iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5050

Performance of Wood Steel Hybrid Multistorey Buildings

Maruf Kazi[1], Roshni John[2]
[1] *Mumbai University, Department of Civil Engineering, M.E. Student, Saraswati College of Engineering, Kharghar, Navi Mumbai-410210, India*
[2] *Head of Civil Engineering Department, Saraswati College of Engineering, Kharghar, Navi Mumbai-410210, India*

Abstract: This paper involves detailed study on performance of timber based wood steel hybrid multistorey buildings. This paper examines the performance of wood steel hybrid multistorey buildings for regions with high seismic hazard indexes based on certain criteria like time period, base shear and displacement of the system. Different wood-steel hybrid models are modelled and analysed using finite element based software SAP2000 to predict structural response, more effective and economic way of implementing shear walls in the design. The wood steel hybrid structure incorporates Cross Laminated Timber (CLT), Oriented Strand Boards and Steel as shear walls in steel moment frames. Static analysis and Dynamic analysis are performed on the structure and it is observed that shear walls significantly reduce the time period, base shear and displacement of the steel frame. Parametric studies have been carried out on hybrid wood steel structures with different materials for varying panel configuration (Alternate bays, Middle bays and Every bays). The use of hybrid wood and steel systems allows for the combination of high strength and ductility of the steel frame with high rigidity and light weight of the hybrid structures. The focus of the analysis is on comparing the key structural performances between different cases including displacement, time period and base shear. The different loads considered were dead load, live load, seismic loads, and their load combinations as per IS:1893 (Part-I) 2002.
Keyword: Lightweight structure, cross laminated timber, oriented strand boards, dynamic performance, time period, base shear, displacement.

I. INTRODUCTION

A hybrid system is a combination of two or more structural materials. Steel and concrete hybridization is the most common type of hybrid system. Steel structures are very common in the world because of its short duration of construction and high strength. To improve resistance and to overcome other limitations of individual steel structure it can be combined with other materials like hybrid systems. This project involves detailed study of hybrid wood-steel structures and its application in the construction industry. Wood and steel effective hybridization creates a system in which only minimum steel is used where high strength and ductility are required. Steel is much stronger and provides significant post-yield deflection capability, known as ductility. Steel frames are extremely ductile, with large deformations during seismic events. Wood shear walls are also provided for buckling resistance of the building. Wood shear wall contributes to the stiffness and strength of the steel frames thus increasing stiffness and strength of Hybrid Wood-Steel Structure. Benefits include increase in tensile capacity, seismic performance of the structure, and cost savings. Hybrid systems design is often considered for aesthetic purpose, sustainability, optimal use of different material properties. The hybrid materials can be integrated at component levels (hybrid slab/diaphragms, hybrid beams, hybrid columns, hybrid diagonals, hybrid post-tensioned joints) and/or at the building system levels (hybrid frames, hybrid system of steel frames and wood diaphragms, vertical mixed system and hybrid trusses). To elaborate on these types of hybridization and their advantages and challenges, case studies of steel-timber are provided. The considered software package is SAP2000. Modelling of Hybrid Wood-Steel Structures and analysis is done by using SAP2000 software. In SAP2000 Static Analysis and Dynamic Analysis is performed and the effect of shear wall on the structure is also studied.

II. METHODOLOGY

Fig. 1 shows plan of Hybrid Wood-Steel building 24m x 36m. Case studies using (G+3) and (G+7) hybrid buildings will be numerically modelled (Fig.2). For the formation of hybrid structure Steel, Cross Laminated Timber and Oriented Strand Board are used. First storey height of each building was 4 m and all other storeys were 3m height. Components include beams, columns, slab and shear walls. Beams are the flexural member in the buildings. It can transfer the loads to columns. The material used for the construction of beams is steel which is an I-section. Beams are having cross section W310 x 254 x 86 kg/m (Nominal Depth x

Width x Weight). Columns are the compression members, which has the capacity to transfer the loads from beams. The material used for the construction of columns is steel which is an I-section. Columns are having cross section W310 x 313 x 179 kg/m (Nominal Depth x Width x Weight). Slab is a flat piece of wood serves as a walking surface. The thickness of the slab considered is 150mm.

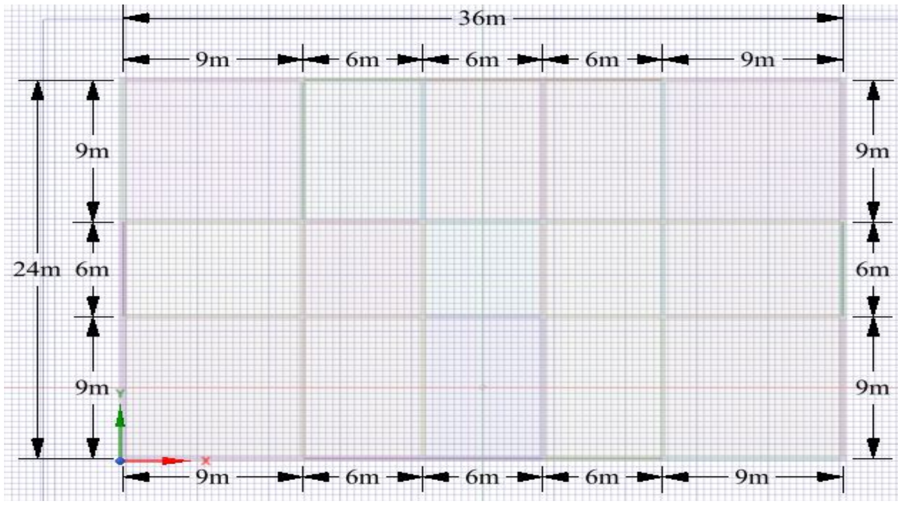

Fig. 1. Plan of Hybrid Wood Steel Buildings

Shear walls are vertical elements of the horizontal force resisting system. A shear wall is a wall which is designed to resist shear, lateral force which causes the bulk of damage in earthquakes. The thickness of the shear wall is 100mm. Loads combinations considered including dead load, live load and seismic loads. Details of the loads and load combination are taken as per IS: 1893 (Part-I) 2002. (G+3) and (G+7) hybrid building 3-D finite element models with SAP2000 were used to predict structural responses under these loads. Numerical model using floor and wall components were modelled as four node shell elements. Beam and Column components were modelled as line elements. Dynamic analysis via response spectrum method is used to apply seismic loads on the structure. The frequency and acceleration are taken corresponding to seismic zone V.

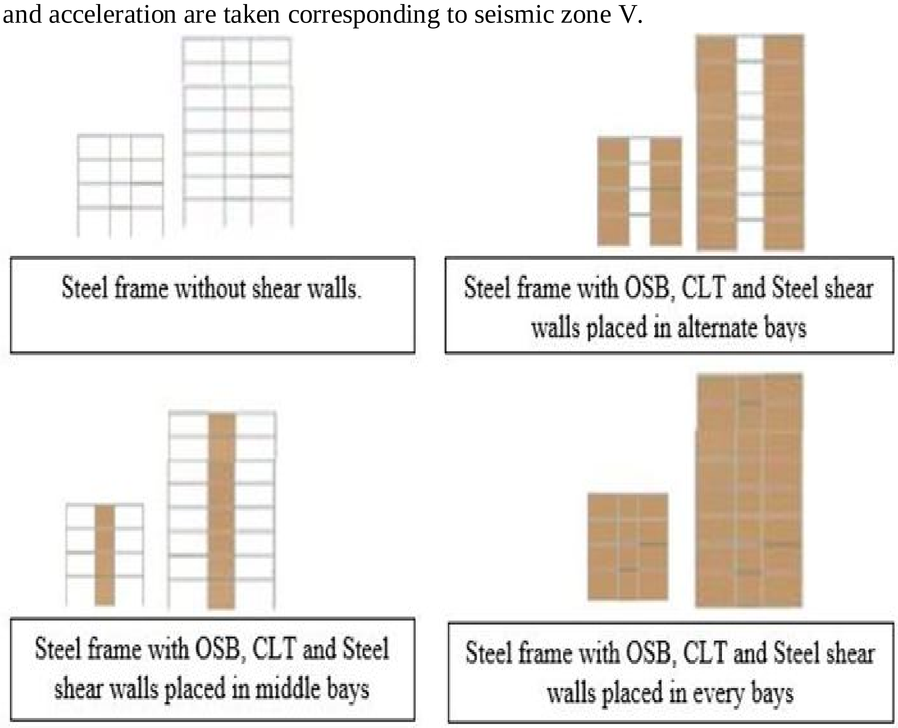

Fig. 2. Shows Models of (G+3) and (G+7) Wood Steel Hybrid Buildings

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

III. MATERIALS AND PROPERTIES USED FOR THE FORMATION OF HYBRID BUILDINGS

A. Steel (ASTM A36)

Steel is the main material used for the formation of the building. Steel is a material which has good ductility and good strength. Properties of steel referred from American standards for Material Testing [13].

TABLE I
PROPERTIES OF STEEL (ASTM A36)

Properties	Steel	Units
Density	7850	Kg/m^3
Elastic Modulus	200000	Mpa
Yield Strength	250	Mpa
Tensile Strength	400	Mpa
Poisson's Ratio	0.26	-

B. Cross Laminated Timber (CLT)

Cross Laminated Timber is a multi-layer mass timber product made from gluing layers of solid-sawn lumber together. Each layers of boards are oriented perpendicular to adjacent layers, so that the panels are able to achieve better structural rigidity in both directions. Properties of Cross Laminated Timber referred from Canadian Technical Design Guide [14] and ascelibrary.org [15].

TABLE II PROPERTIES OF CLT

Properties	CLT	Units
Density	485	Kg/m^3
Elastic Modulus	9500	Mpa
Compression Strength	20	Mpa
Poisson's Ratio	0.46	-

C. Oriented Strand Board (OSB)

OSB is a mat-formed panel product made of strands bonded with exterior type resins under heat and pressure. OSB panels consist of four or five layered mats. Properties of OSB are referred from the link [16] and [17].

TABLE III PROPERTIES OF OSB

Properties	OSB	Units
Density	642	Kg/m^3
Elastic Modulus E_X	4160	Mpa
Elastic Modulus E_Y	1650	Mpa
Elastic Modulus E_Z	400	Mpa
Shear Modulus G_{XZ}	85.7	Mpa
Shear Modulus G_{YZ}	55.7	Mpa
Shear Modulus G_{XY}	1250	Mpa
Poisson's Ratio	0.226	-

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

IV. RESULTS & DISCUSSION

Analysis of G+3 and G+7 Hybrid wood-steel multistorey building with different shear wall material in various positions and the results are compared. The models of the building is analyzed for static structural analysis and dynamic analysis.

(Fig. 3 & 4) shows the time Period for both G+3 and G+7 buildings installed with OSB, CLT and STEEL shear walls. It is observed that time period of steel frame without shear walls is more and with shear walls is less. It can be seen that for (G+3) hybrid building cases, CLT wall system has much lower time period relative to STEEL wall system. For G+3 building in alternate bays, time period for STEEL shear walls is 0.19 seconds and 0.123 seconds (35 % less) for the CLT shear walls. Also time period for OSB shear walls is 0.23 seconds and 0.19 seconds (17 % less) for STEEL shear walls. Difference between time period values of OSB, CLT and STEEL shear walls installed in alternate bays and every bays is also minimum whereas time period of all the shear wall materials installed in middle bays is more as compared to alternate bays and every bays.

It is observed that for (G+7) buildings time period of steel frame significantly reduced after using shear walls in all three cases. Time period of models installed with CLT and STEEL shear walls in Alternate Bays is less as compared to oriented strand board shear walls. For G+7 building in Alternate Bays, time period for CLT shear walls is 0.262 seconds and 0.19 seconds (27 % less) for the STEEL shear walls, whereas time period in Every Bays for STEEL shear walls is 0.188 seconds and 0.186 seconds (l% less) for the CLT shear walls which is a minimum difference.

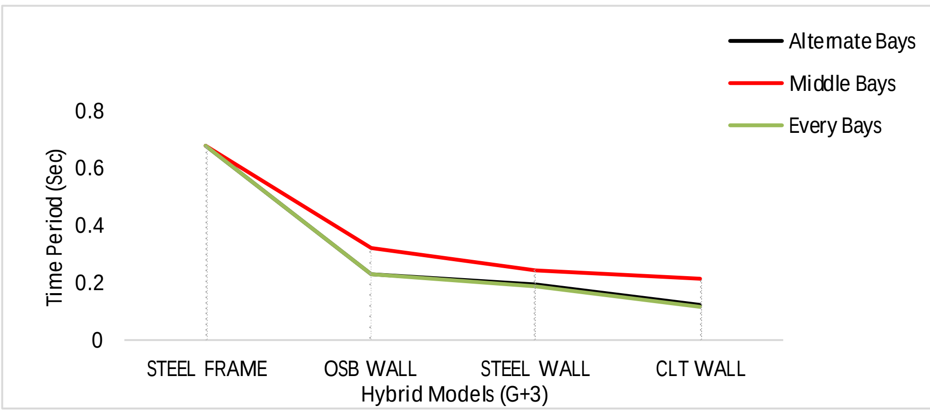

Fig. 3. Time Period of (G+3) Hybrid Buildings

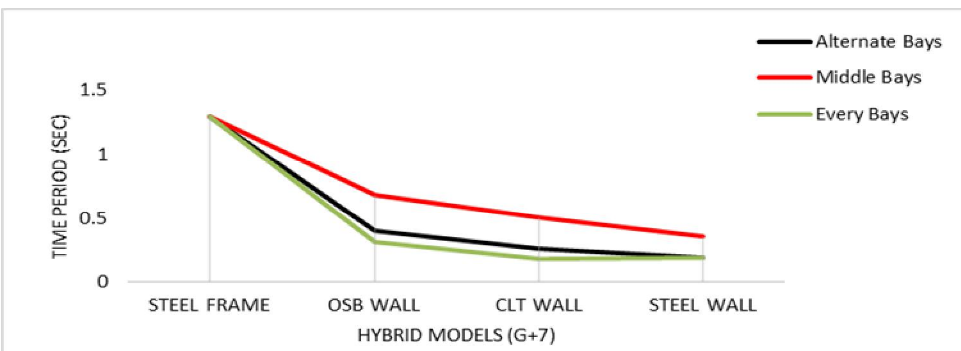

Fig. 4. Time Period of (G+7) Hybrid Buildings

TABLE IV COMPARISON OF BASE SHEAR OF G+3 HYBRID BUILDINGS

	Hybrid Models (G+3)					
	Base Shear-X (kN)			Base Shear-Y (kN)		
	STEEL Wall	CLT Wall	OSB Wall	STEEL Wall	CLT Wall	OSB Wall
Alternate Bays	1023.63	920.53	359.515	909.12	898.43	406.82
Middle Bays	503	262.747	203.331	519	756.67	855.32
Every Bays	1005.99	398.62	279.65	939.88	561.92	369.48

Table. IV shows that base shear in X and Y directions of hybrid models installed with OSB and CLT shear walls in alternate bays is less as compared to steel shear walls. For (G+3) hybrid building base shear in X-direction is almost reduced by 65% and in Y-direction by 55% when installed with OSB shear walls in alternate bays relative to Steel shear walls It is also observed that base shear in X-direction of hybrid models installed with OSB and CLT shear walls in middle bays is less relative to Steel shear walls and base shear of models installed with steel shear walls in Y- direction is less compared to OSB and Steel walls. This is due to less number of shear walls installed in case of Middle Bays in Y-direction as compared to X-direction, stiffness of building is less in Y-direction and hence base shear of models installed with oriented strand board and cross-laminated timber shear walls is more in Y-direction.

Table. V shows that for (G+7) hybrid building base shear in X-direction is almost reduced by 23% and in Y-direction by 6.87% when installed with OSB shear walls in alternate bays relative to Steel shear walls. Overall Base Shear of models installed with OSB and CLT shear walls is less relative to models installed with STEEL shear walls.

TABLE V COMPARISON OF BASE SHEAR OF G+7 HYBRID BUILDINGS

	Hybrid Models (G+7)					
	Base Shear-X (kN)			Base Shear-Y (kN)		
	STEEL Wall	CLT Wall	OSB Wall	STEEL Wall	CLT Wall	OSB Wall
Alternate Bays	1888	1640.02	1514.199	1550.8	1488.04	1477.37
Middle Bays	1368.803	1288.03	1135.94	2154.39	1254.52	1187.84
Every Bays	2092.447	1594.7	1570.25	1647.2	1566.85	1534.19

TABLE VI
COMPARISON OF DISPLACEMENT OF G+3 HYBRID BUILDINGS

	Displacement-X (mm)				Displacement-Y (mm)			
	Steel Frame	OSB Wall	CLT Wall	Steel Wall	Steel Frame	OSB Wall	CLT Wall	Steel Wall
Alternate Bays	11.51	7.51	3.04	0.5	16.68	10.38	3.12	1.09
Middle Bays	11.51	3.32	1.21	0.57	16.68	6.39	3.14	1.31
Every Bays	11.51	7.54	3.08	0.39	16.68	10.4	3.1	0.82

TABLE VII
COMPARISON OF DISPLACEMENT OF G+7 HYBRID BUILDINGS

	Displacement-X (mm)				Displacement-Y (mm)			
	Steel Frame	OSB Wall	CLT Wall	Steel Wall	Steel Frame	OSB Wall	CLT Wall	Steel Wall
Alternate Bays	24.23	13.38	4.42	0.51	31.16	13.87	5.02	1.1
Middle Bays	24.23	7.225	2.982	0.58	31.16	18.77	12.62	6.66
Every Bays	24.23	13.1	3.175	0.392	31.16	11.59	3.73	0.804

Table VI & VII shows that displacement of the steel frame significantly reduced after using shear walls. For (G+3) Hybrid Buildings displacement is reduced by 73.58% in X-direction and 81.3 % in Y-direction of steel frame when cross laminated timber shear walls installed in alternate bays. Whereas Displacement is reduced by 73.24% in X-direction and 81.41 % in Y-direction of steel frame when cross laminated timber shear walls installed in every bays. For (G+7) Hybrid Buildings displacement is reduced by 81.75 % in X-direction and 83.88 % in Y-direction of steel frame when cross laminated timber shear walls installed in alternate bays. Whereas Displacement is reduced by 86.9% in X-direction and 88 % in Y-direction of steel frame when cross laminated timber shear walls installed in every bays. The percentage difference between displacement values in alternate bays and in every bays is minimum. Displacement in X and Y directions of models installed with cross-laminated timber and steel shear walls in Alternate Bays, Middle Bays and in Every Bays is less as compared to oriented strand board walls.

V. CONCLUSIONS

Analysis results showed that the time period, displacement of the steel frame significantly reduced after using shear walls. Time period of (G+3) hybrid building installed with cross-laminated timber and steel shear walls is less as compared to OSB, however there is a minimum difference between time period values of OSB, CLT and STEEL shear walls when used in alternate bays and in every bays respectively as observed from (Fig 3). Time period of (G+7) hybrid building installed with cross-laminated timber and steel shear walls is less as compared to OSB. Difference between time period values of (G+7) hybrid building installed with Steel and CLT shear walls is also minimum when used in alternate bays and every bays (Fig 4). Therefore oriented strand board and cross-laminated timber can be used in place of steel in alternate bays as it is cheap. Through the proper use of oriented strand board and cross-laminated timber shear walls, we can obtain a light weight hybrid structure and stiffness much greater than that of typical steel shear walls. Stiff and light weight hybrid building performs much better than the steel building under earthquake loads since forces in an earthquake are proportional to the weight of the structure. The result of the study indicates that cross-laminated timber and oriented strand board walls greatly reduces base shear relative to the steel shear walls. After analyzing all the result parameters, it was observed that wood and steel hybrid structure having wooden shear walls installed in the alternate bays model showed the best performance in all cases. Considering from cost and aesthetic view models with wood shear wall in alternate bays consumes less material and hence it is economical. Overall the system shows significant promise for future construction.

VI. ACKNOWLEDGMENT

I wish to acknowledge my deep sense of gratitude to my guide Professor Roshni John, Head of Civil Engineering Department, Saraswati College of Engineering, Kharghar – 410210, India. Her constant encouragement enabled me to work enthusiastically throughout the project work. She has always been a source of knowledge and inspiration to me and I owe a lot for her kindness, invaluable guidance and precious time, which she spent in guiding me. I would also like to acknowledge the help, unconditional support and motivation received from my colleagues during my work. Finally, I wish to express my deepest gratitude to my family who gives me more loving devotions than I could ever return in a lifetime.

REFERENCES

[1] Andi, A., Smith, I.: Connection System of Massive Timber Elements Used in Horizontal Slabs of Hybrid Tall Buildings. ASCE Journal of Structural Engineering, Volume137, Issue 11, 1390-1393 (2011)
[2] Bharatesh, A. D., Malagi, R.R., Abdulhamid, I. M.: Study of Effect of Tolerance on Flexural Strength of Wood Reinforced Steel Tube. International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 1, 156-163 (2012)
[3] BIS (2002)-IS 1893 (Part 1).: Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1 – General Provisions and Buildings (Fifth Revision), Bureau of Indian Standards, New Delhi (2002).
[4] Dickof, C., Stiemer, S.F., Bezabeh, M.A., Tesfamariam, S.: CLT–Steel Hybrid System: Ductility and Overstrength Values Based on Static Pushover Analysis. ASCE Journal, Volume 28, Issue 6 (2014)
[5] Ismail, S., Ibrahim, A., Ahmad, Z.: A Review On Structural Response Of Hybrid Glulam-Cold Formed Steel Roof Trusses. Researchgate (2016)
[6] Kamyar, T., Wolfgang, W., Tamir, P., Michael, K.: Steel Reinforced Timber Structures for Multi Storey Buildings. World Conference on Timber Engineering, Researchgate (2010)
[7] Minjuan, H., Zheng, L., Frank, L., Renle, M., Zhong, M.: Experimental Investigation on Lateral Performance of Timber-Steel Hybrid Shear Wall Systems. ASCE Journal of Structural Engineering, Volume 140, Issue 6 (2014).
[8] Matiyas, A.B., Solomon, T.: Effects of CLT-Infill Walls on the Collapse Behaviour of Steel Moment Resisting Frames. Conference of Canadian Society for Civil Engineering. Researchgate, (2016).
[9] Maheswaran, N., Hemanth, M. K., Velmurugan, G., Vijaybabu, K., Prabhu, S., Palaniswa-my, E.: Characterization of Natural Fibre Reinforced Polymer Composite. International Journal of Engineering Science and Research Technology, 362-369 (2015)
[10] Oana, S., Nicolae, T.: Analysis of Hybrid Polymeric Composite-Timber Beams using Nu-merical Modelling. Researchgate, 19-29 (2011)
[11] Schneider, J., Zhang, X., Thomas, T., Marjan, P., Erol, K., Stiemer, S.F., Solomon, T.: Novel Steel Tube Connection for Hybrid Systems. World Conference on Timber Engineer-ing, Researchgate (2014)
[12] Zheng, L., Minjuan, H., Zhong, M., Wang, K., Renle, M.: In-Plane Behavior of Timber-Steel Hybrid Floor Diaphragms: Experimental Testing and Numerical Simulation. ASCE Journal of Structural Engineering, Volume 142, Issue 12 (2016)
[13] https://www.aisc.org/globalassets/modern-steel/steelwise/022012_steelwise_spec.pdf
[14] Structurlam, http://www.structurlam.com/wp-content/uploads/2017/03/Canadian-Design-Guide-LR.pdf
[15] https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CF.1943-5509.0000614
[16] https://www.researchgate.net/publication/225539437_Poisson's_ratios_of_an_oriented_strand_board
[17] https://www.researchgate.net/publication/279665712_Feasibility_study_of_hybrid_wood_steel_structures