strength of G12 mixture increased by 7% in comparison with the control specimen, increased by 42.29% for deflection value under the maximum load (Figure 4). Deflection values under the maximum load decreased at B18, E18 and F6 mixtures having the lowest slump value (150 mm) in comparison with the control specimen.

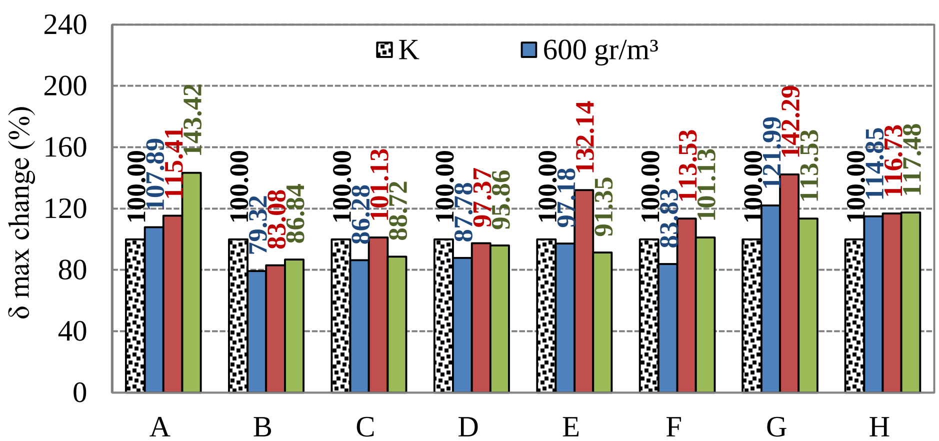

Fig. 4: Differences of deflection at the maximum flexural load (28 days).

Deflection values under the maximum load increased by 17% at H12 and H18 mixtures having the highest slump value (190 mm) in comparison with the control specimen. Increase of wetter within H12 and H18 mixtures effected deflection value under maximum load in a positive way. Deflection value at the breaking moment provide similar results with deflection values under maximum load (Figure 5). Difference between the deflection value at breaking moment and deflection value under maximum load was calculated as well. Deflection difference at B6, C6 and D6 mixtures are higher than the other ones.

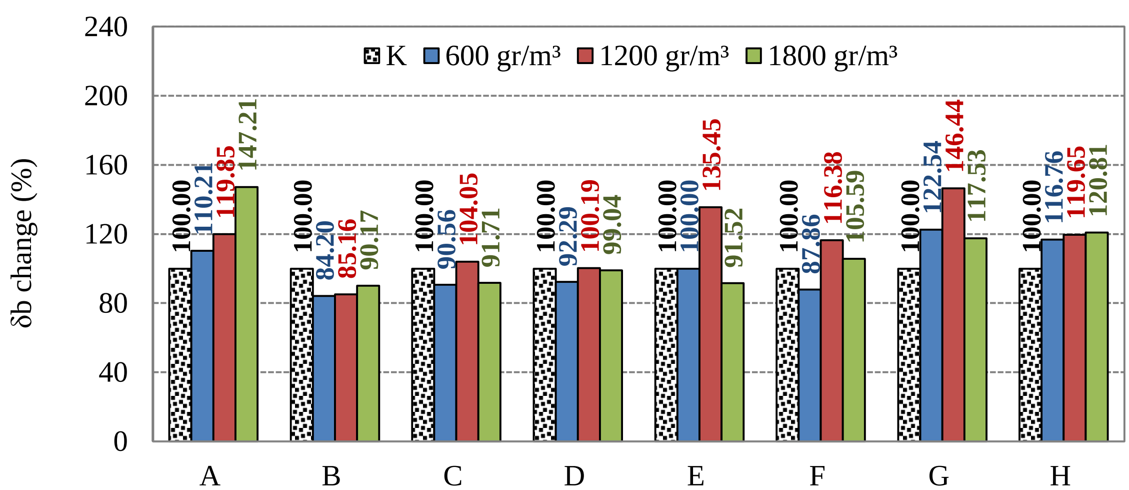

Fig. 5: Differences of deflection at breaking moment (28 days).

4. Conclusion

Polypropylene fibres decreased the compressive strength of cubes. Its known that fibres added to concrete decreased the slump value of fresh concrete. Fibres form a structural voids within concretes. Increase in added amount of substances at mixtures increased the slump value of fresh concrete. However this didn't create a positive effect over compressive strength. Compressive strength decreased by 17.3% in comparison with the control specimen.

In fibred mixtures, while compressive strength increases, flexural strength decreased. G6 mixture has the lowest compressive strength. However flexural strength of G6 increased by 7%. Flexural strength of H12 and H18 mixtures increased respectively by 10% and 20%. Increase of wetter within H12 and H18 mixtures effected flexural strength in a positive way. Same could be argues for A12, C12 and E12 mixtures as well.

Deflection values generally increased. Deflection values of A18 and G12 mixtures increased respectively by 43.42% and 42.29%. Increase of wetter within H12 and H18 mixtures effected deflection value under maximum load in a positive way. Deflection values under the maximum load decreased at B18, E18 and F6 mixtures having the lowest slump value (150 mm) in comparison with the control specimen. Deflection values under maximum load of H12 and H18 having the highest slump values (190mm) increased 17%.

References

[1] İ. B. Topçu and M. Canbaz, "Effect of different fibers on the mechanical properties of Concrete Containing fly ash," *Construction and Building Materials*, vol. 21, no. 7, pp. 1486-1491, 2006.

[2] A. Nobili, L. Lanzoni, and A. M. Tarantino, "Experimental investigation and monitoring of a polypropylene-based fiber reinforced concrete road pavement," *Construction and Building Materials*, vol. 47, pp. 888-895, 2013.

[3] Z. S. Tabatabaei, J. S. Volz, D. I. Keener, and B. P. Gliha, "Comparative impact behavior of four long carbon fiber reinforced concretes," *Materials and Design*, vol. 55, pp. 212-223, 2014,

[4] P. Pliya, A. L. Beaucour, and A. Noumowé, "Contribution of cocktail of polypropylene and steel fibres in improving the behaviour of high strength concrete subjected to high temperature," *Construction and Building Materials*, vol. 25, pp. 1926-1934, 2011.

[5] E. Campelloa, M. V. Pereirab, and F. Darwish, "The effect of short metallic and polymeric fiber on the fracture behavior of cement mortar," *Procedia Materials Science*, vol. 3, pp. 1914-1921, 2014.

[6] A. A. Ramezanianpour, M. Esmaeili, S. A. Ghahari, and M. H. Najafi, "Laboratory study on the effect of polypropylene fiber on durability, and physical and mechanical characteristic of concrete for application in sleepers," *Construction and Building Materials*, vol. 44, pp. 411-418, 2013.

[7] N. A. Libre, M. Shekarchi, M. Mahoutian, and P. Soroushian, "Mechanical properties of hybrid fiber reinforced lightweight aggregate concrete made with natural pumice," *Construction and Building Materials*, vol. 25, pp. 2458-2464, 2011.

[8] S. P. Yap, U. J. Alengaram, and M. Z. Jumaat, "Enhancement of mechanical properties in polypropylene– and nylon–fibre reinforced oil palm shell concrete," *Materials and Design*, vol. 49, pp. 1034-1041, 2013.

[9] M. Hsie, C. Tua, and P. S. Song, "Mechanical properties of polypropylene hybrid fiber-reinforced concrete," *Materials Science and Engineering A*," vol. 494, pp. 153-157, 2008.

[10] N. Salemi and K. Behfarnia, "Effect of nano-particles on durability of fiber-reinforced concrete pavement," *Construction and Building Materials*, vol. 48, pp. 934-941, 2013.

[11] P. Asokan, M. Osmani, and A. D. F. Price, "Improvement of the mechanical properties of glass fibre reinforced plastic waste powder filled concrete," *Construction and Building Materials*, vol. 24, pp. 448-460, 2010.

[12] Z. J. Grdic, G. A. T. Curcic, N. S. Ristic, and I. M. Despotovic, "Abrasion resistance of concrete micro-reinforced with polypropylene fibers," *Construction and Building Materials*, vol. 27, pp. 305-312, 2012.

[13] M. Fakharifar, A. Dalvand, M. Arezoumandi, M. K. Sharbatdar, G. Chen, and A. Kheyroddin, "Mechanical properties of high performance fiber reinforced cementitious composites," *Construction and Building Materials*, vol. 71, pp. 510-520, 2014.

[14] K. Bendjillali, M. S. Goual, M. Chemrouk, and Z. Damene, "Study of the reinforcement of limestone mortars by polypropylene fibers waste," *Physics Procedia*, vol. 21, pp. 42-46, 2011.

[15] M. Nili and V. Afroughsabet, "The effects of silica fume and polypropylene fibers on the impact resistance and mechanical properties of concrete," *Construction and Building Materials*, vol. 24, pp. 927-933, 2010.

[16] F. Fraternali, V. Ciancia, R. Chechile, G. Rizzano, L. Feo, and L. Incarnato, “Experimental study of the thermo-mechanical properties of recycled PET fiber-reinforced concrete,” *Composite Structures*, vol. 93, pp. 2368-2374, 2011.
[17] P. Rashiddadash, A. A. Ramezanianpour, and M. Mahdikhani, “Experimental investigation on flexural toughness of hybrid fiber reinforced concrete (HFRC) containing metakaolin and pumice,” *Construction and Building Materials,* vol. 51, pp. 313-320, 2014.
[18] H. Wang and A. Belarbi, “Flexural durability of FRP bars embedded in fiber-reinforced-concrete,” *Construction and Building Materials*, vol. 44, pp. 541-550, 2013.
[19] S. P. Yap, C. H. Bu, U. J. Alengaram, K. H. Mo, and M. Z. Jumaat, “Flexural toughness characteristics of steel–polypropylene hybrid fibre-reinforced oil palm shell concrete,” *Materials and Design*, vol. 57, pp. 662-659, 2014.
[20] A. M. Alani and D. Beckett, “Mechanical properties of a large scale synthetic fibre reinforced concrete ground slab,” *Construction and Building Materials*, vol. 41, pp. 335-344, 2013.
[21] G. D. Manolis, P. J. Gareis, A. D. Tsonos, and J. A. Neal, “Dynamic properties of polypropylene fiber-reinforced concrete slabs,” *Cement and Concrete Composites*, vol. 19, pp. 341-349, 1997.
[22] H. Cifuentes, F. García, O. Maeso, and F. Medina, “Influence of the properties of polypropylene fibres on the fracture behaviour of low, normal- and high-strength FRC,” *Construction and Building Materials*, vol. 45, pp. 130-137, 2013.