Timber-Steel-Composite Beams for Framed Structure

[1]Ms.Khan N.S, [2]Prof. Pawar Y. P.
Civil Engineering Department
SKN Sinhgad College of Engineering, Korti,
Pandharpur, Maharashtra, India.

***Abstract* — Due to improvements in the use of recyclable materials in construction, timber–steel composite (TSC) beams demonstrate high potential for future construction. In this study, a proposed simulation modeling, which was adopted from the simulation modeling of a steel C-shape composite, was applied to estimate the Strength of TSC beams. The strength of e beam could be determined. However, connection at the web and fastened with screws and nails at the flange, respectively, revealing, the strength of the TSC beams with connection at the web that were fastened by screws was approximately 15% higher than that of TSC beams. For connection of timber steel beam system with connectors bolts and screws taken. For that Gun driven nails method which are developed for the connection of steel-steel plates as same it can also be used for timber-steel connections the assembling can be implement.**

The composite elements both in horizontal and in vertical direction have an increased load bearing capacity without increasing cross sections. High loads can be transmitted with simple connections which accelerate the construction time. The total weight stays very low which is advantageous in case of earthquake. In case of fire the steel members are protected by the wooden elements and the temperature of the wood cross sections increase less rapid. Steel timber structures present a light, fast and clean construction method.

Index Terms— Timber, Steel, Flitch-beam, composite beam.

I INTRODUCTION

Composite construction combines the structural and architectural features of components made from different materials. In Composite construction, various materials may work independently or act together homogeneously, but are always better than a single material.

During the last decade a lot of research has been done on applications of composite structures; however, the available information and details for steel and timber composite structures are dispersed and not readily accessible to builders. The major aim of this project is to perform a detailed study on existing composite steel and timber structures and identify current engineering techniques of hybridization along with the benefits and challenges associated with them. The literature review has highlighted the opportunity for steel – timber composite buildings and existing knowledge gaps. Moreover, technical software packages are investigated and their advantages and limitations in terms of predicting structural responses of composite systems are discussed.

Timber member reinforced with steel plates (C-section) are another type of composite steel timber beams. This type of wood member reinforced by steel plates on top and bottom or reinforced with steel plate in between. Alternatively the Timber member can be reinforced by attaching channels to opposite sides of an existing Timber beam. Advantages of such members include increased in fire resistance, improved buckling capacity, and increased in bending strength.

When combining the Timber with the inserted steel it is essential to have clearance to allow for possible dimension change of steel and timber due to expansion of steel or shrinkage of timber.

The idea is to optimize the geometry of the timber-steel composite beam regarding cost effectiveness and load bearing capacity. A new idea is to use cold formed "C" profiles made of thin steel plates. Based on structural performance requirements, some static calculations of middle-span timber-steel composite beams with loads.

First economical calculations and static analyses were presented WCTE 2010 Trento [1]. The good results of the static calculations demonstrate the efficiency of timber-steel-composite beams. A cost reduction can be expected and steel-steel connections become possible.

In-depth understanding of the properties of each material is essential for designing a composite structural system. Engineers and architect should remember the strengths of each material and know in what context each of them work best. Table 1 below shows the approximate material properties for steel and structural timber.

TABLE 1
APPROXIMATE MATERIAL PROPERTIES FOR STEEL AND STRUCTURAL TIMBER

Approximate Material Properties for Steel and timber						
Material	Yield Strength (MPa)	Density (kg/m3)	Poisson Ratio	Modulus Elasticity (MPa)	Compressive Strength (MPa)	Tensile Strength (MPa)
Steel	350	7800	0.3-0.31	200000	400-1000	400-1000
Structural Timber	N/A	400-600		8000-11000	Parallel 30 Perpendicular 8	Parallel 6 Perpendicular 1

Combining steel and Timber will increase the seismic performance of the structure. Timber has a high strength to weight ratio therefore Timber buildings tend to be lighter than other building types [2]. Table 2 shows a comparison of strength/density ratios for some structural materials. For clear wood this ratio is significantly higher than other building materials.

TABLE 2
STRENGTH/DENSITY RATIOS FOR STRUCTURAL MATERIALS

Material	Density (kg/m3)	Strength (MPa)	Strength/Density (10-3 MPa.m3/kg)
Structural Steel	7800	400-1000	50-130
Clear softwood, tension	400-600	40-200	100-300
Clear softwood, compression	400-600	30-90	70-150
Structural timber, tension	400-600	15-40	30-80

Lightness is an advantage in an earthquake. Since forces in an earthquake are proportional to the weight of the structure, lightweight timber-frame buildings that are properly designed and built can be expected to perform very well in earthquakes.

Steel is a non-combustible material, but the mechanical properties of structural steel are affected by heat [3]However, in fire, timber member's char on faces exposed to fire but still retain strength and stiffness by virtue of the much cooler core within the charred surfaces and thus their performance is predictable and collapse is unlikely [4]. Hence, Timber steel composite structures perform better in fire.

II. ASSEMBLING OF BEAM

The beams were assembled using two cold formed C steel profiles and glue laminated or cross laminated timber cross sections. The cold formed section works together with a timber beam (Figure 1a, b). 2 mirror-inverted timber-steel beams (Figure 1c) are fixed together with some bolts and can be reinforced, if necessary, with steel plates on both sides. These plates can be connected with screws or gun driven nails (Figure 1a-d).

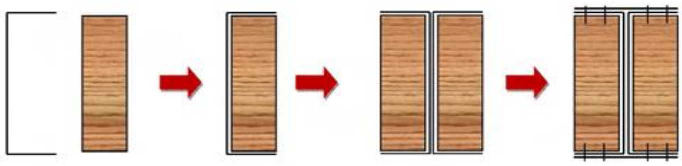


Figure 1: Assembly process of completed timber-steel composite beam

The elements of the timber-steel composite beam the assembling of steel member and timber member by using screws or gun driven nails are shown in Figure 2.

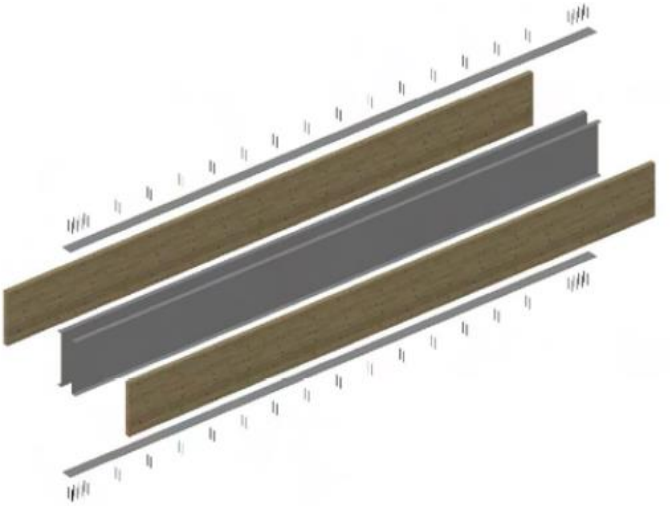


Figure 2: Elements of the timber-steel-composite beam

The fixing of the reinforcement with thin steel plates on both sides connected with driven nails is shown in figure 3


Figure 3: Reinforcement with thin steel plates on both sides connected with driven nails

III TIMBER MATERIALS

In this composite beam different timber materials are used to connection. The material is glue laminate timber or cross laminated timber. After that using of timber materials the load are going to distribute on whole beam. That type of timber is must be well seasoned as well as fire resistance also.


a

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 06, June-2019

b

c

Figure 4(a, b, c): Different timber materials

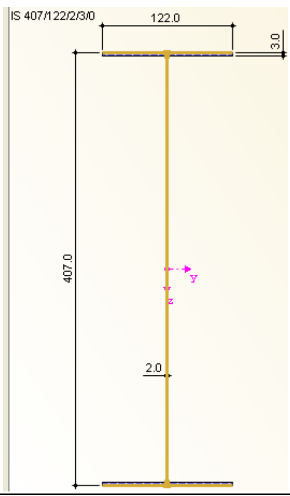
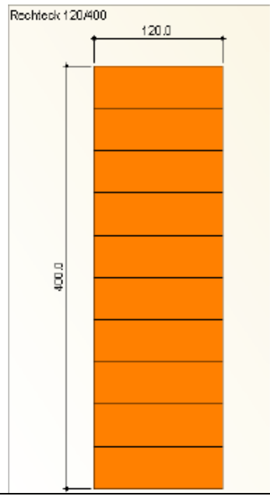
IV SAMPLES

In the following chapters the shortcut C1 describes the composite beams with 2 cold-formed C-steel profiles with each a depth of section h of 407 mm, with a flange width b of 61 mm, with a thickness of 1 mm additionally reinforced on both sides with 2 steel plates with a width b of 120 mm and a thickness of 2 mm.
The shortcut C2 describes the composite beams with 2 cold formed C-steel profiles with each a depth of section h of 329 mm, with a flange width b of 100 mm and with a thickness of 2 mm.
The shortcut GL stands for the glue laminated timber
The shortcut CLT stands for the cross laminated timber working as a beam with a width of 5, 7 cm (2 vertical layers and one horizontal layer each of 1, 9 cm).
The shortcut S describes the connection with screws [5].
The shortcut N describes the connection with shooting nails [5]. Both parts of the beams were joined together using four steel bolts with a diameter of 30 mm. These bolts were located at the resting and loading sections of the beam. A gap of 5 mm in the bottom part of the all these beams was provided for the tolerance dimensions of both elements. This gap was filled using steel plates in the resting and loading sections of the beam.

IV. I. SAMPLE 1 AND 2 (C1-GL-S / C1-GL-N)

The first sample (C1-GL-S) consists of 2 glue-laminated beams and 2 cold-formed C steel profiles, reinforced by 2 steel-plates (each 2 mm) on both sides. The connection advices are screws. This first option proved to be very laborious because of the requirement of pre-drilling the 2 mm thick reinforcement steel plates.
The second sample (C1-GL-N) consists of 2 glue laminated beams and 2 cold-shaped C steel profiles, reinforced by 2 steel-plates (each 2 mm) on both sides. The connection advices are Hilti-nails. The properties of the components and of the assembled composite beams are illustrated in Table 1.

TABLE 3: CHARACTERISTICS OF SAMPLE C1-GL-S AND C1-GL-N

C1-GL-S	C1-GL-N
	
Cross sections	
Steel	Timber
	
A= 15,34 cm²	A= 480 cm²
G= 12 kg/m	G= 24kg/m
EI= 85293390 kNcm²	EI= 80640000 kNcm²
EI/EI_{tot}= 0,51	EI/EI_{tot}= 0,49

V BEHAVIOR OF BEAM

Before starting the test, some simplified simulations have been carried out. The aim was to estimate the load bearing behavior of the composite beams. The interconnection between the timber beam (element below) and the steel profile (element above) was simulated by 2 simple rigid links.
According to the flexural stiffness, each beam has to carry the own part of the loading forces.

The separated bending moments for the hybrid beams C1-GL-S and C1-GL-N are shown in Figure 5.

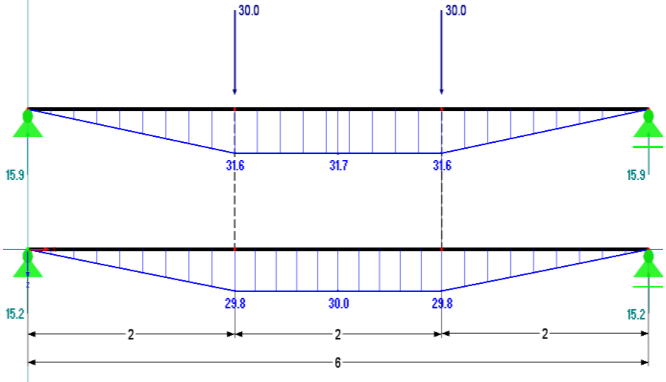


Figure 5: Bending moments and support reaction H1-GL

The deflection for the hybrid beams C1-GL-S and C1- GL-N is shown in Figure 6.

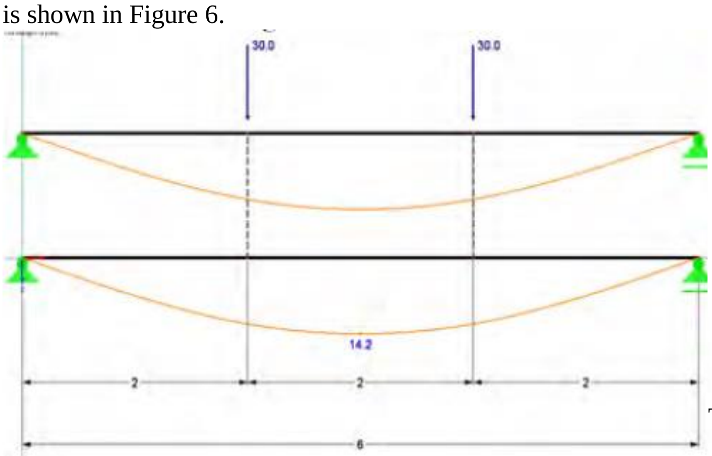


Figure 6: Deflection C1-GL.

VII EXECUTION OF STATIC TESTS

At first, two glulam beams and one CLT beam were tested. In the case of the glulam beams the cross section was 80x400 mm. In the case of the CLT beams the cross section was 57x400 mm. These two reference beams were obtained from the same original pieces used to assemble the hybrid beams. The idea was to find out the flexural stiffness of the used timber beams.

In the second step, a series of four different types of timber-steel composite beams were tested. All of them had a span of 6 meters.

All the timber steel composite beams were tested in a four point static bending test. The beams were single span and simply supported over pin joints.

The two loading points were located at the one third points of the span (at 2 and 4 meters).

The load was gradually applied and the results of the deflection of the beam were recorded every 2 KN of applied load. Three recording devices were located under the beam, one at the middle and the other two under every loading section.

In the following load-deformation diagrams only the maximum deflection in the middle is diagrammed.

Steel tubes and timber struts were connected in the compression zone of the beams to avoid the buckling problem of the thin steel plates. When reaching high loads this measure could not avoid the buckling effect.

VI RESULTS OF THE STATIC TESTS

Every beam was loaded till the state of failure of the timber elements. Because of technical and security reasons the deformations were not measured till this state. Figure 7, 9, 11, 13 show the load-deformation diagrams including the ultimate load for all tested composite beams.

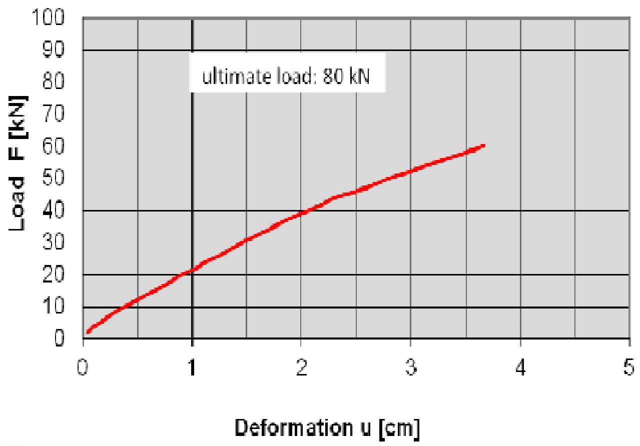


Figure 7: Load–deformation diagram C1-GL-S

The failure pattern for C1-GL-S is shown in Figure 08.

Figure 8: Failure pattern under ultimate load C1-GL-S

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 06, June-2019

Figure 9: Load-deformation diagram C1-GL–N

The failure pattern for C1-GL-N is shown in Figure 10.

Figure 10: Failure pattern under ultimate load C1-GL-N

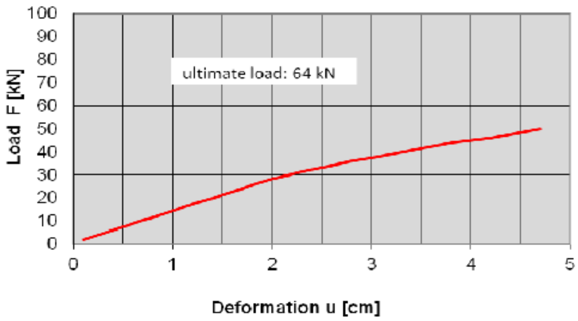


Figure 11: Load–deformation diagram C1-CLT–N

The failure pattern for C1-CLT-N is shown in Figure 12.

Figure 12: Failure pattern under ultimate load C1-CLT-N

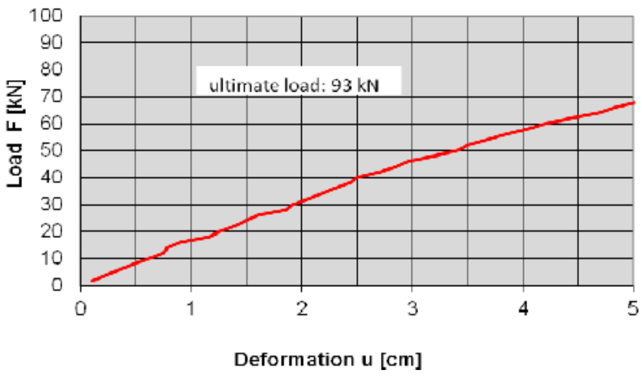


Figure 13: Load–deformation diagram C2-GL

The failure pattern for C2-GL is shown in Figure 14.

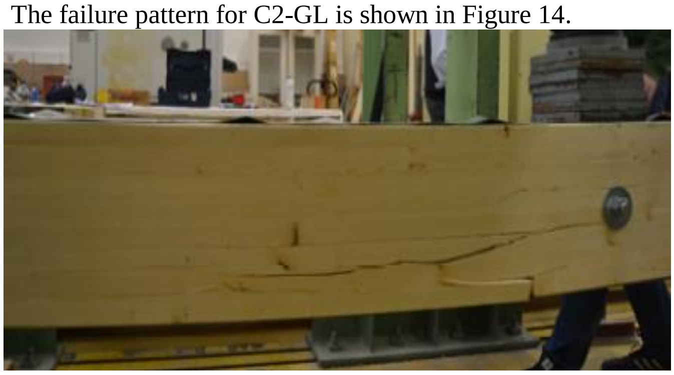


Figure 14: Failure pattern under ultimate load C2-GL

VIII ANALYSES

The assembling of beam was the easiest one. The higher use of material was compensated by faster assembling and by reduction of problems with buckling of the compressed upper flange.

For the other three beams, the positioning and the number of used nails (or screws) should be optimized to reduce the assembling time and the weakening of the cross-section, especially in the tension area.

The load-deformation behavior of all tested beams is combined in Figure 15.

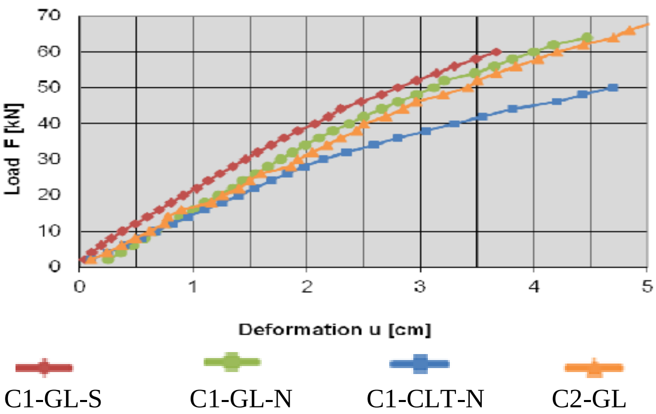


Figure 15: Load–deformation diagram for all beams

The weakest beam, C1-CLT-N failed because of lateral torsional buckling. The weakening of the cross-section by connecting nails affected this kind of beam much more than

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 06, June-2019

C1-GL-N or C1-GL-S. The reason is the existence of only two (of totally three) load bearing (vertical) layers.

The reason of failure for C1-GL-N, C1-GL-S and C2- GL was the fracture in the tension area of the timber beams.
The evaluation of the results is still in process.

IX CONCLUSION

For Framed structure buildings timber-steel elements present a very useful construction method. Steel and timber structures are light in weight so that it gives the light weight timber–steel beams. The bunch of these two materials leads to economic and environmental benefits as the construction height can be optimized, the earthquake resistance structure and the assembling can be implement more efficiently. An extra development of flitch-beams is economically and statically advantageous and should be considered as the new generation of timber-steel composite beams. The idea is to optimize the geometry of the timber- steel composite beam regarding cost effectiveness and load bearing capacity. It also resists all the earthquake resistance structures like static and dynamic forces.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of department of Civil Engineering of SKN Sinhgad college of Engineering Korti, Pandharpur - 413304, India. The gratitude is also extended to Dr. C.P. Pise and Dr. K.J. Karande for their valuable guidance during this work.

REFERENCES

[1] Kamyar Tavoussi, Institute of Architectural Sciences, Structural Design and Timber Engineering, Vienna University of Technology, Karlsplatz, 2010 13/259/2, 1040 Vienna, Austria..
[2] Slavid.R. Wood Architecture, London Laurence King Publishing Ltd, pp 239, (2005).
[3] Gehri E. The Fire Resistance of Steel Structures, Fire Technology, Vol. 21, No. 1, p. 22, (1985).
[4] Cheung, K.C. (2000) Multi-Story Wood-Frame Construction, Retrieved: Sept 6, 2010.
[5] Hilti Austria Ges.m.b.H. Altmannsdorferstr. 165, Postfach 316, A-1231 Wien