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Behaviour of hybrid fibers in oil palm shell and palm oil fuel ash reinforced concrete beam

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ABSTRACT – This paper presents the investigation of structural behavior of hybrid fibers in oil palm shell (OPS) and palm oil fuel ash (POFA) reinforced concrete beam. Four-point bending test was conducted on five beams with various fiber volume fraction ranging from 0 % to 2.0 %. Based on the results obtained, it was observed that fibers have the capability to increase the load carrying capacity, shear strength and ductility of the beam. Moreover, the crack propagation is lower when the amount of fiber is increased.

1. INTRODUCTION

Palm oil industries is one of the biggest industry in Malaysia. Being one of the largest palm oil producers in the world, the industry continuing generates high solid waste, for example OPS and POFA. The wastes produced needs to manage and dispose in appropriate manner that may contribute to some environmental problems. Thus, in order to cater these issues, some researcher attempted to reuse the waste to produce green material, and one of the way is to replace some of the material in concrete [1-4]. For instance, the OPS have been used to replace the aggregate whereas the POFA is used as partial cement replacement [1-2,4], thus producing a lightweight aggregate concrete. However, lightweight concrete is a brittle material. Therefore, in order to add ductility to the concrete, fibres are added into the concrete mixture. This is because fibres have the capability to improve the strength and ductility of the reinforced concrete structures [3,5].

2. METHODOLOGY

In order to study the structural behavior of hybrid fibers in OPS and POFA reinforced concrete beam, two types of fibers, namely kenaf fiber and steel fiber are mixed into the concrete. The type of steel fiber used is hooked end with aspect ratio of 120. Whereas, for kenaf fiber the specification is 30 mm length and diameter in range 0.5 – 1.5 mm.

The ratio of the fiber is half. Five volume fractions are considered; 0%, 0.5%, 1.0%, 1.5% and 2.0% represented in Mix1, Mix2, Mix3, Mix4 and Mix5, respectively, as shown in Table 1. The coarse aggregate of the beam is fully replaced with OPS, whereas 20% of POFA is used to replace the cement. The OPS is sieved to get the size of 15 mm. Water cement ratio considered for this study is 0.5. To maintain water cement ratio, superplasticizer is added as addition of fibers onto the mixture will reduce its workability.

Table 1 Concrete mix design.

Properties	**Mix 1**	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**
V_f (%)	0	0.50	1.00	1.50	2.00
Water(kg)	18.00	18.00	18.00	18.00	18.00
OPS (kg)	26.00	26.00	26.00	26.00	26.00
POFA(kg)	7.14	7.14	7.14	7.14	7.14
OPC(kg)	29.00	29.00	29.00	29.00	29.00
Sand(kg)	62.00	62.00	62.00	62.00	62.00
SP (kg)	0.60	0.60	0.60	0.60	0.60
Kenaf fiber (kg)	0	0.25	0.50	0.83	1.08
Steel fiber (kg)	0	1.52	2.95	4.47	5.99

A square beam of 150 x 150 mm is constructed with total length of 1500 mm. 3T10 and 2T10 are used for its tensile and compressive longitudinal reinforcement, while R6 is used for its shear reinforcement. The loading arrangement, shear links spacing and dimension of the beam are given in Figure 1. All the beam is tested on 28th day.

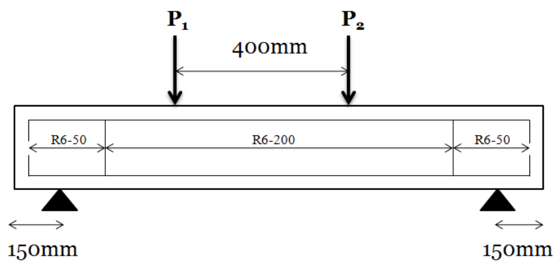

Figure 1 Loading arrangement and beam dimension.

3. RESULTS AND DISCUSSION

Figure 2 shows the load versus deflection curves of the tested beams. It can be seen that, as the amount of fibers increases, the stiffness and the load carrying capacity of the beam increased as well. The key data extracted from the load-deflection curves such as Yield Load (Py) and its deflection (δy), Maximum Load Carrying Capacity (Pmax) and its deflection (δmax) and Ultimate Load (Pu) before failure and ultimate deflection (δu), are summarized in Table 2.

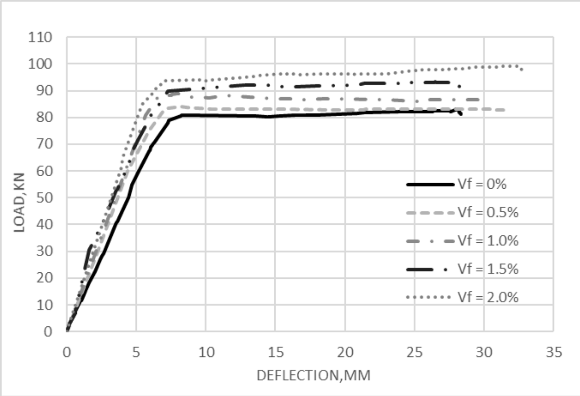

Figure 2 Load vs deflection curves.

From the table, it can be seen that the as the fiber content increases, the strength (Py and Pmax) of the beam also increase. This is due to the fact that fibers reduce the rate of crack propagation, and higher forces is required in order to produce larger crack width. Indirectly, the load carrying capacity of the beam will also increase. In term of ductility, μ is ductility ratio obtained by dividing δu by δy as shown in Table 2. It can be seen that the ductility ratio of the beam continuing to increase up to 1.5% of fiber content. This is the limit of the fibers amount of the beam. After this amount, the ductility ratio is reduced due to the effect of multiple cracking.

Table 2 Key results from the load-deflection curves.

Properties	**Mix 1**	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**
V_f (%)	0	0.5	1.0	1.5	2.0
Py (kN)	58.40	64.20	70.60	76.10	78.30
δy (mm)	5.01	5.20	5.23	5.30	5.40
Pmax (kN)	80.66	83.50	88.70	89.80	94.00
δmax (mm)	7.20	7.28	73.30	7.38	7.40
Pu (kN)	78.90	80.50	86.80	88.00	92.00
δu (mm)	21.60	23.30	25.50	24.00	23.30
μ	4.31	4.48	4.88	4.53	4.32

The load at first crack and cracking pattern of the beam at failure is shown in Figure 3. Similarly, the values of the load at first crack is also in upward sequence as the amount of fibers are increased. For the 1st beam with 0% fiber, the beam failed in shear-bending mode. Adding hybrid fibers change the failure mode to a more ductile one, as the beam now show bending mode of failure. However, as explained earlier, as the optimum amount of fibers is observed at 1.5%, the mode of failure now become bending-shear.

4. CONCLUSION

Hybrid fiber consistently enhances the load carrying capacity and the ductility of the beam. Furthermore, the fibers help in slowing the crack propagation, thus improves the strength of the reinforced concrete beam. However, sufficient amount of superplasticizer is needed in order to improve the workability of the mixture while maintaining the water cement ratio.

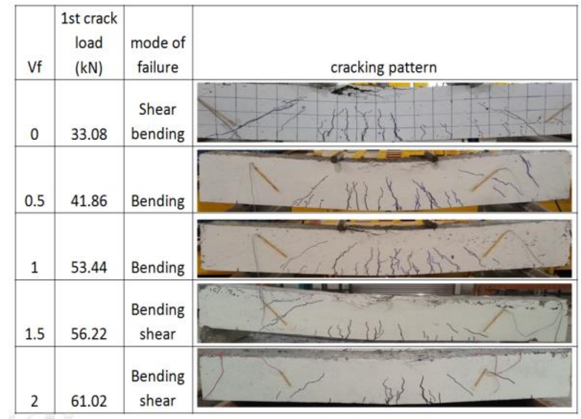

Figure 3 Beam failure mode and cracking pattern.

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