Application of Flexural Timber Reinforcement in Light Concrete Beam Structure

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Abstract. Timber is a capable alternative for reinforcement in concrete beam because it possesses high strength ratio compare to its weight although its strength is incompatible to steel. This study was conducted to highlight the flexural behaviour of beam reinforced with two types of timber; *Balau* and *Meranti*. Comparisons of behaviour have been made between samples applying the Reinforced Concrete Design to EC2. The result of flexural test shows that steel reinforcement beam (SRB) carried the utmost loads compared to timber sample beam which reinforced with *Balau* (BRB) and *Meranti* (MRB). Compared to the flexural strength of SRB, BRB reached about 69 % of the value while MRB reached to 66 % respectively. It was found that the failure mode of the timber beam was closely related to the load-deflection behaviour same as conventional steel beam. The larger the load-deflection value, the wider the range of cracking occurred.

Introduction

Structure assembly that constructed from timber have played an important role in construction industry for centuries especially in countries which have good resource of timber. Basically, timber is tough, strong and long lasting element. Timber has been used as a construction material in many ways. Usages for the entire structure are well known for houses and bridges. The usage of timber as a reinforcement material in concrete is rarely known. Its application as a reinforcement material in concrete structure had received very little attention.

Timber and concrete are inexpensive building material. Both are relatively easy to work on. As composite elements, timber can provides tensile strength for the concrete in a same way of steel reinforcement. Several researchers had conducted full scale testing of different means of achieving composite action between timber and concrete. Most studies dedicated on timber–concrete composite floors which focused on load-deflection capacity, mechanical properties, short term behaviour and also connections [1–4].

Near to this study, bamboo was one of the most commonly used study materials to substitute reinforcing steel bar in concrete [5,6]. Prior to the durability of organic materials, treatment and curing are essential consideration before application [6]. A comparison between steel and bamboo shows that there are benefits and ill effects for both materials [6,7] Even though composite mineral materials based on fibre reinforced polymer (FRP) has become outstanding replacement for conventional steel reinforcement [8], this study has the intention to add to the knowledge base of timber reinforced concrete with locally obtainable timber to produce concrete structural elements.

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Methodology

In this study three samples of reinforced concrete beam were prepared. Two of them were reinforced with timber reinforcement and one was the control beam which is reinforced with steel reinforcement. The grade of concrete that has been used for this study is 20 N/mm2. Meanwhile, all the beam samples used the same size for its link reinforcement, which is 6 mm diameter (R6), steel of grade 250 N/mm2. Each beam sample was identified and reinforced as SRB (steel reinforcement), BRB (*Balau* reinforcement) and MRB (*Meranti* reinforcement). The dimension for all beam are 150 mm x 200 mm x 1500 mm. The lengths for all reinforcement bars were 1460 mm, which was shorter than the actual length of beam minus the thickness of concrete cover for both sides.

In this study, the concrete covers for all samples were decided to be 20 mm. The diameter for steel reinforcement that has been used was 12 mm (Y12), steel grade 500 N/mm2. Square cross section of timber reinforcement was used in this because its availability in market is limited in round shape. The arrangements of the reinforcements are shown in Figure 1. However, the surface area for both materials ware totally different. The surface area for timber reinforcement was larger than steel reinforcement. The size of timber reinforcement is 35 mm x 35 mm (TR35). It was for the reason to balance a comparable overall strength between the steel and timber reinforcement bars.

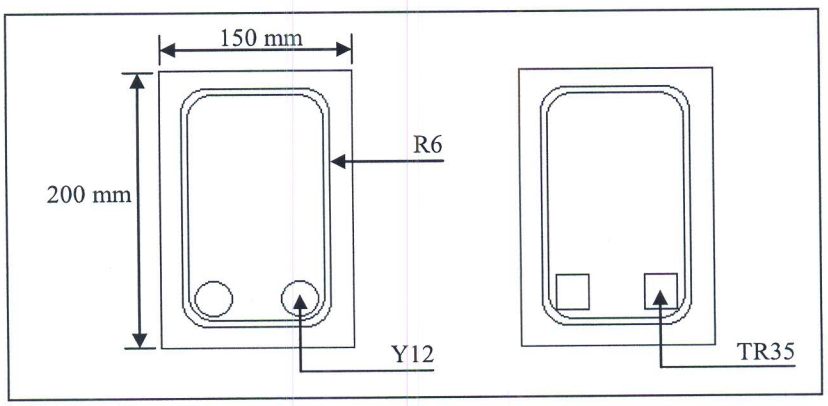

Figure 1 Dimension of control beam (left), sample beam (right)

Tensile Test. Before starting the whole process of constructing the concrete beam, the tensile test was conducted for all samples including steel. The test was executed to get the ultimate tensile load for all samples. As mentioned before, each type of timber required three samples that went through the tensile test.

Beam Flexural Test. Flexural tests are extremely sensitive to specimen preparation, handling and curing procedure. Beams are very heavy and can be damaged when handled and transported to the testing equipment. In beam flexural test, two main measurement can be measured which are flexural strength and deflection. In this study, the beams were assumed to be a simply supported beam. When load was applied at the middle span of the beam, deflection will occur. Transducer will measure the deflection of beam and the data was recorded by data logger.

Results and Discussions

Tensile Test. All the reinforcement that used in all beam samples was tested to determine their tensile strength including the steel reinforcement. The timber had to be cut into 'I' shape to make sure when the tensile test is run, the failure happens affectively at the centre of the sample. The area of both end of sample must be larger than at centre part because to make it grip well to the machine. Universal Material Tester (Model ID-F150) is used in this test.

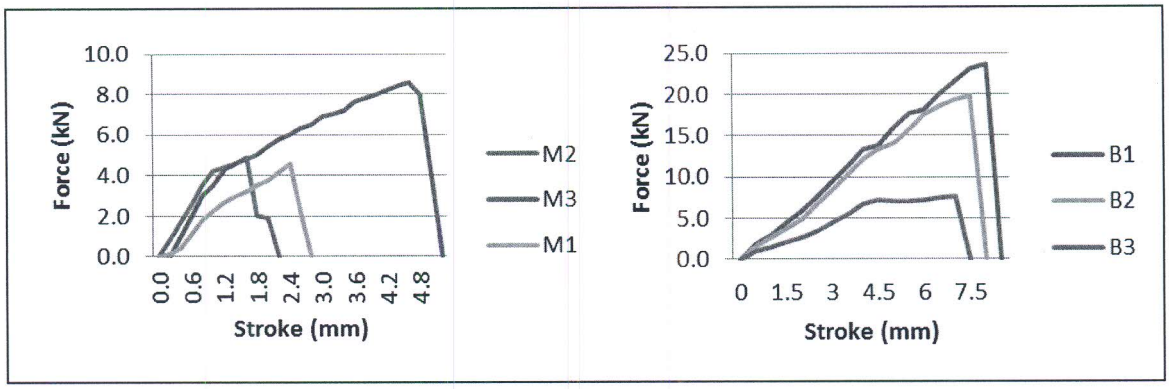

Figure 2 Graph tensile force for *Meranti* and *Balau*

Figure 2 above simply shows the value of ultimate tensile load for all timber samples where M represent for *Meranti* and B represent for *Balau* timber. Each timber was tested with three samples, where the results obtain varies. In other words, even the same type of timber indicated an unequal value of tensile load and showed the big difference between them. These inconsistencies are the result well known to organic fibre that varies in many ways depend on many factors. As can be seen from the result, *Balau* reached the highest value of tensile load.

Beam Flexural Test. From the result of beam flexural test, the beam reinforced with timber can carry the load and behave normally with less flexural strength. Each BRB and MRB could carry maximum load of 50.92 kN and 48.89 kN respectively. Meanwhile, the maximum loading of SRB was the highest among the three concrete beams with the value of 73.18 kN. Based on the result, BRB and MRB comparison was unexpected to behave this way. BRB is expected to carry much higher load compare to MRB established by the result of tensile test; *Balau* timber has the higher tensile strength than *Meranti*. Further detail investigation will be conducted for this behaviour.

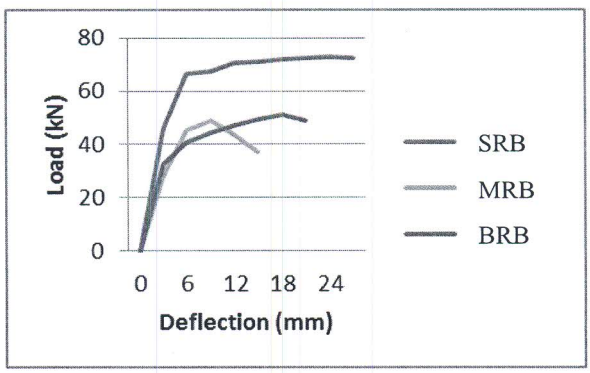

Figure 3 Load-deflection curve for all beams

Figure 3 presents the result of load and deflection behaviour for all samples. During the beam flexural test, the load applied and the deflection of the beam is interconnected with each other. The bigger the load applied to the beam, the higher the deflection will occur as shown in Figure 3. For BRB, the maximum load applied is 50.92 kN and deflected about 17.84 mm, meanwhile for MRB, the maximum load is 48.89 kN and deflected about 6.91 mm. For control beam which is SRB, the maximum load is 73.18 kN and it deflected about 26.14 mm.

From the experimental result, between the concrete beams that reinforced with timber, BRB produced more cracks than MRB, due to its high ultimate load resistance of beam. SRB still shows the highest cracks range among all beam samples because its ultimate load resistance was the highest.

Summary

This study concluded that *Balau* timber showed the highest resistance in tension load compare to *Meranti* timber. The tensile load of timber is tested by using the tensile test and the value of tensile force for both type of timber is much different. *Balau* timber is classified as hardwood and be in group SG 1 in strength group of timber, which is the highest rank of timber classification. Meanwhile, *Meranti* timber is located in SG 6 and classified as light hardwood timber. This gives the new exposure in civil engineering field about the potential of *Balau* timber to be used as a structural material construction.

It was found by this study that timber have high potential as renewable reinforcement for concrete structure. This study found that beam reinforced with *Balau* and *Meranti* can achieve up to 70% in term of flexural strength compared to steel reinforcement bar with diameter of 12 mm. And it also can achieve up to 90% deflection even though with a lesser strength. The formation of cracks and mode of failure showed that *Balau* reinforcement bar was a better material for concrete beam, which supported high imposed load compare to *Meranti* timber.

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