Behaviour of Oil Palm Shell Reinforced Concrete Beams Added With Kenaf Fibres

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Abstract. The present article reports the findings of a study into the behaviour of oil palm shell reinforced concrete (OPSRC) beams with the addition of kenaf fibres. This work aims at examining the potential of kenaf fibres to improve the strength and ductility of the OPSRC beams as well as observing its potential in serving as part of shear reinforcement in the beams. Two different arrangements of the shear links in OPSRC beams with a selection of kenaf fibres content (10kg/m^3 and 20kg/m^3, respectively) were tested under monotonic loading. The results show that the addition of kenaf fibres enhances the load carrying capacity, ductility apart from altering the failure mode of the beams from brittle shear mode to flexural ductile mode. Furthermore, the study shows that kenaf fibres are compatible with OPSRC with desirable results.

Introduction

As one of the major oil palm producers in the world, Malaysia contributes to over 4 million tonnes oil palm shell (OPS) as agricultural waste [1,2]. Therefore, in order to preserve the environment, plenty work on using OPS as lightweight aggregate in lightweight concrete are carried out [1-4]. However, the performance of the OPS concrete with natural fibres has never been published. The current work incorporates the use of kenaf fibres in concrete as this type of fibre reinforced concrete was reported to be a potentially promising "green" construction material to be used in a number of different structural applications [5].

Therefore, the present work sets to investigate the potential advantages of adding kenaf fibres to oil palm shell concrete in order to enhance the structural response of the concrete structures. Furthermore, potential of kenaf fibres as part of shear reinforcement in oil palm shell (OPS) reinforced concrete beams were also observed by testing the beams with different amount of shear reinforcement.

Methodology

Preparation of the OPS concrete mixtures. Table 1 lists the properties of the OPS concrete mixtures. OPS kernels were taken from a local factory and was washed with soapy water before it was left for air dry. The OPS then was sieved and only those with size between 10 mm to 20 mm were used in the mixture.

On the other hand, the kenaf fibres included in the mixtures were 30 mm of length with a diameter between 0.1 mm to 2 mm. The amounts of fibres considered in this study were 10 kg/m^3 and 20 kg/m^3, respectively. The water/cement ratio of the mixture was set to 0.4. One mixture of the OPS concrete was used to cast the beam with full shear reinforcement, and this beam was taken as control beam.

Table 1 Properties of the OPS concrete mixtures

Content	Mix 1	Mix 2	Mix 3
Ordinary Portland Cement (kg/m^3)	510	510	510
Oil palm shell (kg/m^3)	848	848	848
Sand (kg/m^3)	308	308	308
Water (kg/m^3)	204	204	204
Superplasticizer (kg/m^3)	20.4	20.4	20.4
Kenaf fibres (kg/m^3)	0	10	20

Testing. The loading arrangement and reinforcement properties of the beam are illustrated in Fig. 1 and Fig. 2. The beams were initially designed with shear reinforcement less than that is required to cause shear failure. Two arrangements were considered (i) full shear reinforcement and (ii) reduced in shear reinforcement (this was carried out by increasing the spacing between the shear links by 50 %). Subsequently, two amounts of fibres contents were added into the OPS concrete mixture to examine the effect of kenaf fibres in OPS reinforced concrete beams. Therefore, five beams (three for full shear reinforcement and two for reduced in shear reinforcement) were tested under four-point bending test. The beam with full shear reinforcement without fibres was considered as the control beam. The test was carried out on the 56th day in order to ensure that the OPS reinforced concrete beams added with kenaf were fully hardened.

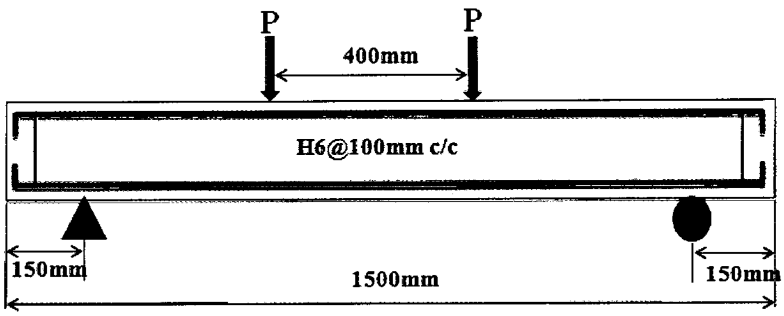

Figure 1 Loading arrangement and dimensions of the beam

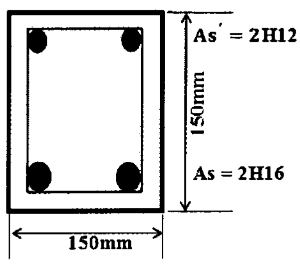

Figure 2 Main reinforcement arrangement and dimensions of the beam

Results

OPS Reinforced Concrete Beams With Full Shear Reinforcement. Fig. 3 illustrates the load-deflection curves of the experimental work obtained for OPS-kenaf fibre reinforced concrete (OPS_KFRC) beams for full shear reinforcement arrangement. It could be observed from the load-deflection curves, that the beam without fibres failed early at a deflection of 12 mm and at a load carrying capacity of 69.8 kN. However, the beams with the inclusion of fibres show an increase in the peak strength and ductility as the fibres content is increased.

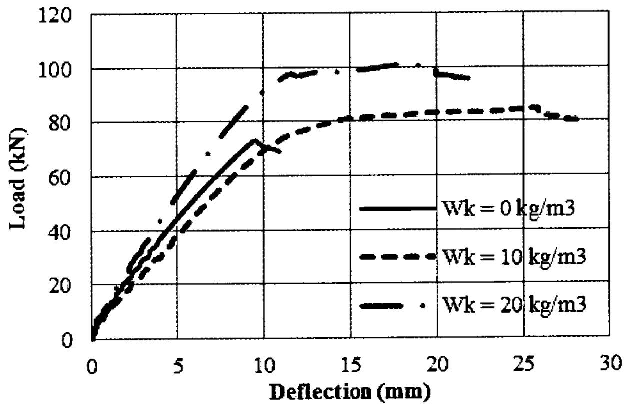

Figure 3 Load-deflection curves for OPS-KFRC beams with various fibres content

To study this further, the key results have been summarised in Table 2 below (where P_{max} represents the maximum strength, $P_{max,o}$ represents the maximum strength of the control beam, P_u the ultimate (i.e. residual) strength, δ_y the yield deflection, δ_u the ultimate deflection and μ the ductility). The table shows that the peak strength of the beam is increased to up to 22% with W_k = 20 kg/m^3. Notable increase in the stiffness can also be seen for beams with higher content of fibres. This suggests that there are clear benefits of adding fibres at the serviceability limit state. Furthermore, significant increase in the ductility to up to 67% may be observed from both Fig. 3 and Table 2. This demonstrates that with the inclusion of the fibres facilitates ductile mode of failure.

Table 2 Results for OPS-KFRC beams (* this ratio represents the change in maximum strength, † this ratio represents the change in residual strength, ‡ this ratio represents the change in ductility)

W_k (kg/m^3)	P_{max} (kN)	P_{max}/ P_{maxo}*	P_u (kN)	P_u/ P_{max}†	Δy (mm)	δu (mm)	μ=δu/ δy ‡
0	73.4	1.00	69.8	0.95	10	12	1.20
10	78.0	1.06	82.0	1.05	12	24	2.00
20	89.4	1.22	90.8	1.02	12	20	1.67

Fig. 4, Fig. 5 and Fig. 6 show the cracking of the beams with W_k = 0 kg/m^3, W_k = 10 kg/m^3 and W_k = 20 kg/m^3, respectively at failure. The results obtained implies that the fibres acts appropriately in controlling the crack propagation of the beam. Hence, sufficient amount of fibres serve potential as part of shear reinforcement, which in turn changes the mode of failure from brittle (beam without fibres) to a more ductile manner (beam with fibres).

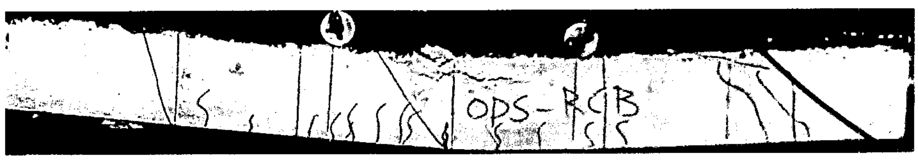

Figure 1 OPS reinforced concrete beam without fibres (Control beam)

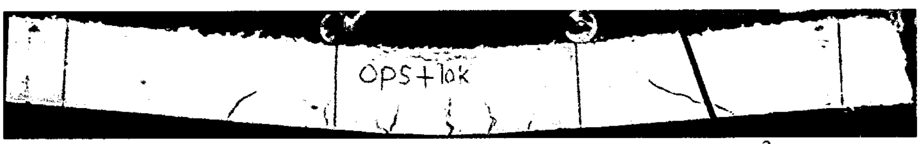

Figure 2 OPS reinforced concrete beam added with 10 kg/m^3 kenaf fibres

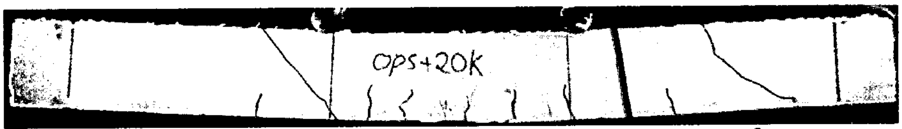

Figure 3 OPS reinforced concrete beam added with 20 kg/m^3 kenaf fibres

OPS Reinforced Concrete Beams With Reduced Shear Reinforcement. A further investigation was carried out by reducing the shear reinforcement (this is carried out by increasing the spacing between the shear links by 50%), adding two amounts of kenaf fibres and testing under four-point bending test. The results obtained is depicted in Fig. 7 and are summarized in Table 3. In this shear links arrangement, only beams with inclusion of fibres were tested as the beam without fibres was believed to fail in more brittle manner compare to the control beam.

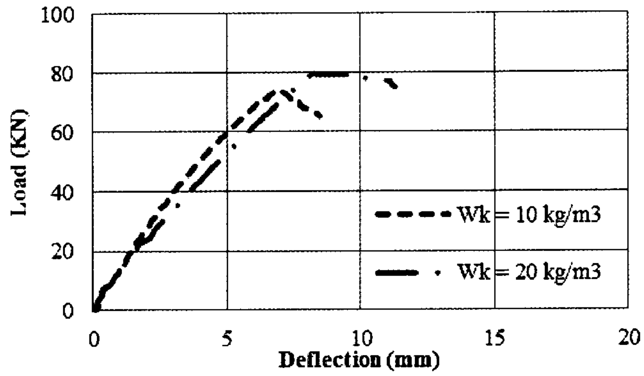

Figure 7 Load-deflection curves for OPS-KFRC beams with reduced in shear reinforcement

Table 2 Results for OPS-KFRC beams with reduced in shear reinforcement (* this ratio represents the change in maximum strength, † this ratio represents the change in residual strength, ‡ this ratio represents the change in ductility)

W_k (kg/m^3)	P_{max} (kN)	P_{max}/ P_{maxo}*	P_u (kN)	P_u/ P_{max}†	δy (mm)	δu (mm)	μ=δu/ δy ‡
10	74.2	1.01	65.0	0.88	8	9	1.10
20	80.0	1.09	78.8	0.88	8	12	1.46

The results show that the peak strength of the beams with reduced in shear reinforcement increased up to 10% in comparison to the control beam (with full shear reinforcement). Sufficient ductility is observed for both beams with 10% for W_k = 10 kg/m^3 and 46% for W_k = 20 kg/m^3. In comparison to the control beam, the ultimate deflection obtained for beam with W_k = 10 kg/m^3 is similar at 12 mm. This reflects the extremely brittle nature of the beams with reduced shear links and demonstrates the potential for fibres to enhance both peak strength and ductility.

Conclusion

A study on the behaviour of OPS reinforced concrete beams added with kenaf fibres was carried out. An enhancement in the load carrying capacity and ductility was observed with the presence of fibres. Similar results were observed on the study carried out for steel fibres [6]. This demonstrates that kenaf fibres serve good potential in restraining the crack propagation of the beam, hence contributing to higher strength and ductility. Furthermore, the mode of failure of the beams was observed to change into a ductile manner with the inclusion of fibres. Therefore, this result shows that kenaf fibres have potential to compensate for a reduction in shear links. This can be useful in situations where the amount of shear reinforcement required can lead to congestion of the links and can also simply complex construction arrangements.

Acknowledgement

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References

[1] U. J. Alengaram, B. G. Al Muhit, and M. Z. Jumaat, Utilization of oil palm kernel shell as lightweight aggregate in concrete – A review, Construction and Building Materials 38 (2013) 161–172.

[2] D. C. L. Teo, M. A. Mannan, V. J. Kurian, and C. Ganapathy, Lighweight concrete made from oil palm shell (OPS): Structural bond and durability properties, Building and Environment 42 (2007) 2614–2621.

[3] U. J. Alengaram, M. Z. Jumaat, H. Mahmud, and M. M. Fayyadh, Shear behaviour of reinforced palm kernel shell concrete beams, Construction and Building Materials 25 (2011) 2918–2927.

[4] M. A. Mannan, and C. Ganapathy, Concrete from agricultural waste-oil palm shell (OPS), Building and Environment 39 (2004) 441–448.

[5] A. Elsaid, M. Dawood, R. Seracino, and C. Bobko, Mechanical properties of kenaf fiber reinforced concrete, Construction and Building Materials 25 (2011) 1991–2001.

[6] S. Syed Mohsin, A. Abbas, and D. Cotsovos, Shear behaviour of steel-fibre-reinforced-concrete beams, 11th International Conference on Concrete Engineering and Technology 2012 (CONCET2012).