Influence of steel fibers on flexural behavior of rubberized hybrid reinforced concrete beam in layered

H. Alasmari, B.H. Abu Bakar, H.M. Akil

Abstract--- This study investigates the effect of crumb rubber aggregates with and without steel fibers on flexural behavior of hybrid reinforcement concrete beam in layered. Eighteen (18) hybrid reinforced concrete beams in three groups were prepared in this experimental works with ratio of aggregate replacement of 10%, 12.5%, and 15% by volume of sand. Rubberized layer concrete will be cast at top layer of the beam with reinforcement at the bottom. Two types of steel fibers were incorporated to concrete for the bottom layer of beams i.e., micro copper coated steel and hooked-end fibers with an aspect ratio of 60 and 80, respectively. The amount of selected fibers in the rubberized hybrid concrete is 0.5% by its volume. The performance of hybrid rubberized reinforced concrete beams were observed and measured based on its failure patterns, total energy (toughness), and stiffness, and ultimate deflection, modulus of rupture, strain capacity and ductility index. As a result, the hybrid rubberized reinforced concrete beams incorporating copper steel fiber and crumb rubber has shown a promising performance in the majority of characteristics such as, first crack, ultimate deflection, ductility index, the failure pattern (number of cracks), and critical strain from strain gauges and stress-strain cures a while, the rest characteristics (e.g. ultimate load, toughness, stiffness, and modulus of rupture and width of cracking) observed on hybrid beams contain crumb rubber and hooked-end fiber. It was noticed that hybrid rubberized concrete beam without steel fiber has shown less performance in their characteristics than the others which indicated that combination with other materials has potential for further enhancement.

Keywords: Rubberized Concrete, Hybrid, Steel Fibre, Layered Beam

I. INTRODUCTION

The last two decades have seen that the economy and construction industry grow rapidly. This growth has led to the use of new materials in construction including the use of rubber from scrap tire. Prior to this, scrap rubber tires were a major environmental issue due to being discarded in landfills, buried, or burnt. An estimated over 50% of scrap tires were disposed of without proper treatment. This merits renewed an investigation into the potential applications of this material. As a result, many studies have been carried out since the 1990s to determine the reasonable rate of additional scrap tire to the concrete mixture or compostedwith other material. Numerous discoveries studies, that done in small-scale testing such as cubes, cylinders, and prisms Many studies reported that there is an improvement in toughness, strain capacity, ductility, cracking resistance and reduced self-weight [1,2]. In contrast, there were decreased in some mechanical characteristics(e.g., compressive and split tensile stresses, the Modulus of Rupture). In contrary, The impact resistance of concrete has been improved with the inclusion of crumb [3,6]. Most studies mentioned that used crumb rubber at 10% replacement as a good homogenous and interaction with the rest of the concrete composite and to provide the best result especially in total energy, (Toughness) [7]. In other findings, Li et al. [8] investigated an isolated hybrid rubberized concrete with two layers up to 30% of its overall depth placed on top of the beam while, the scrap rubber in bottom and tested under resonant excitation and point out that these kinds of structure can help to reduce the structure response when exposed to load.

Accordingly to that caught the interest of scientists and shed light on this kind of structure, Al-Tayeb et al. [9] used rubber powder in hybrid such through conducted experimental at the prisms beams containing two layers, one filled with rubberized concrete up to 50 % of height and located at the top while normal concrete filled at the bottom and the layered beam exhibited better.

Ahmed Tareq [10] adopted the previous study by the authors (Al-Tayeb et al. [9]) with inclusion steel fiber and due to that many researchers have explored its benefits in concrete, especially for hardening. For instance, Norambuena et al. [11] Fitzgerald [12], and Mahrez et al. [13] reported that the strength, fatigue resistance, ductility and crack ultimate, tensile strength and fracture resistance were improved. Under optimum load, the crack can be delayed to emerge in fiberized concrete compared to normal concrete and that has led to a good indication of its utilization. Ahmed carried out the investigation with small size (prisms) under static and impact load. The main experimental variables were hooked-end steel fibre fixed at 0.5% of volume fraction and located at the bottom and partial replacement of fine aggregate by crumb rubber with different percentages (5%,10%,15%,17.5 %, 20%,22.5%, and 25%) and located at the top. It was concluded that impact and static energy improved by obtaining the best overall results for initial crack and delays of ultimate failure. On the other hand, limited studies have been conducted in large-scale testing of a structural member made of rubberized concrete with inclusion steel fibre (Non-layer).

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For instance, Mohamed et al. [14], studied the effect of the crumb rubber with two types of steel fibres in two different lengths on flexural behaviour. They pointed out that, with the increase of crumb rubber it will lead to the reduction of crack widths and increased the number, reduce self-weight of concrete, decrease in toughness at 15% of crumb rubber. In addition, it exhibited an improvement in the majority of characteristics especially with the small length of fiber (low aspect ratio). A study carried out by Mohamed et al. [15], investigated the toughness, the shear capacity, cracking resistance of the plain, rubberized and the rubberized-fiberized reinforcement concrete beam with no shear reinforcement and tested under a four-point bonding loading. In this study, fine aggregates were replaced by a volume of 5%, 15 %, 25 and 35% with crumb rubber. Two types of steel fiber were added in different percentages i.e. 0.35% and 1% but both are having the same aspect ratio of 65 with different lengths (35 mm and 60 mm).

They concluded that crumb rubber and steel fiber affected directly the capacity of the beam and delayed their deformation. Hence, ultimate of energy absorption of the beam had been improved by increased steel fibre amount with inclusion a rubber at 5%, replacement while, there are 23.6% reduction in the beam toughness by added crumb rubber from 15% to 25%, and more than 25 % of crumb rubber ratio caused a higher reduction in the amount of energy absorption compared to lower ratio. Another study [16,17] conducted on the flexural behavior of reinforced self-consolidating rubberized concrete (SCRC) and vibrated rubberized concrete (VRC) beams. It showed reduction in first crack load, ultimate failure load, and stiffness by using crumb rubber up to 20% of fine aggregate replacement while, the deformation capacity, ductility, toughness, and the concrete's strain increased. In large-scale testing of the Hybrid layered rubberized concrete beam, a few researches in this issue investigated.

For instance, Mohd. [18] conducted an experimental study in the hybrid concrete beam with two layers at the top and bottom of plain concrete and crumb rubber at 20% of volume for fine aggregate respectively and their layers division based upon the neutral axis. The study revealed that performance of rubberized reinforced concrete beam is the same with hybrid reinforced concrete beam during the first crack during loading, the stiffness of hybrid exhibited a better performance than others. The reason is that of the hybrid reinforced concrete beam has a slightly lower deflection than rubberized reinforced concrete beam. An extensive literature review carried out on this kind of structure with large scale has revealed that no one has yet investigated and measured hybrid beams in the two-layer one for crumb rubber at (i.e., 10%, 12.5%, and 15%) of volume and fine aggregate replacement, and the other layer for steel fibre whether straight or hook-end at constant volume of 0.5%. which has provided an opportunity for this research to carry out such measurement and test of their characteristics.

II. EXPERIMENTAL PROGRAM

A. Materials

The materials used in the experimental works: Type 1 of ordinary Portland cement with a relative density of 3.15. 10 mm maximum size of natural crushed aggregate is approximately, 10 mm and natural river sand were used as coarse aggregates and fine aggregates respectively. The relative density, fineness modulus and absorption of fine aggregates were 2.64, 3.42.and 1 % respectively. A crumb rubber aggregates with a maximum size up to 4.75 mm and their specific gravity of 1.22. Two types of steel fiber with different aspect ratio were used in this experiment. The first one was hooked-end bundled Steel fiber with aspect ratio of 80, a 60 mm length circular diameter of 0.75 mm, specific gravity of 7.90, and tensile strength of 1050 MPa while the second type was micro copper coated steel fiber with 60 aspect ratio, a 21 mm length, 35 mm diameter, specific gravity of 7.90 and 2800 MPa tensile strength. Superplasticizer (SP) was used with a specific gravity of 1.06 to adjust the workability of the mixture. The tested beams of 1000X150X200 mm dimensions contained four bar of 10 with stirrups of 6 diameters for shear at 125 mm spacing between center to center. All steel bars and had an average yield stress of 400 MPa.

B. Concrete Mixtures

Nine mixtures were prepared for 18 beams in three groups. and two specimens i.e. beams for each mixture. This design was calculated in a comprehensive way to investigate the influence of CR with and without steel fiber under the flexural behavior. Because of hybrid layered beams, the casting was prepared into two stages based on the materials distribution in its layer. The first group consists of six (6) beams used only crumb rubber at the top layer and percentage varied from 10% to 15% with reinforcement concrete at the bottom. The second and third groups were six (6) beams contain two types of steel fiber with the volume fraction of 0.5% for the bottom layer of the beam for each. The type mixtures and mix proportions are presented in Table I

C. Flexure test setup, instrumentation, and loading procedure

Eighteen (18) rubberized hybrid layered concrete beams were prepared using the nine (9) designed mixtures. All tested beams have a cross-sectional area of 150 mm X 200 mm, with a total length of 1000 mm and an effective span of 900 mm and were casting in two-layered at100 mm height. Fig 1 shows the configuration of the beams, reinforcement details, and test setup. A strain gauge was mounted at the main bottom steel bar and at the top middle of the concrete surface with different length to measure the strain during the loading. The strain gauge manufactured by electronic instrument-japan, 30 mm length used for concrete, while 5 mm length for longitudinal reinforcement. The beams were then tested under four points load to determine its flexural strength. The linear variable differential transformer (LVDT) was used to record and measure the mid-span deflection until failure. An incremental load was applied to the tested beams while the first crack was monitored and observed by the naked eye at a different level of loadings (first cracking Load and

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ultimate load), were detected and marked it.

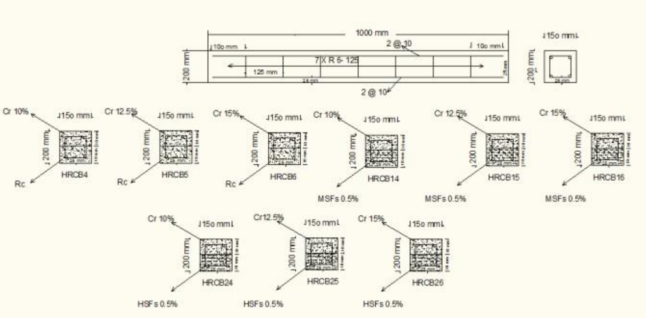

Table I. Mixture proportions

Type of Mix Beam		Cement (kg/m³)	Coarse Aggregates (kg/m³)	Water (kg/m³)	Fine Aggregates (kg/m³)		Crumb rubber (kg/m³)		Steel Fiber (kg/m³)		Superplasticizer (kg/m³)	
Group	Name				First layer	Second layer	% Cr	First layer	Second layer (MSFs)	Second layer (HSFs)	First layer	Second layer
A	HRCB4	360	1060	173	641.7	713	10.00%	32.86	-	-	1.08	0.9
	HRCB5	360	1060	173	623.88	713	12.50%	41.08	-	-	1.08	0.9
	HRCB6	360	1060	173	606.05	713	15.00%	49.38	-	-	1.08	0.9
B	HRCB14	360	1060	173	641.7	713	10.00%	32.86	39.5	-	1.08	1.3
	HRCB15	360	1060	173	623.88	713	12.50%	41.08	39.5	-	1.08	1.3
	HRCB16	360	1060	173	606.05	713	15.00%	49.38	39.5	-	1.08	1.3
C	HRCB24	360	1060	173	641.7	713	10.00%	32.86	-	39.5	1.08	1.3
	HRCB25	360	1060	173	623.88	713	12.50%	41.08	-	39.5	1.08	1.3
	HRCB26	360	1060	173	606.05	713	15.00%	49.38	-	39.5	1.08	1.3

III. RESULTS AND DISCUSSIONS

A. Characteristics of load-deflection

Table II shows the characteristics of the mid-span deflection of beams through the flexural test. It can be seen that the first cracking load decreased as the percentage of CR increased. For example, the inclusion of 15 % Cr in HRCB6 has shown a Reduction of 6 % compared to HRCB4 with 10% Cr. It was Noticed by incorporating steel fiber with crumb rubber there was a delay of the first cracking load, of beams slightly around 1 or 2 of their loads compared to crumb rubber only, as can see from the table II by an average in HRCB4 to HRCB6 compared to HRCB14 to HRCB26. These because of the fiber content had a Little effect on first cracking load

Table II. Characteristics of beam results

Types of Mix		specimens No.	Cracking Load, Pcr (KN)	Cracking Deflection, Δcr (mm)	Yield Load Pyield (KN)	Yield Deflection, Δyield (mm)	Ultimate Load, Pult (KN)	Ultimate Deflection, Δult (mm)	Total energy, E total (Toughness) (KN.mm)
Group	Name								
A	HRCB4	1	42	2.27	86.51	4.92	106.37	8.36	340.47
		2	42	2.09	87.84	4.75	107.39	8.86	326.21
		Average	**42**	**2.18**	**87.17**	**4.84**	**106.88**	**8.61**	**333.34**
	HRCB5	1	40	2.31	77.32	3.64	97.10	8.302	311.51
		2	40	2.17	87.74	4.74	104.02	10.65	312.23
		Average	**40**	**2.24**	**82.53**	**4.19**	**100.56**	**9.48**	**311.87**

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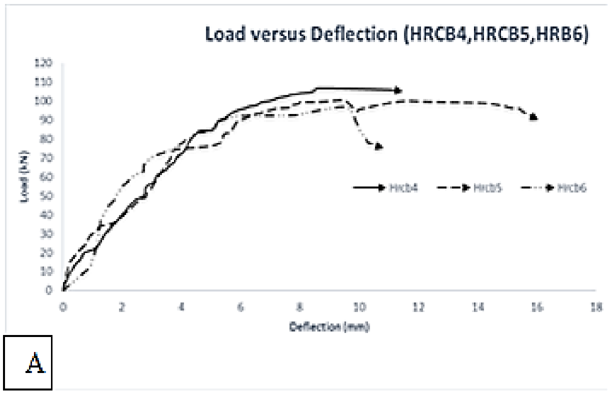
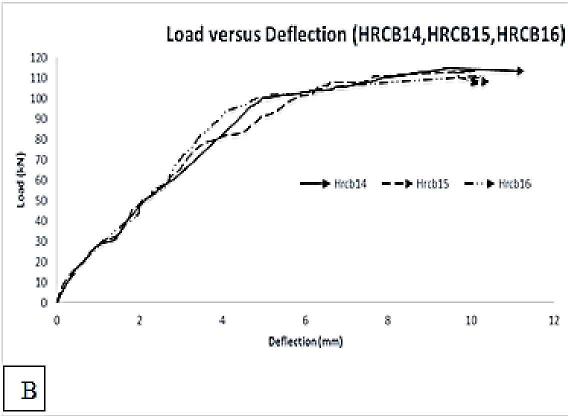
	HRCB6	1	39	2.28	91.95	4.27	102.80	10.51	274.80	15.41	2.46
		2	39	2.26	75.66	4.10	90.17	8.76	336.63	12.53	2.14
		Average	**39**	**2.27**	**83.81**	**4.19**	**96.48**	**9.63**	**305.72**	**13.97**	**2.30**
B	HRCB14	1	44	1.97	101.00	4.87	114.37	9.25	333.57	18.23	1.90
		2	43	1.88	97.00	4.97	115.50	9.63	354.51	15.06	1.94
		Average	**43**	**1.93**	**99.00**	**4.92**	**114.94**	**9.44**	**344.04**	**16.64**	**1.92**
	HRCB15	1	41	2.16	87.00	4.05	117.50	9.88	353.81	16.22	2.44
		2	42	2.03	90.87	4.26	109.31	10.22	279.31	16.16	2.40
		Average	**42**	**2.09**	**88.94**	**4.16**	**113.40**	**10.05**	**316.56**	**16.19**	**2.42**
	HRCB16	1	42	2.22	91.21	4.24	109.41	9.63	302.23	16.43	2.27
		2	42	2.12	90.26	3.94	112.43	10.94	309.80	15.01	2.78
		Average	**42**	**2.17**	**90.74**	**4.09**	**110.92**	**10.29**	**306.02**	**15.72**	**2.52**
C	HRCB24	1	42	1.87	101.60	5.27	128.12	8.89	392.87	17.27	1.69
		2	43	1.86	99.28	4.65	125.10	9.36	395.25	18.41	2.01
		Average	**42**	**1.87**	**100.44**	**4.96**	**126.61**	**9.13**	**394.06**	**17.84**	**1.85**
	HRCB25	1	42	1.89	87.91	4.31	122.73	10.03	358.91	16.90	2.33
		2	41	1.93	93.78	4.06	126.84	9.67	339.04	17.83	2.38
		Average	**41**	**1.91**	**90.85**	**4.19**	**124.79**	**9.85**	**348.98**	**17.37**	**2.35**
	HRCB26	1	40	1.94	94.31	4.07	116.04	9.68	217.83	14.72	2.38
		2	40	1.96	89.31	4.17	119.01	10.54	452.19	17.82	2.53
		Average	**40**	**1.95**	**91.81**	**4.12**	**117.53**	**10.11**	**335.01**	**16.27**	**2.45**

while had a significant effect on the ultimate load and their deflection [19]. Fig. 2 & Table II shows the ultimate load-deflection curves in an average for each group and represents in clearly figure. It indicates that by increasing the percentage of CR from 10% to 15% appeared to increase the ultimate deflection to 11.8%, while the ultimate load exhibited reduction at 9.7% compared to HRCB4 with 10% Cr. Thus, it is expected that there will be less strain in steel at tension by increasing Cr content which, can be attributed to a decrease in the ultimate load [14]. Using 0. 5 % MSFs (21mm) and HSFs (60mm) in two groups respectively appeared to increase both deflection and load in ultimate compared with crumb only as presented in Table II. Such findings, the ultimate load of HRCB14 increased by an average of 7.5% compared to HRCB4 due to the inclusion of 0. 5%MSFs (21 mm). Whereas, using 0. 5%HSFs (60 mm) was performed better by increased the ultimate load to 18.45 % in HRCB24 compared to HRCB4. Thus, use of higher aspect ratio (80) of steel fiber performance better than the lower one (60) in term of the ultimate load.





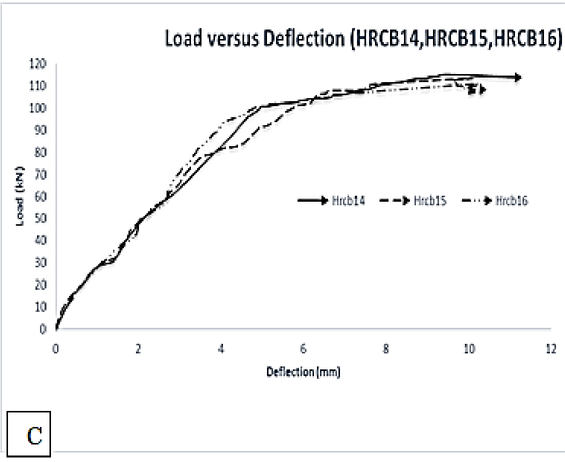


Fig 2 Experimental load defection curve for groups A,B&C

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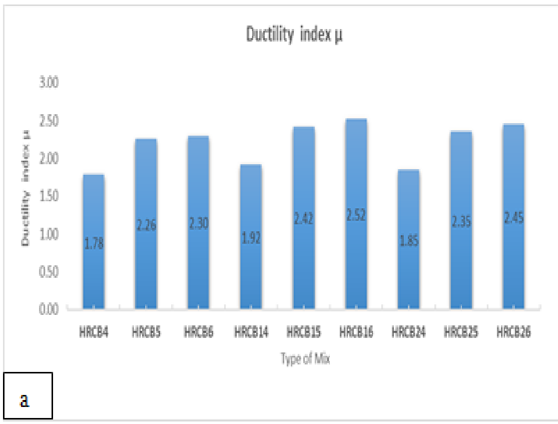
Load and this due to that fiber with high aspect ratio are more effective in improving the flexural strength [20]. Other studies [21], reported that the ultimate load increases with an increase in the fiber length. For example, In HRCB24 ultimate load was in an average of 126.61 kN higher than HRCB14, 114.94 kN. On the other hand, the deflection with shorter fibers performance better than the longer one. For example, the ultimate deflection for HRCB15 & HRCB25 increased to 6% & 4 respectively compared to HRCB5. Using short steel fiber (21mm) showed comparable results to those of longer HSFs (60 mm) in a team of first crack loading, ultimate deflection strain and ductility a which was agreed with previous researches [14, 15]. The area enclosed by the deflection curve represents the toughness (Total Energy) by an average as shown in Fig 2, it can seen the area reduced by increasing the percentage of Cr, which indicated reductions in the toughness. In group (A), varying from 10%to 15% of crumb rubber percentage lead to reduce on toughness by 8.28%. In group (B) &(C) at failure, absorbed a higher amount of total energy than in the previous group, which means, that greatly improved the toughness for beams with steel fiber. For example, at 10% Cr of beam HRCB4 increased from 333.34 to 344.04 & 394.06 kN.mm for beams HRCB14 and HRCB24, respectively. Thus, beams with hooked fibers were 14.5% greater compared to beams with straight fibers and this is an agreement with other researchers [22, 24]. Other reason reported by the author [24] that, when the fiber sizes become longer, post-yield load carrying capacity and toughness actually increase but under specific conditions that specimens only in the static condition. Fig3(a) shows that the Ductility index (μ) in three groups generally improving by increasing the crumb rubber percentage which indicated that the rubber can contribute to improving strain and deformability and lead to enhancing the ductility.For instance, increasing the rubber from 10 -15 % in group (A) leads to an increase in the ductility by 24.3 %.Addition of steel fiber to other groups significantly enhanced the ductility. The results of the present work match with other studies that have been reported. [14, 17]. So, the shorter of steel fiber performance better then the longer one. Such finding of fiber action that HRCB16 beams ductile more than HRCB26 at 2.53&2.45 respectively. Against this trend was observed in results of stiffness such as HRCB15 with 21 mm-MFCs exhibits slightly lower values compared to HRCB25 with 60mm HFSs. As mentioned in previous research[14], that the longer fiber helped the beams for further cracking control and led to higher beam stiffness as shown in Fig3 (b)



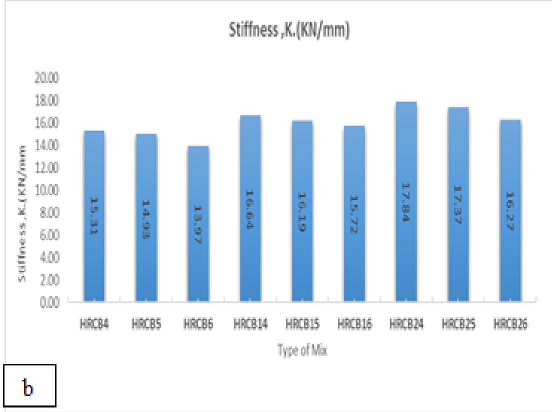


Fig 3 (a) Ductility index μ and (b) Stiffness, K for groups A, B&C

B. Cracking behavior

Fig4. &Table III shows the characteristics of the cracking (angle, widths, and numbers) and their patterns of the tested beams. In group A, increasing the crumb rubber from 10% to 15% lead to a slight increase in the number of cracking while their widths appeared to narrow. For example, HRCB6 at 15% Cr reduce the cracks width by 25.7% compared to HRCB4 while, the number of cracks increased from 9 to 10. This is because of rubber aggregate have low modulus of the elasticity and affected the number of cracking on the beams during the loading. [14, 17]. Consequently, it is considered as a reason of reduced the crack width at failure. Including steel fiber in tested beams will help in further to reduce the cracking number and maximum width. The steel fiber was confirmed by many authors [26, 25], through the enhanced ductility and reduced cracking. The crack propagation in beams started from the bottom that will encounter several fibers which dedicated a layer of beams volume in this study and that helped to delay the fracture as passable. The fiber with shorter lengths could be beneficial in the micro-cracking whereas, the larger sizes able to “bridge” a crack upon significant failure (macro-cracking) [24]. For example, as small fiber use, the cracking widths at ultimate load decreased by an average of 29.8% as showing in HRCB6 compared to HRCB16. The longer fiber in the group (c) appeared to have a smaller width comparison with other groups as showing in HRCB26 compared to HRCB16 at 1.69 mm and 1.88 mm respectively. The crack number for two groups (B&C) inclusion steel fiber were lower compared without steel fiber in group A.

C. Modulus of rupture.

Modulus of rupture was also determined from the load-deflection curve of the tested beams and presented in Table III. It was observed that there was a reduction with the increase in rubber ratio. For example in group A, The rates of Decrease were 5.9%, 9.75%, at 12.5%, 15 % compared to 10 % crumb rubber content respectively. A similar trend observed when steel fiber using with further enhancement. The shorter steel fiber in the bottom with 15% crumb rubber in top in HRCB16 beams provided enhancement by an average 13% compared to HRCB6, while the longer one improved more by an average 21.8% in same distribution. This finding was also previously indicated by many studies.

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Table III. Cracking and stress-strain Characteristics of tested beams results

Types of mix		Ultimate load (KN)		Modulus of Rupture pa		Stress at Ultimate load συ (N/mm²)		Strain at ultimate load ?υ: From load-strain curve ?υ (%)		Strain at ultimate load ?υ: From Strain gauges recorded (mm/mm)X10??				The cracks behivour at beam failed in flexure process					
Group	Name	load Pult KN	Average	Flexura strength	Averge	Stress συ (N/mm²)	Average	strain ?υ (%)	Average	longitudinal reinforcement at tension zone ?cυ	Average	concrete strain ?cυ	Average	No.of sperial	Average	Max of crack width (mm)	Average	Angle of crack (deg. ?)	Average
A	HRCB4	106.373	106.88	15.96	16.035	3.55	3.57	4.18	4.305	305	343.5	-1153	-1319	8	9	3.28	3.38	38	38
		107.387		16.11		3.58		4.43		382		-1485		10		3.48		38	
	HRCB5	97.1	100.562	14.57	15.085	3.24	3.36	4.15	4.74	495	560	-1062	-1326	8	9.5	3.12	2.78	37	37
		104.023		15.6		3.47		5.33		625		-1590		11		2.44		37	
	HRCB6	102.79	96.475	15.42	14.47	3.43	3.22	5.26	4.82	344	594.5	-1905	-1412.5	8	10	2.3	2.51	35	35
		90.16		13.52		3.01		4.38		845		-920		12		2.71		35	
B	HRCB14	114.37	114.935	17.16	17.245	3.81	3.83	4.63	4.725	1095	1129.5	-1624	-1402.5	7	7	2.2	2.50	42	40
		115.5		17.33		3.85		4.82		1164		-1181		7		2.79		38	
	HRCB15	117.5	113.4	17.63	17.015	3.92	3.78	4.94	4.775	1599	1189.5	-1462	-1467.5	7	7.5	2.2	2.19	60	55
		109.3		16.4		3.64		4.61		780		-1473		8		2.18		50	
	HRCB16	109.41	110.92	16.41	16.635	3.65	3.70	4.82	4.895	1447	1213.5	-1413	-1488.5	7	7.5	1.9	1.88	35	35
		112.43		16.86		3.75		4.97		980		-1564		8		1.85		35	
C	HRCB24	128.12	126.61	19.22	18.995	4.27	4.22	4.45	4.565	769	890.5	-1278	-1364.5	8	8	2.43	2.31	40	38
		125.1		18.77		4.17		4.68		1012		-1451		8		2.19		36	
	HRCB25	122.73	124.785	18.41	18.72	4.09	4.16	5.02	4.75	931	904.5	-1073	-1422.5	8	8	1.5	1.78	30	40
		126.84		19.03		4.23		4.48		878		-1772		8		2.06		50	
	HRCB26	116.047	117.529	17.41	17.63	3.87	3.92	4.34	4.845	1032	1107.5	-1394	-1460	7	8	1.68	1.69	25	30
		119.01		17.85		3.97		5.35		1183		-1526		9		1.7		35	

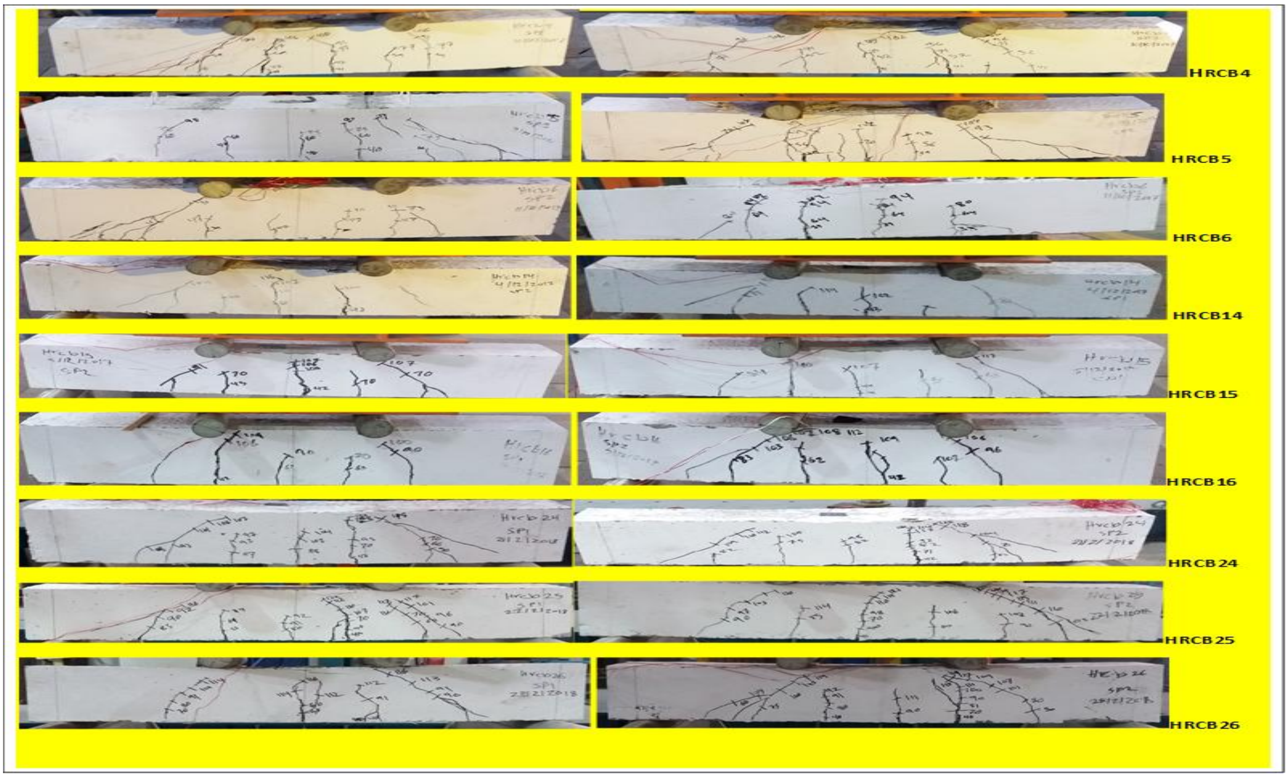
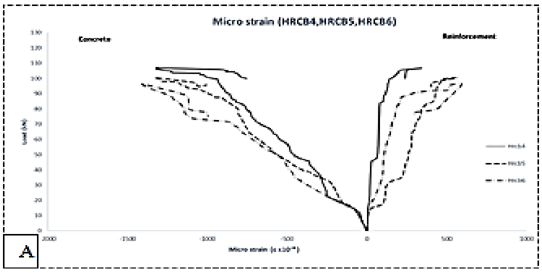
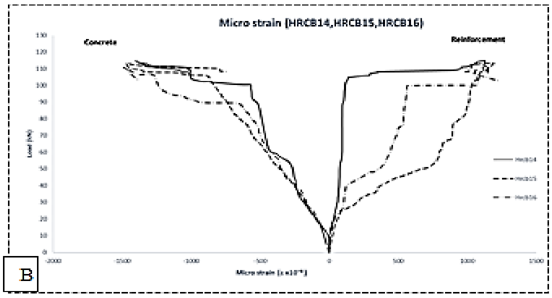
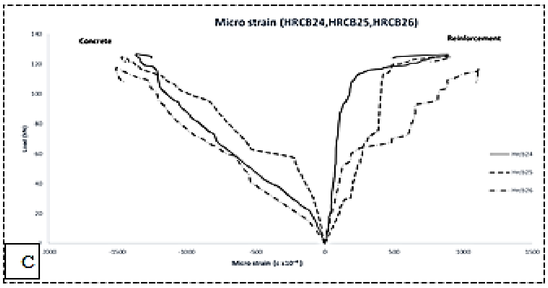


Fig 4 Crack patterns of tested beams at failure





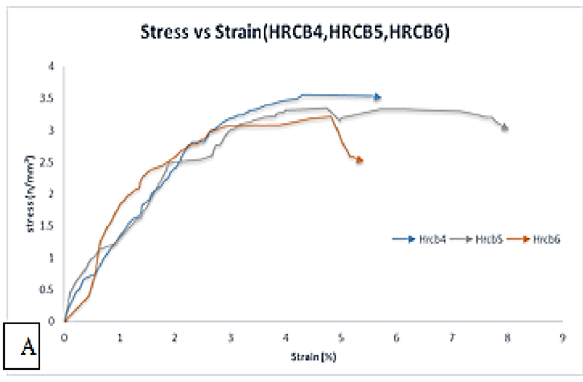


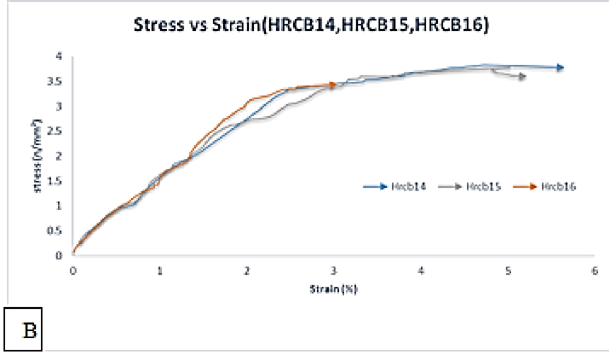
1. Strain gauges

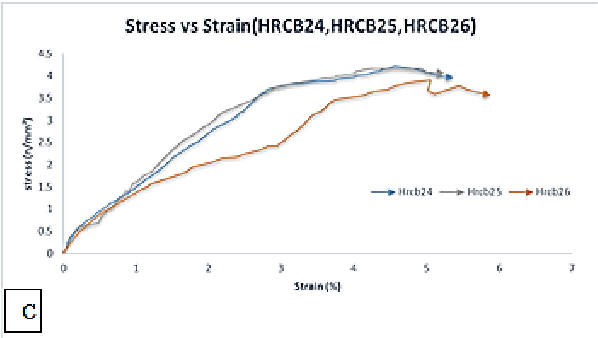
Which in fact that lengths of fiber when became longer will play major role of developing the bonding between the fibers and concrete mixture and led to improving flexural strength as reported by other researchers previously [14, 15].

B. Strains by stress-strain curve and strain gauges

An enhancement of the strain measured up to failure load was observed from the stress-strain curve (Fig5.b) with the increase the percentage of crumb rubber in the concrete mixture (Table III). The maximum strain was obtained at 15% content of crumb rubber for HRCB6 at 12.09% compared to HRCB4 and that indicated the deformability of rubberized increase. A similar trend was observed for shorter and longer with more improvement.Such as finding with 21 mm of steel fiber long in the bottom and 15 %Cr at the top the strain increases slightly and reaching up to 2 % compared with beams contains the same percentage of crumb rubber in a top







2. Stress-strain curve

layer without steel fiber in bottom whereas, the longer steel fiber perform less than shorter by 1%. According to the previous work, that smaller fiber exhibit higher in term of strain but when fiber sizes increased, the strain decreased [24]. These results were confirmed by strains gauges curve as showing in Fig 5 and Table III. The gauges recorded the strain during the flexure process until failure for top concrete surface that exposed the load and longitudinal reinforcement at tension zone. It is clear from the table that the strain of steel bar increased as the Rubber contains increased in top layer of beams. However, the strain was less than 600 (mm/mm) X10^{-6} and this indicated by other authors used crumb rubber with and without steel fiber and confirmed that strain in steel bar at tension zone will be less with crumb rubber only [14]. It clearly forms the Table III that strain for beams using smaller fiber in bottom performed better than the longer one. These results have confirmed the data that extract by the stress-strain curve

IV. CONCLUSION

Eighteen (18) rubberized reinforced concrete layered beams with and without steel fiber were investigated under flexural behavior. Double-layer beam with a rubberized on the top with a ratio of 10%, 12.5% and 15 % of sand volume replacement. The reinforcement concrete, 0.5% of micro copper coated steel ratio of 60 and hooked-end fibers with an aspect ratio of 60 and 80 respectively at the bottom. The failure patterns, total energy (toughness), and stiffness, and ultimate deflection, modulus of rupture, strain capacity and ductility index were studied for all beams. Based on the experimental results, the following conclusions were made:

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1. The double-layered beams of steel fiber with lower aspect ratio at the bottom have shown better performance as compared to higher aspect ratio in most cases such as the failure patterns (number of cracks),first cracking load, ultimate deflection, ductility index, strain for both strains gauges (concrete and steel bar) and stress-strain curve – comment based on aspect ratio.
2. The beams with longer steel fiber and located at the bottom helped the beams for further cracking control by reduced the widths of cracking due to that fiber with the larger sizes able to "bridge" a crack upon significant failure (macro-cracking) as result led to higher beam stiffness comment based on the aspect ratio.
3. In contrary, the high aspect ratio of steel fiber has improved bonding between the fibers and concrete mixture and which to led to improving flexural strength, ultimate load, and toughness due to bridging effect. – bridging effect.
4. It seems that the performance of double-layered beam specimens in group B and C are better compared to group A.
5. The results obtained in this investigation has shown a promising performance in the application of steel fiber in rubberized concrete which require future studies.

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REFERENCES

1. L. Zheng, H.X. Sharon, Y. Yuan, Experimental investigation on dynamic properties of rubberized concrete, Constr. Build. Mater. 22 (5) (2008) 939–947.
2. K.B. Najim, M. Hall, Mechanical and dynamic properties of self-compacting crumb rubber modified concrete, Constr. Build. Mater. 27 (2012) 521–530
3. M.M. Reda-Taha, A.S. El-Dieb, M.A. Abd El-Wahab, M.E. Abdel-Hameed Mechanical, fracture, and microstructural investigations of rubber concrete, J. Mater. Civ. Eng. 20 (10) (2008) 640–649
4. M.M. Al-Tayeb, B.H. Abu Bakar, H. Ismail, H.M. Akil, Impact resistance of concrete with partial replacements of sand and cement by waste rubber, Polym. Plast. Technol. Eng. 51 (12) (2012) 1230–1236.
5. T. Gupta, R.K. Sharma, S. Chaudhary, Impact resistance of concrete containing waste rubber fiber and silica fume, Int. J. Impact Eng. 83 (2015) 76–87
6. M.K. Ismail, A.A.A. Hassan, Behaviour of self-consolidating rubberized concrete under drop-weight impacts, in: 8th International RILEM Symposium on Self- Compacting Concrete – SCC 2016. RILEM Bookseries, 2016, pp. 445–454
7. Rashad, A.M. A comprehensive overview about recycling rubber as fine aggregate replacement in traditional cementitious materials. International Journal of Sustainable Built Environment (2015), http:// dx. doi. org/10.1016/j.ijsbe.2015.11.003(some citation in table adopted)
8. Li VC. A simplified micromechanical model of compressive strength of fiber reinforced cementitious composites. Cem Concr Compos 1992;14(2):131–41
9. Mustafa Maher Al-Tayeb1, B. H. Abu Bakar1*, Hanafi Ismail2 and Hazizan Md Akil2(2012).Experimental and Nonlinear Dynamic Analysis of Hybrid Powder Rubberized-Normal Concrete under Impact Load. Caspian Journal of Applied Sciences Research, 1(11), pp. 23-31, 2012.
10. Ahmed Tareq Noamana, *, B.H. Abu Bakar and Hazizan Md. Akil.(2016). Effect of curmb rubber aggregate on toughness and impact energy of steel fiber concrete. PhD of engineering, Civil Eengineering, Universiti Sains Malaysia.
11. J. Norambuena-Contreras a,b, V. Gutierrez Aguilar, I. Gonzalez-Torre, 2015. Physical and mechanical behaviour of a fibre-reinforced rubber membrane with self-
12. R.L. Fitzgerald, Novel applications of carbon fiber for hot mix asphalt reinforcement and carbon–carbon pre-forms (M.Sc. Thesis), Department of Chemical Engineering, Michigan Technological University, 2000
13. A. Mahrez, M. Karim, H. Katman, Prospect of using glass fiber reinforced bituminous mixes, J. East. Asia Soc. Trans. Stud. 5 (2003) 794–807.
14. Mohamed K. Ismail, Assem A.A. Hassan.,2017. An experimental study on flexural behavior of large-scale concrete beams incorporating crumb and steel fiber. Engineering Structure 145 (2017) 97–108
15. Mohamed K. Ismail, Assem A.A. Hassan.,2017. Shear behaviour of large-scale rubberized concrete beams reinforced with steel fibres. Construction and Building Materials 140 (2017) 43–57
16. M.K. Ismail, A.A.A. Hassan, Performance of full-scale self-consolidating rubberized concrete beams in flexure, ACI Mater. J. 113 (2) (2015) 207–218.M.K. Ismail, A.A.A. Hassan, Ductility and cracking behavior of reinforced selfconsolidating rubberized concrete beams, J.
17. Mater. Civ. Eng. (2016), http://dx. doi.org/10.1061/(ASCE)MT.1943-5533.0001699, 04016174
18. Mohd Abqari Bin Abd Wahab, and Badorul Hisham Aku Bakar.(2016). Stress-strain respond of full scale rubberized reinforced concrete beam in bending. Dissertation for bachelor of engineering, Civil Eengineering, Universiti Sains Malaysia
19. Zemei Wua, Caijun Shi, Wen He, Linmei Wua (2016). Effects of steel fiber content and shape on mechanical properties of ultra-high performance concreteConstruction and Building Materials 103 (2016) 8–14
20. X. Gao. Q. L. Yu. R. Yu. H. J. H. Brouwers (2017). Evaluation of hybrid steel fiber reinforcement in high performance geopolymer compositesMaterials and Structures (2017) 50:165
21. Wasim Abbass, M. Iqbal Khan, Shehab Mourad (2018). Evaluation of mechanical properties of steel fiber reinforced concrete. Construction and Building Materials 168 (2018) 556–569
22. Faisal Fouad Wafa (1990).Properties and application of fiber reinforced concrete, king Abdul-Aziz university, Jeddah, Saudi Arabia JKAU: Eng. Sci., Vol. 2, pp. 49-6~ (1410 A.H./1990A.D.)
23. V. Ramakrishnan, George Y. Wu, And Grrish Hosalli (1989). Flexural Behavior And Toughness Of Fiber Reinforced Concretes, Transportation Research Record 1226.
24. Dylan A. Scott, Wendy R. Long, Robert D. Moser, Brian H. Green, James L. O'Daniel, and Brett A. Williams (2015). Impact of Steel Fiber Size and Shape on the Mechanical Properties of Ultra-High Performance Concrete report. Geotechnical and Structures Laboratory,The U.S. Army Engineer Research and Development Center (ERDC), 2015
25. Abu Bakar, Ahmed Tareq,and Hazizan Md (2017): Cumulative Effect of Crumb Rubber and Steel Fiber on the Flexura Toughness of Concrete. Engineering, Technology & Applied Science Research Vol. 7, No. 1, 2017, 1345-1352
26. R. Olivito, F. Zuccarello, "An experimental study on the tensile strength of steel fiber reinforced concrete", Composite Part B: Eng., Vol. 41, No3, pp. 246-255, 2010