Comparison of Built up Timber Beams with Timber Trusses

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ABSTRACT: The following work is based on a comparison of timber box beams with parallel chorded timber trusses. Box type built up box beams have been adopted based on past research conducted in the Sri Lankan context. Two types of parallel chorded trusses have been compared with a box beam, where the trusses are of the same overall dimensions. Built up box timber beams are found to be the most effective and efficient solution compared to parallel chorded timber trusses of same depth as an alternative for heavy timber beams. Since the serviceability limit state governs the design criteria, load carrying capacities at allowable deflection were concerned. Built up box beam performed 2 to 2.5 times when compared to the Pratt and Warren trusses in terms of load carrying capacity per unit timber cost at allowable deflection.

1 INTRODUCTION

1.1 *Background Study*

Timber is one of the most applied structural materials in the construction industry. In the ancient times timber was extensively used for all sorts of structural applications. However the use of timber is now limited due to its non-availability in large quantities, non-availability in large dimensions, high price and scarcity.

The use of timber should not be discouraged since there are number of advantages associated with timber compared to other construction materials in terms of sustainability. Manufacturing of both cement and steel contribute to the greenhouse effect. Timber requires the least energy as a structural material. As timber is a renewable source of structural material, if sufficient amount of replantation programmes are implemented, the scarcity of timber could be solved

Therefore the effective use of timber should be promoted. Timber trusses and built-up timber beams are very good options for the effective use of timber. There the amount of materials consumed is reduced by considerable amounts and it also enables the use of timber in situations where it is not possible to adopt solid sections. This research has been carried out in order to select the most appropriate solution for the effective use of timber beams.

Much research related to built-up timber beams has been done at the University of Moratuwa in the Sri Lankan context, all of which have focused on the structural optimization of built up box type timber beams. However there have been no studies regarding the comparison of built-up timber beams with timber trusses nor solid beams with timber trusses. In this research this gap of comparative performance of built up box beams versus trusses has been addressed.

1.2 *Objective*

The objective of this study is to compare the performance of built-up timber beams with timber trusses of the same depth and thereby identify the most effective type of substitution for the heavy solid timber beams.

1.3 *Method of Research*

Referring to the literature a suitable built up timber beam design and truss arrangements have been adopted. It was identified that the actual performance of structures tested can deviate from theoretical predictions to a greater extent due to method of construction and various other associated issues of timber material. Therefore the adopted structural patterns have been physically modelled and tested. The load-deflection behaviour of each model under an incremental loading mechanism was observed and used for the performance comparison. Load carrying capacity is compared from this results. Again it was noted that there is a significant difference in timber costs as well. Therefore the performance of the structures with respect to both strength and timber costs has been compared.

2 LITERATURE REVIEW

2.1 *Introduction*

Research work on a comparison of timber trusses with timber built-up beams was not available. Neither was available literature comparing steel beams with steel trusses.

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The appropriate truss forms were selected by studying the evolution of parallel chorded trusses.

2.2 *Evolution of Trusses*

"Warren Truss" is a simple parallel chorded truss design made up by equilateral triangles found in many bridge constructions. Here the members are all determinate type of members and is aesthetically considered as appreciable, than other available parallel chord designs.

"Pratt Tru**ss**" is a further development which is also a quite significant turning point in case of flat trusses. According to Littmarck (2012) the use of the Pratt truss bridge dates back to 1844.

2.3 *Built-up Beams*

The optimum section for a nailed built up box beam has been shown in Chandraratna et al (2011) as two 25mm x 225mm timber webs with two 50mm x 50mm top and bottom flanges. The box beam has been optimized with respect to strength and material cost, for a span of 1800mm.

3 EXPERIMENTS

3.1 *Introduction*

The optimized built-up box beam derived in Chandraratne et al (2011) was selected for the built up beam structure. Thereafter investigating the evolution of the truss patterns Warren and Pratt type truss arrangements were selected. Another arrangement of having only vertical web members in the same plane was chosen to try the effect of verticals alone, and to compare the effect of diagonal members in the trusses.

The dimensions of the truss members have been derived so as to tally with the overall dimensions of the chosen built-up box beam model. The depth of the trusses was quite low compared to the member cross-sections. Thus it was unable to apply gusset plates to avoid eccentricities of the member axes at nodes. A single nail of 3mm diameter 50mm long was adopted for each member to member connection. Nails of 5.7mm diameter 75mm length were used to connect the flanges to vertical members.

Due to eccentricities at joints, behaviour of nailed joints versus pin joint, method of construction the theoretical derivations may be far different from the practical scenario. In that case it is a must to implement a physical model testing allowing all the practical circumstances.

The four physical models were fabricated using 'Hora' (*Dipterocarpus zeylanicus*) species timber.

3.2 *Physical Models*

The dimensions of the different structures tested are shown in figs 1 to 4. All dimensions are in millimeters.

3.2.1 Built up box beam

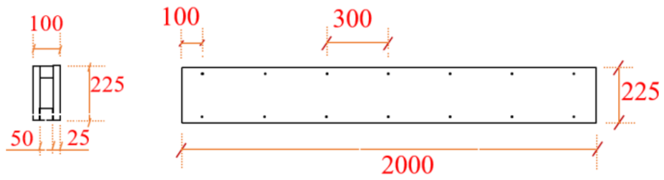

Figure 1: Dimensions of the Box Beam

3.2.2 Warren truss

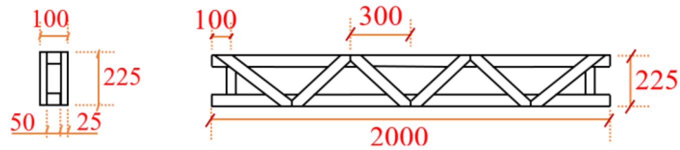

Figure 2: Dimensions of the Warren Truss

3.2.3 Pratt truss

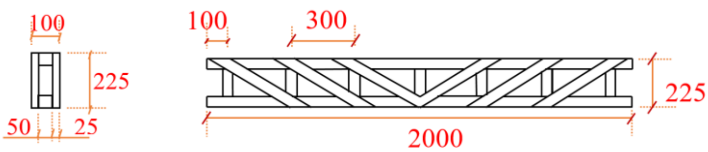

Figure 3: Dimensions of the Pratt Truss

3.2.5 Verticals only arrangement

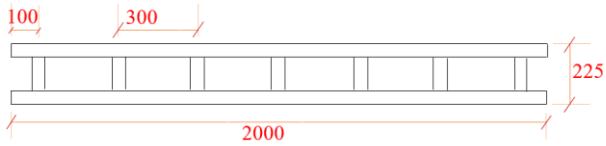

Figure 4: Dimensions of Verticals only Frame

3.3 *Load Arrangement*

The loading arrangement used for the testing of models is shown in fig 5. All dimensions are in millimeters.

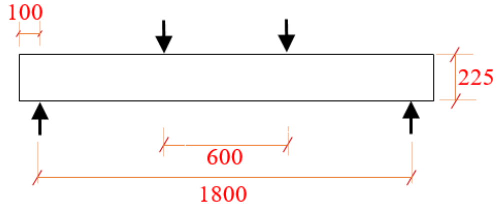

Figure 5: Loading Arrangement for Testing

3.4 *Failure Criteria*

Shearing at nails was observed in the built up box beam as shown in figure 6. As shown in figure 7 the Warren truss underwent failure in shear and flexure simultaneously. Flexural splitting was ob-

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served in Pratt truss as seen in figure 8. Figure 9 shows the failure of the verticals only arrangement, in which flexural splitting occurred in the top flange.

3.4.1 Built up box beam

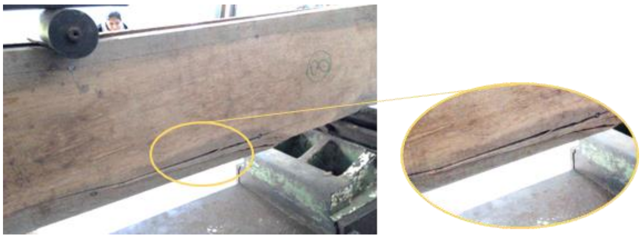

Figure 6: Shearing at nail in built up box beam

3.4.2 Warren truss

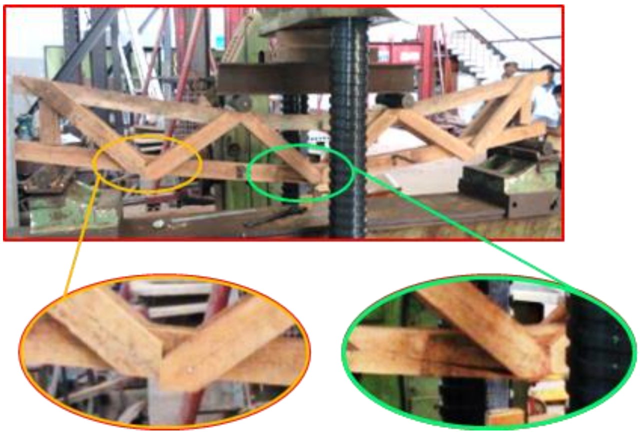

Figure 7: Failure of warren truss in shear and flexure

3.4.3 Pratt truss

Figure 8: Flexural splitting in Pratt

3.4.4 Verticals only arrangement

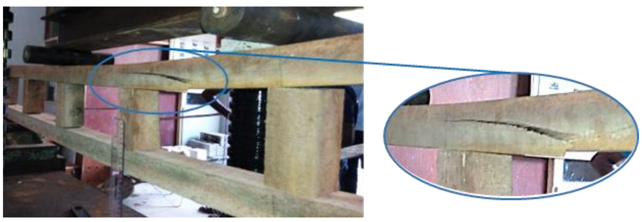

Figure 9: Top flange splatted in the verticals only arrange-

3.5 *Results*

The load vs deflection behaviour of the trusses and beams have been plotted in fig: 10 to compare the strengths and stiffness of the structures.

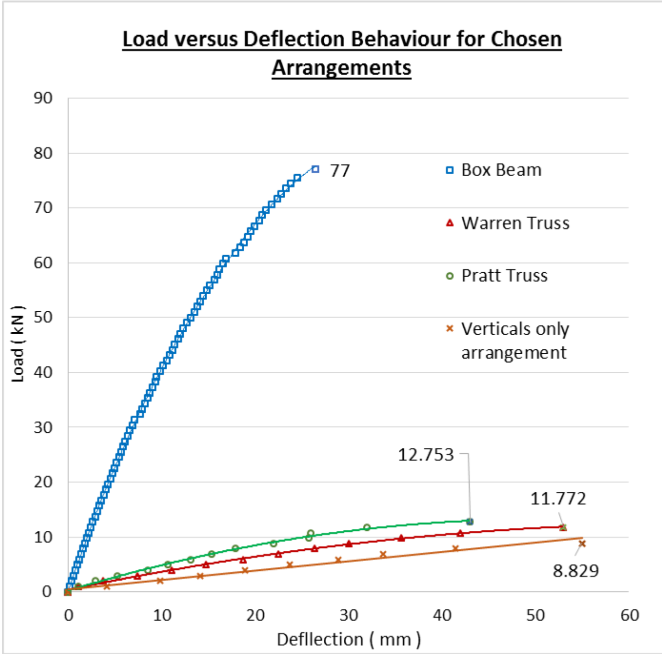

Figure 10: Experimental Load-Deflection behaviour

Table 1 provides the maximum load and the load at a deflection of 0.003 of the span which is the serviceability limit used in design.

Table 1: Comparison of both Strength and Cost Aspects

Model Identification	Load Capacity (kN)		Cost of Timber (Rs.)	Load carrying capacity per unit cost (kN/Rs.) x 10^3	
	At allowable deflection of 5.4 mm	Maximum		At allowable deflection of 5.4 mm	Maximum
Box Beam	24.3	77	4130	5.88	18.64
Warren Truss	2	11.77	888	2.25	13.25
Pratt Truss	2.85	12.75	1023	2.78	12.46
Verticals only arrangement	1.12	8.83	855	1.31	10.33

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Fig: 10 illustrates that the stiffness of the box beam is much higher when compared with truss arrangements. At the 10 kN load, deflection at mid span of the box beam is only 2 mm whereas the deflections of the trusses are around 25mm and 38 mm in Pratt and Warren trusses respectively. The stiffness of the Verticals only arrangement is the lowest.

The built up box beam shows a brittle type behaviour at failure while the trusses go through considerable deformations prior to failure. It can be thus observed that an appreciable stiffness and load capacity are obtained with built up beams compared with the trusses.

Moreover it is reflected in fig: 10 the maximum load capacity of box beam is 6 to 7 times that of the trusses. Maximum capacity of the verticals only arrangement is the lowest.

4 PERFORMANCE COMPARISON

The comparison of the performance among the structures should not be based on load carrying capacity alone. Though the built up beam made the highest load carrying capacity it was the most expensive structural component as well. It is assumed that labour cost is approximately the same for all. However cost of timber was considered. A performance comparison is carried out considering the load carrying capacity and timber cost.

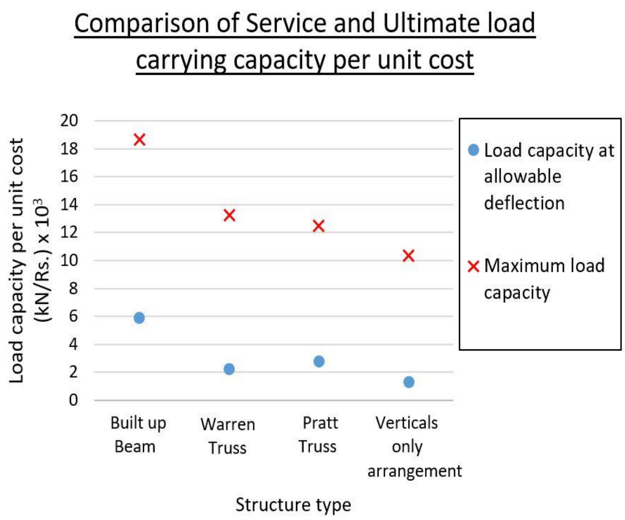

Figure 11: Experimental Load-Deflection behaviour

Considering the serviceability limit state design criteria, the performance of the structures at allowable deflection which is 5.4mm have been studied. The performance of two truss patterns compared to the verticals only arrangement shows the effectiveness of diagonal braces. A cost increment of 4% to the verticals only arrangement the capacity has been increased by 80% in the Warren truss. For the Pratt truss the cost increment of 20% resulted in a load carrying capacity increment of 150%.

Comparison between truss arrangements indicates 15% increase in cost from Warren truss to Pratt truss whereas the increase in capacity is 42%.

In the box beam structure the webs are two solid timber (fully covered) boards. Enabling a diaphragm effect this enhanced the capacity compared to a series of diagonals. When comparing the performance of box beam against the Pratt truss the cost of the structure is of 4 times that of the truss while the load carrying capacity is 8.5 times that of the truss.

5 CONCLUSION

This research work has focused on box type built up timber beams and parallel chorded timber trusses where the depth of the trusses were kept constant and equal to that of the box beams.

Diagonal bracing of parallel chorded trusses significantly contributes in enhancing the performance of the structure (load capacity per unit cost of 70% to 110% with respect to Warren and Pratt trusses)

Having fully covered web planks produced greater effectiveness to the performance of the structure. (load capacity per unit cost of 350%, 160% and 110% with respect to verticals only, Warren and Pratt arrangements)

Built up box timber beams is found to be the most effective and efficient solution compared to parallel chorded timber trusses of same depth as an alternative for heavy timber beams of solid cross section.

6 REFERENCES

Chandraratne P.G., Priyadarshana K. H. P. V. & Welhena K. M. (2011). Behaviour of Built up Timber Beams. Department of Civil Engineering, University of Moratuwa.

Littmarck, F. (2012). Modelling a Pratt Truss Bridge. Retrieved December 20, 2015 from https://www.comsol.com/blogs/modeling-a-pratt-truss-bridge/

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