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Structural Behaviour of Shredded Waste Paper Reinforced Concrete Beam

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Abstract: *Cement, sand, coarse aggregate, water and reinforcing bar are the materials used to make a reinforced concrete beam. The waste paper has been dumped as waste and causes environmental pollution behind mill or landfill. The industry paper wastage for every year is increasing gradually. More spaces are being needed for landfills, use energy loss of natural resources, and increase expenditure and various types of pollutions. Utilizing waste paper as an addition to reinforced concrete beam production will reduce environmental pollutions. This research is conducted to investigate the structural behaviour of reinforced concrete beam containing 10% shredded mixed and cardboard waste paper as additions in concrete with three types of reinforcements such as full shear reinforcement with stirrup spacing (SS=100 mm) and reduced shear reinforcements with stirrup spacing (SS=150 mm) and (SS=200 mm). All specimens are subjected to air curing at 28 days. The results of load-deflection behaviour and ultimate load-bearing capacity are better with 10% shredded copier and cardboard waste paper at 28 days of air curing with full and reduced shear reinforcements. The finding shows that reinforced concrete beam with full shear reinforcement with SS=100 mm containing 10% addition of shredded cardboard waste paper in concrete exhibits the highest load at yield (Py=96.67 kN), ultimate load (Pu=103.15 kN), maximum load (Pmax=106.78 kN) representing load-carrying capacity, load at first crack (P1=70.84 kN) and the lowest yield deflection (δy=11.98 mm), ultimate deflection (δu=23.04 mm), maximum deflection (δmax=18.12 mm) compared to 10% SCPWP and 0%. This study indicates that shredded copier and cardboard waste paper can be used as additional material in reinforced concrete beam production.*

Keywords: Shredded waste paper, reinforced concrete beam, load-deflection, ultimate load bearing capacity

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1. Pengenalan

Reinforced concrete is widely used in the construction industry due to its advantages such as strong, robust, economical and durable. Nowadays, carbon dioxide (CO_2) gas emissions from houses are attributed to cement usage, which is a massive issue for all nations. Consequently, people's crave for eco-living is increasing. This research is conducted to address these kinds of problems. Using waste paper in concrete can produce new and modern construction material. By using waste paper, the cement amount used reduces as it provides an environmentally friendly construction material (Yun et al., 2007). Portland cement and waste paper are the materials that make a fibrous cemented material called papercrete. Papercrete might be a material initially developed 80 years ago that has recently been rediscovered. It should be noted that papercrete has a limited-range concept (Fuller et al., 2006). For decades, as alternative building material stated by (Fuller et al., 2006), a committed environmentalist has designed homes and structures made of cement, other materials and waste paper. They argued that this papercrete structure is perfect and durable for insulating and durability. A paper reinforced structure is a structurally and economically viable alternative based on the indicated result within a range of size (Titzman, 2006). Portland cement or clay with re-pulped paper fibre develop a new construction material that called papercrete. They identified their discovery of adobe and fibrous cement and found themselves independently (Wikipedia).

Due to the alternative building material known as papercrete, the dead load of the main structure can be diminished (Gunarto et al., 2008). Water and any types of papers such as cardboard, sparkling magazine stock, daily paper, waste mail advertising or any other types of papers are the fundamental components of papercrete. The paper mill produces most of the paper recycling works (Bai et al., 2003; Chin et al., 1998; Chun et al., 2006; Gallardo and Adajar, 2006; Kraus et al., 2003; Naik et al., 2004) or to manufacture cement board (Fuwape at al., 2007; Okino et al., 2000). Other than that, it can end up a reasonable and productive substitute in landfills, incinerators, or other utilize choices (Shukeri and Naser, 2008). Moreover, waste paper can be used in the right way by using it in construction materials to reduce its density, as stated by Yogesh and Mahaveer (Yogesh and Mahaveer, 2017). The building expenses can be reduced by measuring quality, workability, and other papercrete properties (Titzman, 2006). Furthermore, due to its lightweight characteristic, papercrete can also be used for the interior wall of a high-rise building in seismically active regions (Titzman, 2006). Moreover, papercrete usage will decrease the dead load of the structure, the depth of foundation required, and the percentage of steel used, so the labour amount and energy expense will be decreasing significantly (Yogesh and Varma, 2016). Papercrete can grant numerous benefits and wide utilization in concrete. In addition to that, papercrete persuades waste paper recycling, particularly in a community without recycling activity. It cuts the waste space, holds paper production and chemical printing out of the water table (Malthy and Jegatheeswaran, 2011). From previous research, shredded copier and cardboard waste paper have never been used in a reinforced concrete beam (RCB) structural application. So, this research aims to investigate the structural behaviour of RCB containing three different types of concrete mixtures. There are 0% C, 10% addition of shredded copier waste paper (SCPWP) and 10% addition of shredded cardboard waste paper (SCBWP) in the concrete mixture. The investigated structural behaviour of the RCB is load-deflection and ultimate load bearing capacity.

2. Materials and Methods

This research uses cement, sand, coarse aggregate, water, shredded mixed and cardboard waste papers. Ordinary Portland Cement (OPC) used Orang Kuat brand produced by YTL Cement Marketing Sdn. Bhd. to ensure the cement has the same chemical compositions and physical properties as shown in Table 1 (YTL cement, 2015). This type of cement follows MS 522 Part 1:2003 for Portland cement specifications. A local supplier supplied the river sand used in this study. It was obtained from the concrete laboratory at the Faculty of Civil Engineering Technology, Universiti Malaysia Pahang (UMP). The sand used as fine aggregate. Physical properties of sand meet the requirements of British Standard, 1992. Gravel was used as coarse aggregate in this research. The minimum and maximum sizes of gravel are 5 mm and 20 mm. The gravel physical properties meet the prerequisites of British Standard, 1992. The concrete grade used in this research is Grade 30. The reinforcing bars used for compression and tension are 2Y12 and 2Y16 while for the stirrup is R6. Copier and cardboard waste paper were used in this research by collecting them from the office. Both types of paper were then shredded using a paper shredder machine. All sizes and dimensions of shredded waste paper (SWP) used in this research were the same after shredded. Figure 1 and 2 show the shredded copier waste paper (SCPWP) and shredded cardboard waste paper (SCBWP) used in this research.

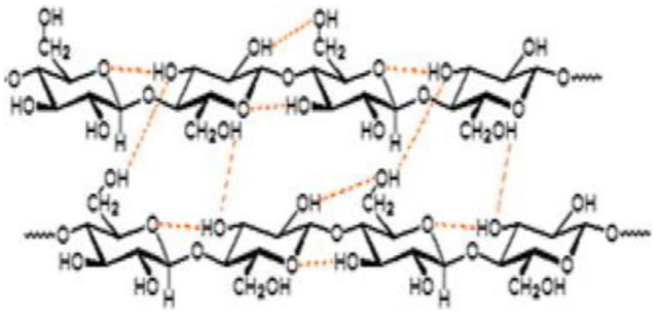
Figure 1: Shredded copier waste paper (SCPWP)

Figure 2: Shredded cardboard waste paper (SCBWP)

Table 1: Chemical compositions and physical properties of OPC [19]

Test	Unit	Specification MS 522-1: 2007 (42.5N)	Test results
		Chemical composition	
Insoluble residue	%	≤ 5.0	0.40
Loss on ignition (LOI)	%	≤ 5.0	3.20
Sulfate content (SO_3)	%	≤ 3.5	2.70
Chloride (Cl^-)	%	≤ 0.1	0.02
		Physical properties	
Fineness	m^2/kg	-	345
Setting time (initial)	min	≥ 60	130
Soundness	mm	≤ 10	1.00

A paper is primarily made of wood cellulose fibre which is known to be a fibrous material. Cellulose is a genuine polymer made by smaller molecules composing associated sugar with a long chain. A sugar type: ß-D glucose is the bonding of the cellulose chain. The polar-OH cellulose bristles make up many hydrogen bonds with OH groups to approach and bundle together the chains, as shown in Figure 3 (Prasad et al., 2015; Iqbal et al., 2017; Harith et al., 2018). The chains also pack in orderly places to form hard and strong regions of crystalline to enable more balance and strength in the bundled chains.



—— Cellulose linear polyglucose joined by β 1-4 bonds
------ Intra and intermolecular hydrogen bonds

Figure 3: Paper chemical structure (cellulose hydrogen bond) (Prasad et al., 2015; Iqbal et al., 2017; Harith et al., 2018)

Table 2 and Table 3 show the fibre properties of two types of waste paper before and after disintegration (Piotr et al., 2007).

Table 2: Fibre properties before disintegration (Piotr et al., 2007)

Types of waste papers	Fibre average length (mm)	Medium fibre content (%)	Long fibre content (%)	Fine fibre and non-fibre contents (%)
Copier	0.40	12	16	66
Cardboard	0.45	23	30	58

Table 3: Fibre properties after disintegration (Piotr et al., 2007)

Types of waste papers	Fibre average length (mm)	Medium fibre content (%)	Long fibre content (%)	Fine fibre and non-fibre contents (%)
Copier	0.42	14	18	68
Cardboard	0.47	25	32	60

Table 4: Strength properties before disintegration (Piotr et al., 2007)

Types of waste papers	Percentage (%)	Bending strength (N/mm^2)	Internal bond (N/mm^2)	Modulus of elasticity (N/mm^2)	Thickness swelling (%)
Copier	0	16	0.28	1600	3
	5	20	0.31	1900	5
	10	26	0.35	2300	10
	15	10	0.23	1200	16
Cardboard	0	16	0.28	1600	3
	5	24	0.33	2100	7
	10	28	0.39	2400	13
	15	14	0.26	1300	18

Table 5: Strength properties after disintegration (Piotr et al., 2007)

Types of waste papers	Percentage (%)	Bending strength (N/mm^2)	Internal bond (N/mm^2)	Modulus of elasticity (N/mm^2)	Thickness swelling (%)
Copier	0	18	0.30	1800	5
	5	22	0.33	2100	7
	10	28	0.37	2500	12
	15	12	0.25	1400	18
Cardboard	0	18	0.30	1800	5
	5	26	0.35	2300	9
	10	30	0.41	2600	15
	15	16	0.28	1500	20

The mixing process of concrete was done by using standard concrete making procedures. The concrete was mixed using a concrete mixer. Before mixing, all the specimens were weighed according to the mix design. SCPWP and SCBWP used as additions in concrete with 10% by weight of the mixture. The cement: sand: aggregate ratio used in this research is 1:0.75:1.5 by

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the weight of the materials and 0.5 is the water to cement ratio used. This ratio is fixed for all specimens. This experiment uses three concrete mix proportions, as presented in Table 6. Figure 4,5,6 show the RCB casting of 0% C, 10% SCPWP and 10% SCBWP concrete mixtures.

Table 6: Concrete mix proportion

Concrete mixture	Cement (kg)	Sand (kg)	Coarse aggregate (kg)	Shredded waste paper (%)	Shredded waste paper (kg)	W/C
0% C	75	56.25	112.5	0	0	0.5
10% SCPWP	75	56.25	112.5	10	28.13	0.5
10% SCBWP	75	56.25	112.5	10	28.13	0.5

Figure 4: 0% C RCB casting

Figure 5: 10% SCPWP RCB casting

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Figure 6: 10% SCBWP RCB casting

The structural behaviour that is load-deflection and ultimate load bearing capacity were investigated using RCB with a size of 1500 mm length x 150 mm wide x 200 mm height. Figure 7 and 8 show the RCB detailing and details of cross-section. Air curing was imposed on all the specimens. The RCB load-deflection and ultimate load bearing capacity were determined by performing a four-point flexural test using a MST hydraulic machine with a maximum load capacity of 300 kN in the Universiti Malaysia Pahang's (UMP) concrete laboratory. The RCB was carefully placed on the MST hydraulic machine using a forklift and tested statically under a four-point flexural test. The three linear variable differential transducers (LVDT) mounted on the RCB's mid-span measured the RCB deflection values. The load was applied at a constant moment region. The applied load was measured using a load cell throughout the test and collected using a device called TDS 302 data acquisition. Figure 9 and 10 show the schematic drawing of RCB test setup and RCB test setup at the UMP's concrete laboratory.

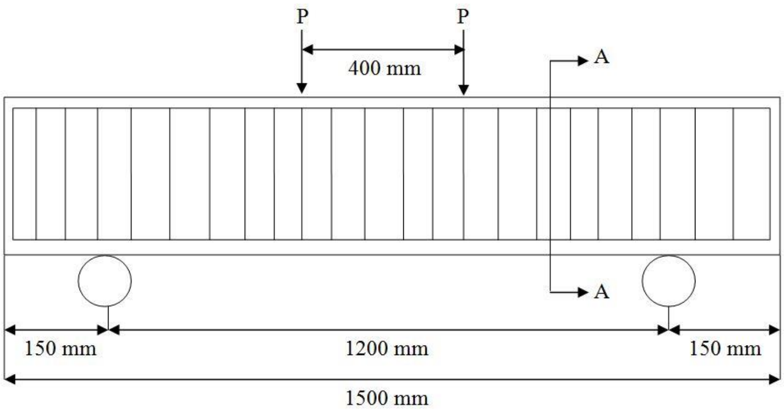

Figure 7: RCB detailing

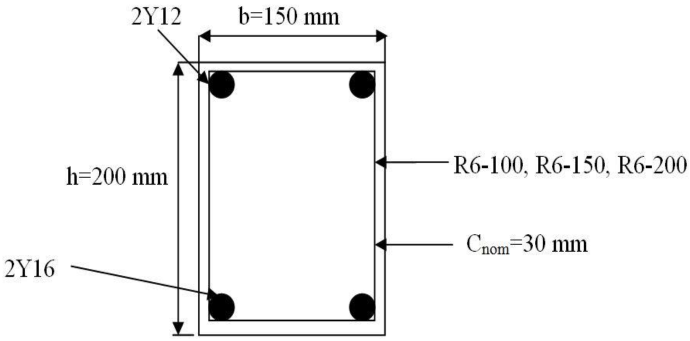

Figure 8: Details of cross-section A–A

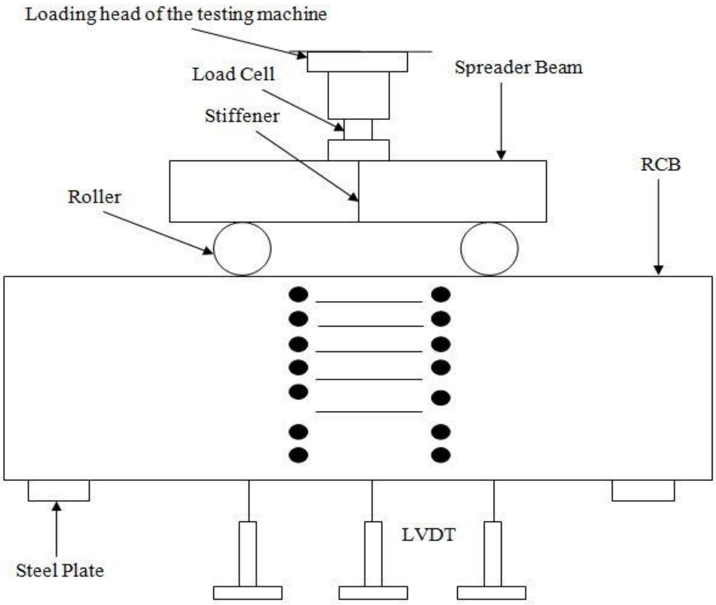

Figure 9: Schematic drawing of RCB test setup

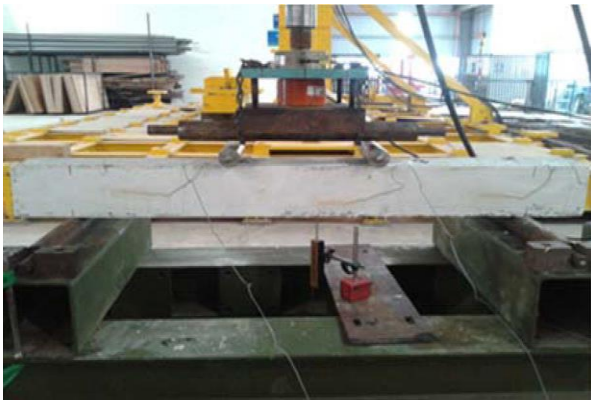

Figure 10: RCB test setup

3. Results and Discussion

Load-Deflection

Figure 11 shows the load-deflection curve of RCB with full shear reinforcement with SS=100 mm at 28 days with air curing. Table 7 shows the values of load at yield (Py), ultimate load (Pu) and maximum load (Pmax), yield deflection (δy), ultimate deflection (δu), maximum deflection (δmax) and ductility ratio (μ=δu/δy) of the RCB with SS=100 mm. The specimen result is affected by the types of SWP and SS. The load-deflection increases with 10% SCPWP and 10% SCBWP addition in the concrete mixture with SS=100 mm. The 10% SCBWP records the highest Py, Pu, Pmax and the lowest δy, δu, δmax compared to 10% SCPWP and 0% C. 10% SCBWP records Py=96.67 kN, Pu=103.15 kN, Pmax=106.78 kN, which are the highest and δy=11.98 mm, δu=23.04 mm, δmax=18.12 mm, which are the lowest compared to 10% SCPWP and 0% C. 0% C records Py=89.01 kN, Pu=90.23 kN, Pmax=100.12 kN, which are the lowest and δy=13.12 mm, δu=25.03 mm, δmax=20.27 mm, which are the highest compared to 10% SCPWP and 10% SCBWP. For 10% SCPWP, Py, Pu, Pmax increase to 4.87%, 7.02%, 3.33%, while for 10% SCBWP, increase to 8.61%, 14.32%, 6.65% respectively in comparison with 0%. The δy, δu, δmax decrease to 4.19%, 2.76%, 4.05% for 10% SCPWP and 8.69%, 7.95%, 10.61% for 10% SCBWP compared to 0% C.

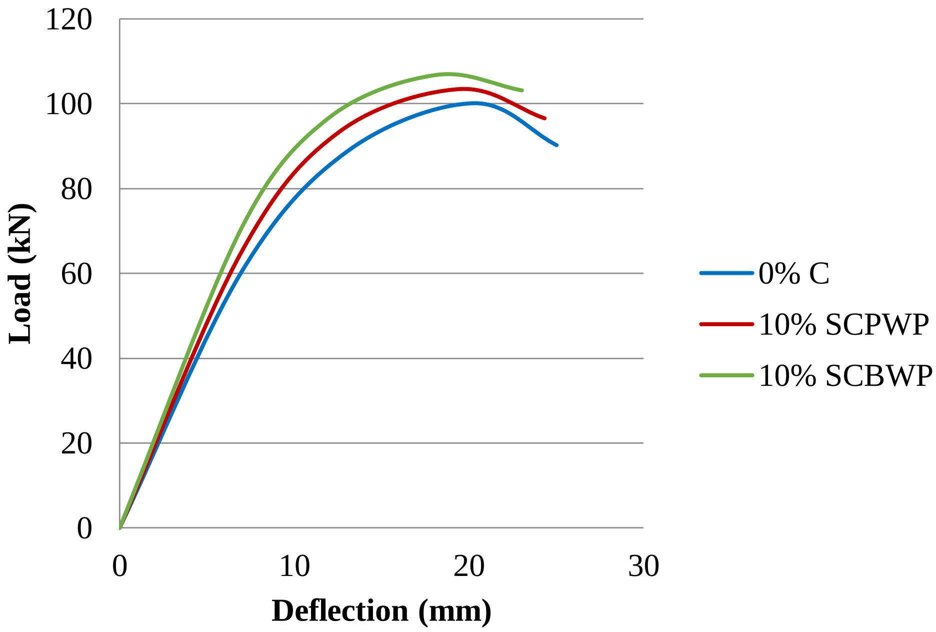

Figure 11: Load-Deflection curve of RCB with full shear reinforcement with SS=100 mm

Table 7: RCB test result with full shear reinforcement with SS=100 mm

Concrete mixture	Py (kN)	δy (mm)	Pu (kN)	δu (mm)	Pmax (kN)	δmax (mm)	u=δu/δy
0% C	89.01	13.12	90.23	25.03	100.12	20.27	1.91
10% SCPWP	93.34	12.57	96.56	24.34	103.45	19.45	1.94
10% SCBWP	96.67	11.98	103.15	23.04	106.78	18.12	1.92

Figure 12 shows the load-deflection curve of RCB with reducing shear reinforcement with SS=150 mm at 28 days with air curing. Table 8 shows the values of load at yield (Py), ultimate load (Pu) and maximum load (Pmax), yield deflection (δy), ultimate deflection (δu), maximum deflection (δmax) and ductility ratio (μ=δu/δy) of the RCB with SS=150 mm. The specimen result is affected by the types of SWP and SS. The load-deflection increases with 10% SCPWP and 10% SCBWP addition in the concrete mixture with SS=150 mm. The 10% SCBWP records the highest Py, Pu, Pmax and the lowest δy, δu, δmax compared to 10% SCPWP and 0% C. 10% SCBWP records Py=76.78 kN, Pu=81.03 kN, Pmax=84.89 kN, which are the highest and δy=9.46 mm, δu=18.11 mm, δmax=13.78 mm, which are the lowest compared to 10% SCPWP and 0% C. 0% C records Py=70.12 kN, Pu=72.34 kN, Pmax=80.23 kN, which are the lowest and δy=10.36 mm, δu=20.04 mm, δmax=15.11 mm, which are the highest compared to 10% SCPWP and 10% SCBWP. For 10% SCPWP, Py, Pu, Pmax increase to 4.75%, 5.99%, 2.90%, while for 10% SCBWP, increase to 9.50%, 12.01%, 5.81% respectively in comparison with

0% C. The δy, δu, δmax decrease to 4.73%, 4.04%, 3.71% for 10% SCPWP and 8.69%, 9.63%, 8.80% for 10% SCBWP compared to 0% C.

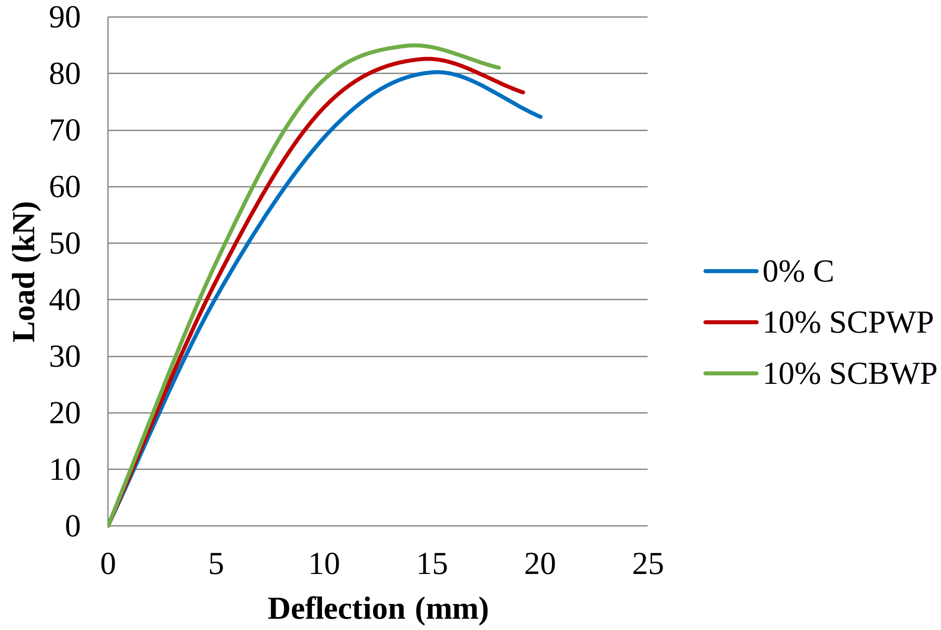

Figure 12: Load-Deflection curve of RCB with reducing shear reinforcement with SS=150 mm

Table 8: RCB test result with reducing shear reinforcement with SS=150 mm

Concrete mixture	Py (kN)	δy (mm)	Pu (kN)	δu (mm)	Pmax (kN)	δmax (mm)	u=δu/δy
0% C	70.12	10.36	72.34	20.04	80.23	15.11	1.93
10% SCPWP	73.45	9.87	76.67	19.23	82.56	14.55	1.95
10% SCBWP	76.78	9.46	81.03	18.11	84.89	13.78	1.91

Figure 13 shows the load-deflection curve of RCB with full shear reinforcement with SS=200 mm at 28 days with air curing. Table 9 shows the values of load at yield (Py), ultimate load (Pu) and maximum load (Pmax), yield deflection (δy), ultimate deflection (δu), maximum deflection (δmax) and ductility ratio (μ=δu/δy) of the RCB with SS=200 mm. The specimen result is affected by the types of SWP and SS. The load-deflection increases with 10% SCPWP and 10% SCBWP addition in the concrete mixture with SS=200 mm. The 10% SCBWP records the highest Py, Pu, Pmax and the lowest δy, δu, δmax compared to 10% SCPWP and 0% C. 10% SCBWP records Py=46.27 kN, Pu=60.27 kN, Pmax=64.30 kN, which are the highest and δy=4.76 mm, δu=13.27 mm, δmax=8.98 mm, which are the lowest compared to 10% SCPWP and 0% C. 0% C records Py=40.36 kN, Pu=50.46 kN, Pmax=60.51 kN, which are the lowest and δy=5.13 mm, δu=15.16 mm, δmax=10.04 mm, which are the highest compared to 10% SCPWP and 10% SCBWP. For 10% SCPWP, Py, Pu, Pmax increase to 7.98%, 9.89%, 2.68%, while for 10% SCBWP, increase to 14.64%, 19.44%, 6.26% respectively in comparison with 0% C. The δy, δu, δmax decrease to 4.09%, 5.15%, 4.78% for 10% SCPWP and 7.21%, 12.47%, 10.56% for 10% SCBWP compared to 0% C.

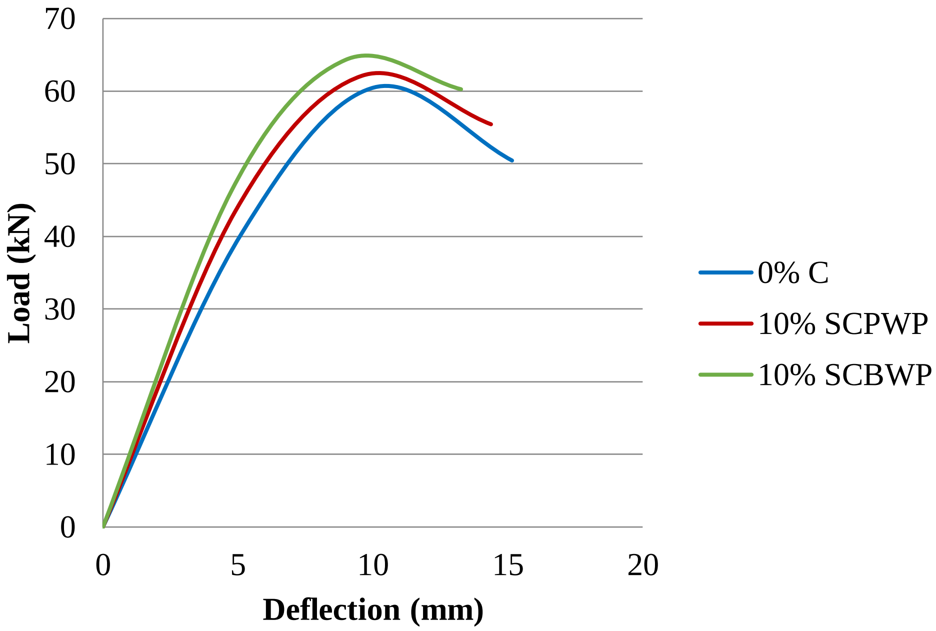

Figure 13: Load-Deflection curve of RCB with reducing shear reinforcement with SS=200 mm

Table 9: RCB test result with reducing shear reinforcement with SS=200 mm

Concrete mixture	Py (kN)	δy (mm)	Pu (kN)	δu (mm)	Pmax (kN)	δmax (mm)	u=δu/δy
0% C	40.36	5.13	50.46	15.16	60.51	10.04	2.96
10% SCPWP	43.58	4.92	55.45	14.38	62.13	9.56	2.92
10% SCBWP	46.27	4.76	60.27	13.27	64.30	8.98	2.79

The result of load-deflection values follows the P1000 & P9000 standards for less than 1500 mm span simply supported beam (Atkore International, 2016). Nevertheless, the improvement of load at yield (Py) and maximum load (Pmax) of SCPWP and SCBWP RCB with reduced shear reinforcements with SS=150 mm and SS=200 mm are unimportant. The load-deflection curve shows that the 0% C RCB failed earlier as compared to RCB with SS=100 mm as in Figure 4.9. In addition to that, Pseudo strain hardening effect or multiple cracking behaviours were shown for RCB with SS=100 mm with 10% SCPWP and 10% SCBWP. Strain hardening is typical behaviour of metal, but experimental work has been demonstrated that short fibre-reinforced composites often display similar behaviour under increasing load accompanied by multiple cracking due to the arrest of microcrack by fibres (Li et al., 1993). With the addition of fibre to the matrix, the bond between the matrix, dowel action and aggregate interlock mechanism increase and cause the load at yield (Py) to increase. (Martin, 2008) stated that the fibre serves as a cracking mechanism or a crack arrestor after cracking has initiated and causes many cracks, resulting in maximum load (Pmax) to increase. Furthermore, for 10% SCBWP, the RCB is less deflects compared to the RCB containing 10% SCPWP and 0% C RCB. It is also clear that the lower the shear reinforcements of SS=150 mm and SS=200 mm, the lower the ultimate displacement. The major role of adequate fibre plays the rising load at yield (Py), maximum load (Pmax) and pseudo stress hardening RCB effect. SWP enhances the load at yield (Py) and maximum load (Pmax) of RCB structure. Subsequently, RCB with full shear reinforcement with SS=100 mm containing 10% SCPWP and 10% SCBWP have a significant role of fibre, which improves the RCB structural behaviour by showing the pseudo strain hardening (multiple cracking) on the RCB surface. The ultimate deflection (δu) is calculated concerning yield deflection (δy) to obtain the ductility ratio (μ) in this study.

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In general, a high ductility ratio shows that a structural member is able to undergo significant deflection before failure. The reinforced concrete structure ductility is essential because each member should undergo substantial deflection at near maximum load-bearing capacity and provide ample warning when the structure is near faulty. Satisfactory ductility is observed in this research for RCBs with SS=100 mm. The findings show a significant increase in ductility of the RCB when sufficient SWP are added to the mixture. The maximum ductility improvement is obtained from the RCB with SS=100 mm with 10% SCBWP and cause the ductility increases to 4.68%. For 10% SCPWP, the ductility increases to 5.47% compared to 0% C RCB. It is investigated that the ductility increases up to a certain point before reducing upon the addition of concrete containing 10% SCPWP and 10% SCBWP. (Syed Mohsin, 2012) showed a similar pattern in which the RCB becomes stiff and fails with less ductility due to more fibres added to the RCB. As crack initiates, the fibre prevents crack growth and creates multiple cracks, ultimately increases the ductility. Since the 10% SCPWP and 10% SCBWP RCBs are more brittle than the C RCB, the ductility shows significant improvement in the structural properties of the RCB with the incorporation of SCPWP and SCBWP. The presence of 10% SCPWP and 10% SCBWP in RCB structures show the ability to control the propagation of cracks and significantly improve the strength and structure ductility.

Ultimate Load Bearing Capacity

The initial cracking of the 0% C RCB took place at a shear distance of 60.47 kN. Eventually, P_1 occurs at 65.22 kN for 10% SCPWP and 70.84 kN for 10% SCBWP with full-shear reinforcement with SS=100 mm. There are 7.86% and 17.15% difference increases for 10% SCPWP and 10% SCBWP compared to 0% C. The Pu are 90.23 kN, 96.56 kN and 103.15 kN for 0% C, 10% SCPWP and 10% SCBWP. There are 7.02% and 14.32% difference increases for 10% SCPWP and 10% SCBWP compared to 0% C. The cracks propagate at two surfaces, which are front and back of the RCB upon load increasing. For 0% C with reducing shear reinforcement with SS=150 mm, a failure occurs in the shear span of the RCB indicated as a shear failure with 72.34 kN Pu. 76.67 kN for 10% SCPWP and 81.03 kN for 10% SCBWP. There are 5.99% and 12.01% differences increase for 10% SCPWP and 10% SCBWP compared to 0% C. For P_1, 10% SCBWP shows a higher value which is 46.50 kN than 10% SCPWP and 0% C, which are 43.24 kN and 40.36 kN. There are 7.54% and 15.21% difference increases for 10% SCPWP and 10% SCBWP compared to 0% C. On the other hand, the P_1 initiates at 20.86 kN, 24.17 kN and 28.53 kN in shear span for the RCB with reducing shear reinforcement with SS=200 mm with 0% C, 10% SCPWP and 10% SCBWP and induces fail in shear at Pu of 50.46 kN, 55.45 kN and 60.27 kN. There are 15.87% and 36.77% differences increase for 10% SCPWP and 10% SCBWP compared to 0% C for P_1 and 9.89% and 19.44% difference increases for 10% SCPWP and 10% SCBWP for Pu. The RCB fails with multiple cracking upon load increasing. Table 10 shows the first crack and ultimate loads for all RCB. The result of P_1 and Pu values follows the P1000 & P9000 standards for less than 1500 mm span simply supported beam (Atkore International, 2016).

Table 10: Load at first crack and ultimate load

Concrete mixture	Stirrup spacing (mm)	Load at first crack (P_1) (kN)	Ultimate load (Pu) (kN)
0% C	100	60.47	90.23
10% SCPWP	100	65.22	96.56
10% SCBWP	100	70.84	103.15
0% C	150	40.36	72.34
10% SCPWP	150	43.24	76.67
10% SCBWP	150	46.50	81.03
0% C	200	20.86	50.46
10% SCPWP	200	24.17	55.45
10% SCBWP	200	28.53	60.27

If reinforced concrete exhibits many cracks and ultimate concrete strength is higher than P_1, it may demonstrate pseudo strain hardening or pseudo ductility during increasing tensile load (Jiang, 2003). This result clarifies that fibres are not sufficient to increase the RCB shear strength to prevent shear failure. Besides that, this demonstrates that an adequate quantity of fibre in RCB with reducing shear reinforcement influences the shear failure from occurring. The cracks propagate at the bottom of the RCB and with further increase in load, the flexural failure ensues. Fibre pullout mechanism acts as cracks arrester, increasing the number of cracks at the bottom of the RCB and reducing cracks width. The presence of fibre in the mix, thus increases the tension contribution of concrete and limited diagonal cracks opening. Moreover, (Martin, 2008) said that fibres control the shear cracks, the mechanism of aggregate interlock, and improve the RCB dowel movement. Furthermore, most other cracks have been found in the 10% SCPWP and 10% SCBWP RCB in a small size to decrease the crack width and increase the number of cracks by the inclusion of fibre. It is obviously evident that fibre increases the tensile characteristic and prevents the crack growth through the pullout mechanism that improves the RCB structural properties. Thus, the shear reinforcement is enhanced by a sufficient amount of fibre by changing from shear to bending for 10% SCPWP and 10% SCBWP RCB failure modes and inhibiting diagonal cracks.

On the other hand, the result shows that fibre is suitably used to control the RCB's crack distribution. There are more cracks form on the RCB as the load increases. The experimental test result also shows that the RCB with fibre increases the load-carrying capacity after cracking. 0% C RCB failure occurs because of insufficient shear strength capacity in shear compression failure. As a result, the fibres are used as a part of shear reinforcement. Both RCB show multiple cracking behaviours with full shear reinforcement with SS=100 mm with 10% SCPWP and 10% SCBWP than the other four RCB with reducing shear reinforcements with SS=150 mm and SS=200 mm. The crack formations were marked on the RCB, which is inevitably detected from the first crack near to the RCB middle span. The cracks formation on the RCB surface is mainly vertical, suggesting that there is a shear failure occurs. It is noted that the number of cracks increases and there are multiple cracking failures by increasing the amount of fibre. The result shows that the formation of the first crack is mainly affected by the amount of fibre. This first crack formation means that the amount of fibre increases the first cracking load and reduces the crack width. In conclusion, the first cracking load increases and the crack width reduces by the influence of fibre. Subsequently, it is also found that an appropriate amount of fibre increases the RCB strength (Py and Pmax) and changes the RCB failure mode from shear to bending.

4. Conclusion

The Py, Pu, Pmax and P_1 increase with 10% SCPWP and 10% SCBWP RCB with full shear reinforcement with SS=100 mm and reduced shear reinforcements with SS=150 mm and SS=200 mm compared to 0% C. 10% SCBWP RCB records the highest Py, Pu, Pmax and P_1 for all types of SS. The δy, δu and δmax decrease with 10% SCPWP and 10% SCBWP RCB with full shear reinforcement with SS=100 mm and reduced shear reinforcements with SS=150 mm and SS=200 mm compared to 0% C. 10% SCBWP RCB records the lowest δy, δu and δmax for all types of SS. The 0% C, 10% SCPWP and 10% SCBWP RCB with full shear reinforcement with SS=100 mm records higher Py, δy, Pu, δu, Pmax, δmax and P_1 than reduced shear reinforcements with SS=150 mm and SS=200 mm. 10% SCBWP RCB records the highest Py, δy, Pu, δu, Pmax, δmax and P_1. Generally, 10% addition of SCPWP and SCBWP is the ideal concrete mix proportion. Using SWP in concrete and RCB, the paper industry disposal cost can be saved, and sustainable concrete and RCB can also be produced in the construction and civil engineering fields. The utilization of waste material such as SWP as additional alternative material in concrete and RCB will benefit the environment. The advantage of using this waste material also gives benefit to the economy in term of cost-effectiveness.

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