Experimental and Analytical Performance of Composite Laminated Timber Beams with Cold Formed Steel

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Abstract - *Today the buildings are constructed on a large scale with conventionally used RCC construction materials. They are found to be highly energy consuming and carbon-intensive compared to wood-based building materials. To reduce the material quantity, time and cost, the composite members are used. The composite member here means the use of laminated rubber wood along with cold formed steel sections. This study attempts to improve bending performance of laminated timber by combining them with cold formed steel. The composite member is derived by attaching several timber laminas to the cold formed steel section using screws. Bending test is used to obtain the force displacement relationship of the laminated timber - cold formed steel (Z section). For identifying the best combination of steel section (Z section, L section, Single C, double C, I section, T section, Hat section) and laminated timber composite ANSYS software is used.*

***Key Words*: Laminated beam, Rubber wood, Cold formed steel, Composite beam, Composite beam connection.**

1. INTRODUCTION

Wood is one of the best sustainable and renewable material. Wood requires less energy for its production and emits less green house gases [1]. Compared to solid sawn timber structures, laminated timber structures have high strength and may require less maintenance during its service. The rubber wood is selected for the study, since it is very economical and light weight.

Compared to hot-rolled steel members cold formed steel members are light weight and easy in terms of fabrication. In addition, they are available in various shapes and corrosion resistant [3].

The use of timber steel composite structures has wide range of application in the recent years. Steel excels in tension while wood reacts much better to compression. We can improve bending performance of laminated timber by combining them with cold formed steel members. In laminated timber composite with mechanical connectors (screws) can significantly increase speed of construction, reduce the self-weight of structure and also facilitate the recycling and reusing of the structural components at end of building service life [4].

2. OBJECTIVES AND METHODOLOGY

This paper shows an innovative method in reinforcing the laminated timber beam with cold formed steel. In the literature studies so far the reinforcement is only provided on the tension side. This paper considers strengthening of laminated timber beams with different cold formed steel sections (Z section, L section, Single C, double C, I section, T section, Hat section). Bending test is used to obtain the load deflection behaviour of the composite beam using Z section. ANSYS software is used for further investigation of composite beam using L section, Single C, double C, I section, T section, Hat section.

3. EXPERIMENTAL INVESTIGATION

An experimental investigation into the flexural strength of composite laminated timber beam was conducted. Three composite beams were investigated experimentally. The composite beams are fabricated by using cold formed Z steel section of 100mm×40mm×20mm×1.6mm (where 100 mm is the height of the section, 40 mm is the flange width, 20 mm is the lip height and 1.6 mm is the thickness of the section) and laminated beams of 36.8mm×98.4mm. The cold formed steel members were combined with timber laminas using screw of 4 mm root diameter and 60 mm length. 200 mm distance is provided between 2 screws in each side. The screws are provided in alternate manner in both sides. Fig- 1 shows the screw dimension provided in the beam.

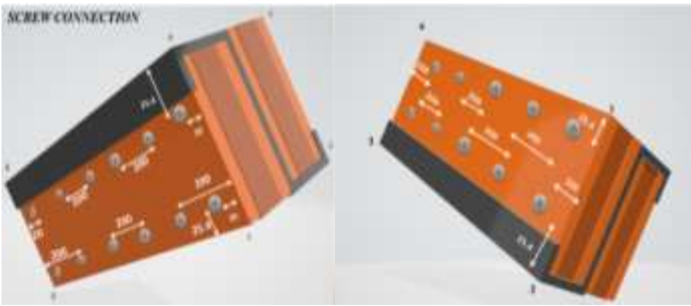


Fig -1: Screw connection of composite beam (all dimensions are in mm)

Laminated timber beam is collected from Kerala State Rubber Co-operative Limited (RUBCO). Thickness of timber laminas which is used for composite beam is 8.4 mm thickness as outer laminas and 20 mm thick inner lamina. Z section selected from the code IS: 811:1987. A universal testing machine was used in this experiment. Compression was done along the length of the specimen at mid-point. Effective span selected as 900 mm. Concentrated load applied at mid point. The loading plate was introduced to prevent localized failure [1]. Laminated beam properties are collected from RUBCO and experimental results. Cold rolled steel sheet properties are taken from IS code 513: 2008 and tensile test was conducted according to IS 1608: 2005. Fig- 2 & Fig- 3 shows the tensile test specimen and test set up of the composite beam using Z section.

Fig -2: Tensile test specimen after testing

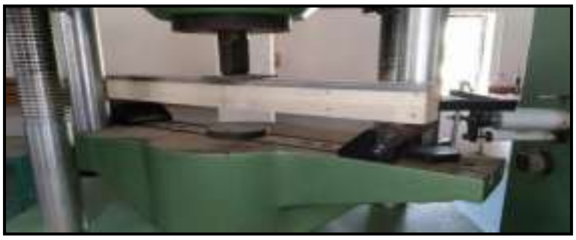


Fig -3: Test set up of the composite beam using Z section

3.1 Results and Discussions

Composite timber beams behavior under the load was ductile. The beams ultimately failed in tension, but the deformation levels were quite high. Screws worked very well in three beams without any de-bonding, but crack commenced in the tension side of the timber and then it propagated longitudinally towards upward. The existence of the screws initiated the tensile cracks (Fig -4). Timber in the compressive zone was crushed but no failure for steel in the compression zone. Tension side steel is deformed at the mid span of the beam. Chart -1 shows the Load deflection graph for composite beam specimen which carry maximum load (C2). The table below shows Load & Deflection of Composite Beam.

Table -1: Maximum Load & Deflection of Composite Beam

Specimen	Load (kN)	Displacement (mm)
C1	46.70	18.20
C2	47.45	13.10
C3	40.95	12.70
Average	45.04	14.60

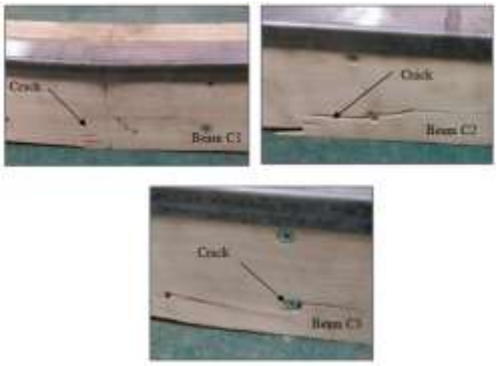


Fig -4: Crack pattern formed in composite beam specimen C1, C2, C3

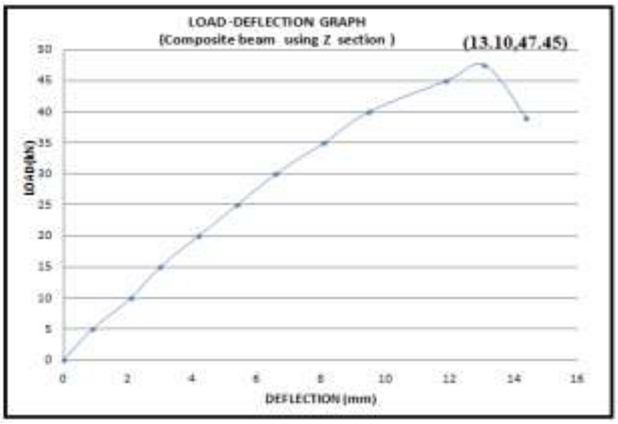


Chart -1: Load deflection graph for composite beam specimen which carry maximum load (C2)

4. ANALYTICAL INVESTIGATION

ANSYS 16.1 software is used in this paper for the analytical study. Fig -5 and Fig -6 shows model of composite beam and its supporting conditions. ANSYS elements BEAM 188, SOLID 186 is used here. Automatic generated meshing is provided.

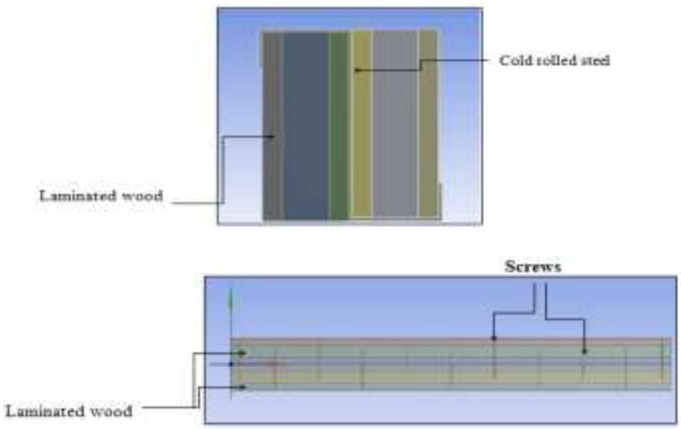


Fig -5: Model of composite timber beam using Z section

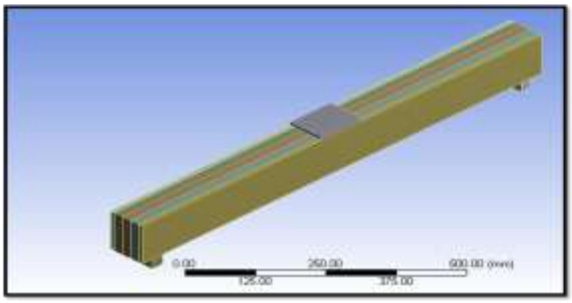


Fig -6: composite beam with supports and loading plate

Simply supported boundary condition is provided here with a loading plate to avoid the local failure.

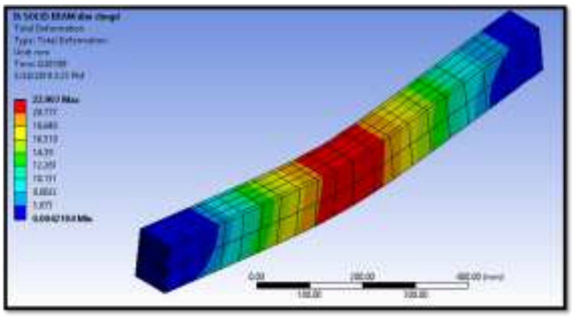


Fig -7: Deformation of Composite beam using Z section

The load bearing capacity obtained from the ANSYS is 44.045 kN and from the experiment is 47.5 kN. The variation of results is about 7.27%, which is within the limit. The deformation of the beam is shown in Fig – 7.

4.1 Unreinforced Laminated Timber Beam

Unreinforced glulam beam modeled by five wood laminations of dimensions 9.2 mm as outer laminas and 20 mm as three inner laminas. The load bearing capacity obtained is 19.562 kN corresponding deflection is 12.594 mm. Chart -2 shows comparison of both reinforced and unreinforced beam.

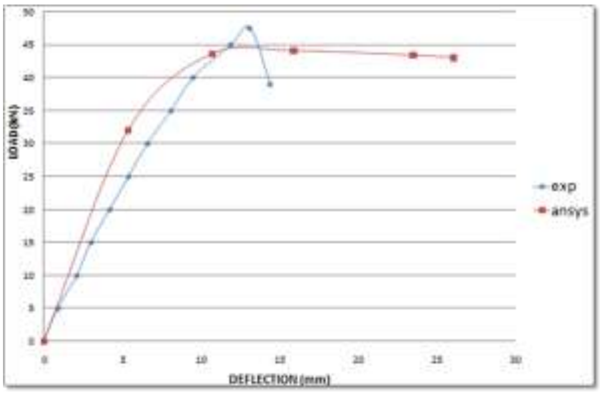


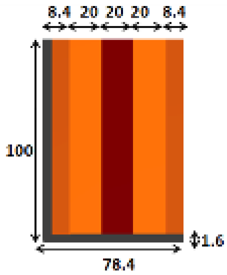
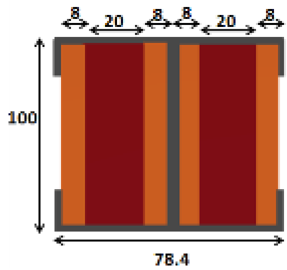
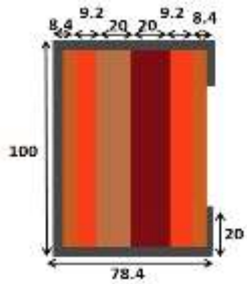
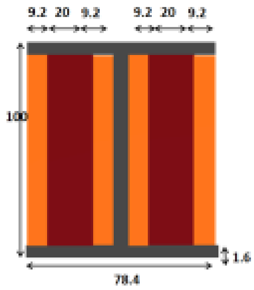
Chart -2: Comparison of Reinforced Beam (Using Z Section) & Unreinforced Laminated Timber Beam

Comparing composite and unreinforced laminated beam it could be seen that composite beams resulted in considerable increase in load bearing capacity. Load bearing capacity increased up to 55.58%. This can be considered as an advantageous when we consider the safety and warning of structure, but disadvantageous in terms of larger deflections.

4.2 Composite Beam Using Different Cold Formed Steel Section

Composite beams with different cold formed steel sections analytically investigated. The dimension of the beam shown in table 2.

Table -2: Composite Beams and Dimensions

No;	Composite section	Dimension of beam
1	Composite Beam Using L Section	
2	Composite Beam Using Double C Section	
3	Composite Beam Using Single C Section	
4	Composite Beam Using I Section	

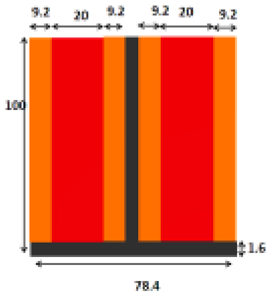
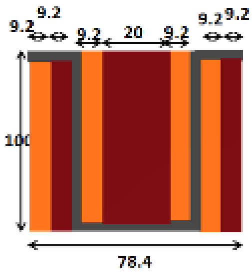
5	Composite Beam Using T Section	
6	Composite Beam Using Hat Section	

Table -3: Comparison of Results

No	Composite beam using	Load (kN)	Deflection (mm)	Cost(Rs)/Load(kN)
1	Z	44.045	15.887	22.433
2	HAT	48.964	10.128	22.677
3	I	46.563	12.298	23.282
4	DOUBLE C	61.04	10.054	23.717
5	C	39.092	15.472	24.652
6	T	33.326	15.115	27.781
7	L	27.955	15.251	31.97

The above results shows that, the composite beam using Double C section has maximum load bearing capacity and minimum deflection. Fig 8-13 shows deformation figures of different composite beams and Chart -3 shows its load – deformation curve. The lowest load bearing capacity is for composite beam using L section and its capacity is about 27.955 kN with 15.251 mm deformation. While comparing cost to load ratio the most suitable sections are Z and HAT. HAT section carry more load compared to Z section. So we can say that composite beam using HAT section is most suitable beam.

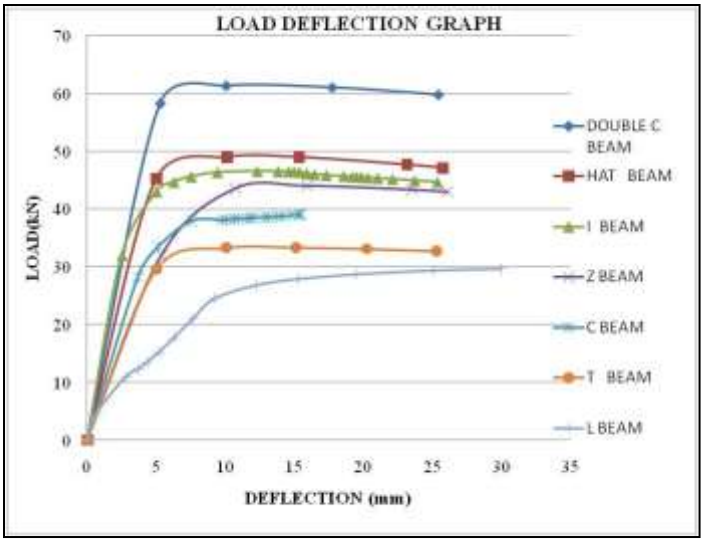


Chart -3: Comparison of test results

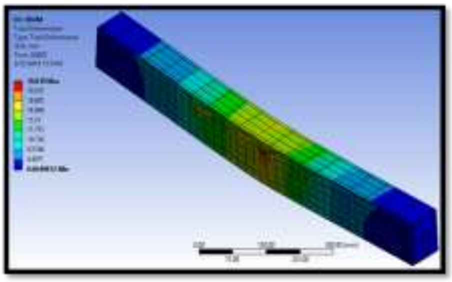


Fig -8: Deformation of Composite beam using L section

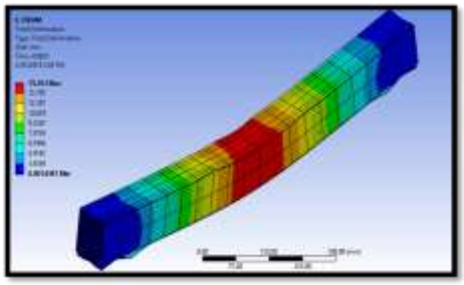


Fig -9: Deformation of Composite beam using I section

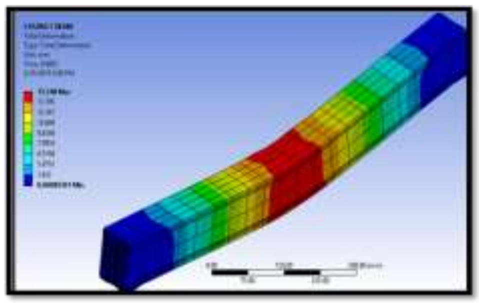


Fig -10: Deformation of Composite beam using Double C section

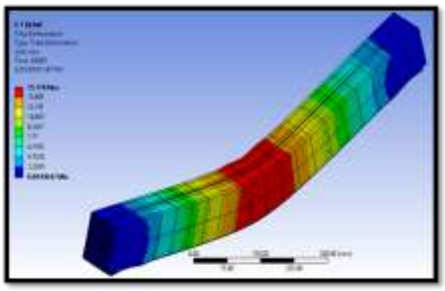


Fig -11: Deformation of Composite beam using T section

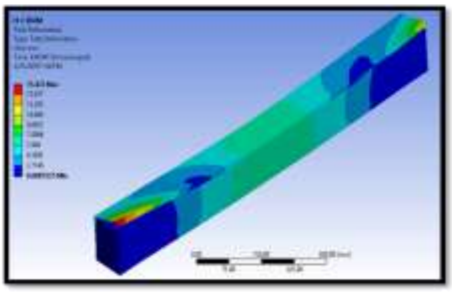


Fig -12: Deformation of Composite beam using Single C section

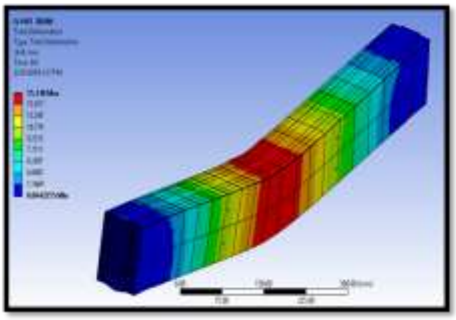


Fig -13: Deformation of Composite beam using HAT Section

5. CONCLUSIONS

- From the experimental and analytical results, we can conclude that composite beam (using Z, HAT, Double C, I sections) carry twice the load than that can carried by the laminated beam and the beams ultimately failed in tension.
- Deformation levels were quite high for composite beam.
- The increase in ductility can be considered as an advantageous while we considering safety and warning, but disadvantageous in terms of larger deflections.
- Composite beam using Double C section has maximum load carrying capacity (61.04 kN) and minimum deflection.
- Composite beam using L section has lowest load bearing capacity about 27.955 kN.
- Comparing cost to load ratio the most suitable sections are Z and HAT. While comparing the loads the composite beam using HAT section carry maximum load (48.964 kN). So from the above study we can conclude that the composite beam using HAT section is most suitable beam.

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