STATIC AND DYNAMIC ANALYSIS OF HYBRID STRUCTURES

DISSERTATION (II)

Submitted by

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IN

STRUCTURAL ENGINEERING

Transforming Education Transforming India

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DECLARATION

I, Rohit Kumar registration no.11601390, hereby declare that this thesis report entitled **"Static And Dynamic Analysis of Hybrid Structures"**submitted for the fulfillment of the requirements for the award of degree of Masters of Technology in Structural Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: **Rohit Kumar**

Place:

CERTIFICATE

Certified that this project report entitled " Static And Dynamic Analysis of Hybrid Structures" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara , carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

Signature of Supervisor

Er. Paramveer Singh

Assistant Professor

ACKNOWLEDGEMENT

Acknowledgement is not a mere formality but a genuine opportunity to thank all those people without whose active support this project would not be possible.

Very sincere and honest words of thanks for **Er. PARAMVEER SINGH my project guide** who not only taught the fundamentals essential for undertaking such a project but also helped us develop as an individual.without there guidance it would have been extremely difficult to implement the project.The encouragement and assistant given by him made this a personally rewarding experience.

Finally,we are thankful to the all mighty God who had given me the power,good sense & confidence to complete our project.

ABSTRACT

The composite material of steel and timber is used in order to get the economical and light weight structure. The cross laminated timber panels are used for this purpose. When the weight of the structure is reduced, the number of columns are also reduced, which helps to save the material.The study about effects of earthquake and lateral loads on both the structure with different material is done.The STADD Pro V8i is used for the analysis and compare it with the other composite material structure.From the result,it can be seen that The maximum effects of different seismic parameter are reduced in the case of steel-timber structure rather than steel-structure.

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ABBREVIATIONS

M	Meter
Mm	Millimeter
KN	kilonewton
Kg/m^3	Kilogram per meter cube
Cm	Centimeter
N	Newton
No.	Number
Φ	Diameter
Sec	seconds
Knm	Kilonewton meter

CHAPTER-1.

INTRODUCTION

1.1 General:-

In the multistoried hybrid structures, there is always a combination of two three and many materials.the different materials used in the hybrid structures plays a different role according to their ability and always gave better performance and results than the single material used in the small constructions.In steel timber hybrid structures,two main materials steel and wood are used.The preferences given to both material according to their strength.The material should be divided in to two systems.

The steel used in the structures should be taken as primary structural system(main structural system) and wood should be taken as secondary structural system.Cross laminated timber panels are used in building floor slabs, the panels are combined with asymmetric slim floor beams (A.S.B.S) with in a steel frame, replacing the precast or poured in situation concrete used in composite material.

It is generally related to the reduces of column sizes,lighter weight and small foundation.Deriving the amount of (C.L.T) slab contributing to the overall stiffness of the supporting frame,along with creating a suitable shear connections at the interface of slab and beam are the main parts of intrest.

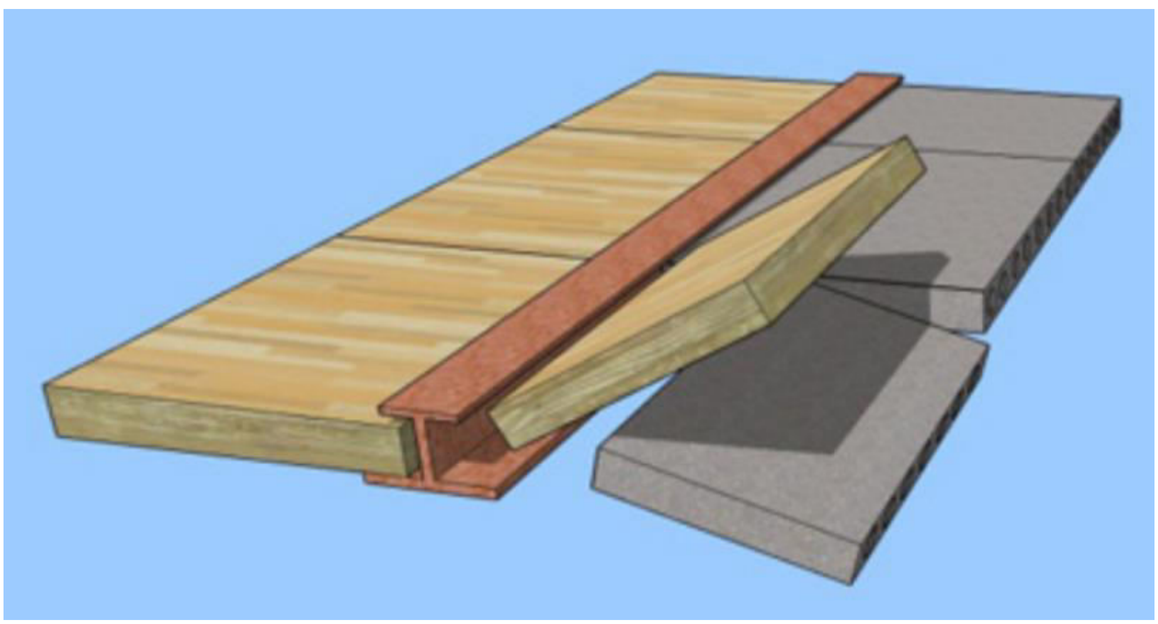


Figure-1.1 Inter connection between steel girder and timber slab

1.2 Preventions of Timber structures:-

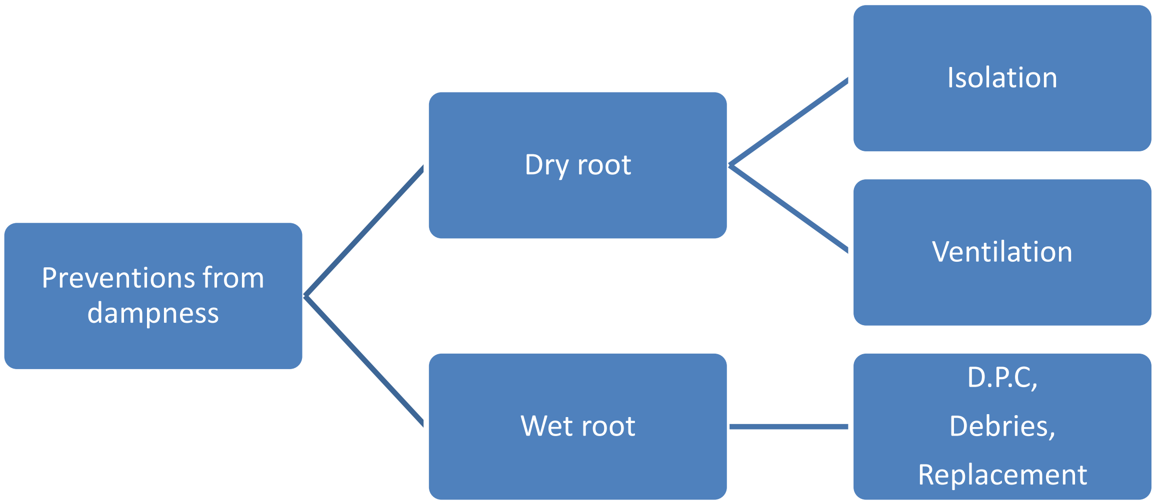


Figure-1.2 Preventions of Timber

1.2.1 Dry root:-

(i) When the chemical is applied to the soil under or around the foundation of building is called as soil chemical barrier.

(ii) When the plastic sheets containing chemicals are typically applied in structures as layers are known as plastic chemical barrier.

Preventions from dampness

(i) In dry root,the removal of the destructed timber should be involved.

(ii) The other approach is to use the environmental control such as,
1) The doors frames and floor slabs outer sider should be provided with damp proof membrane for fully isolate damping.
2)The proper ventilation should be provided around the structures for passage of air.

1.2.2 Wet root:-

(i) The D.P.C should be provided for the protection from moisture.

(ii) In foundation level,the wet soil and debries should be removed properly,where the timber structures would be constructed.

(iii) The defected parts of timber should be replaced.

1.3 Cellular Beams:-

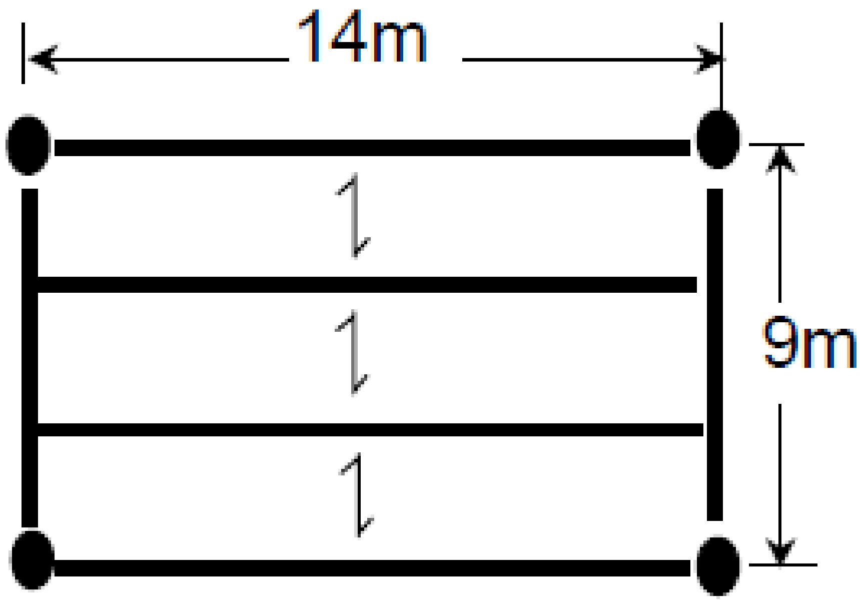
Now a days, there is a world of new construction with new facts,ideas and technology,which increases the efficiency of the hybrid structures and also increases the life span of the structures.

The cellular beams are most important components,which are used in the high rise constructions.because the cellular beam are used on that places where the need of long span and light weight of structure is required.the flexibility of the structure is also increases as the pipes and ducts passes through the wholes of the cellular beams.

Figure-1.3 Cellular beams in highbrid structure

Figure-1.4 Cellular beams in car parking

Example-1. Geometry and properties of cellular beam.



Live Load 4.0 kN/m2,Partitions 1.0 kN/m2,Services, Ceilings & Finishes 0.5 kN/m2,Slab 130 mm

Beam A	**Solution**		
Depth Limit	650 mm maximum	UB 406x178x54	68 kg/m
Service Openings	400 mm minimum	UB 533x210x82	24kg/m2 Floor Weight

Beam B	**Solution**		
Depth Limit	400 mm maximum	UB 254x254x89	113 kg/m
Service Openings	250 mm minimum	UB 305x305x137	42kg/m2 Floor Weight

(i) Beam-A

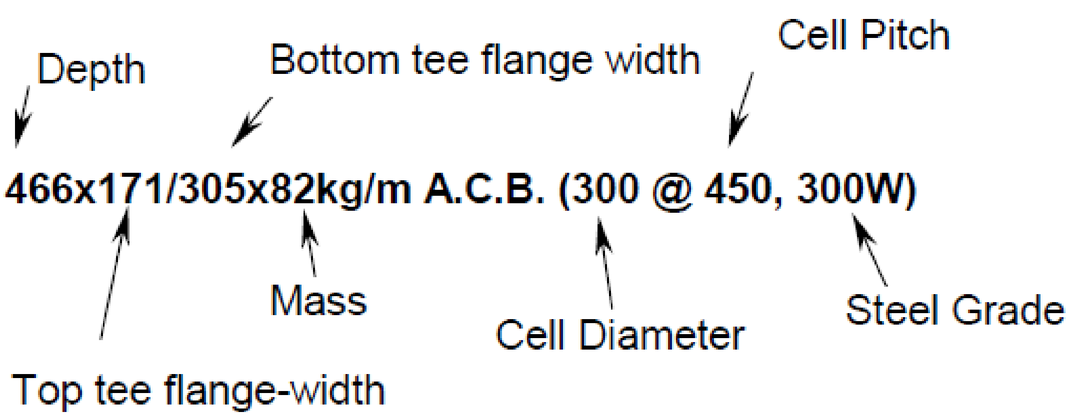
(ii) Beam-B

1.4 Practical applications of cellular beams:-

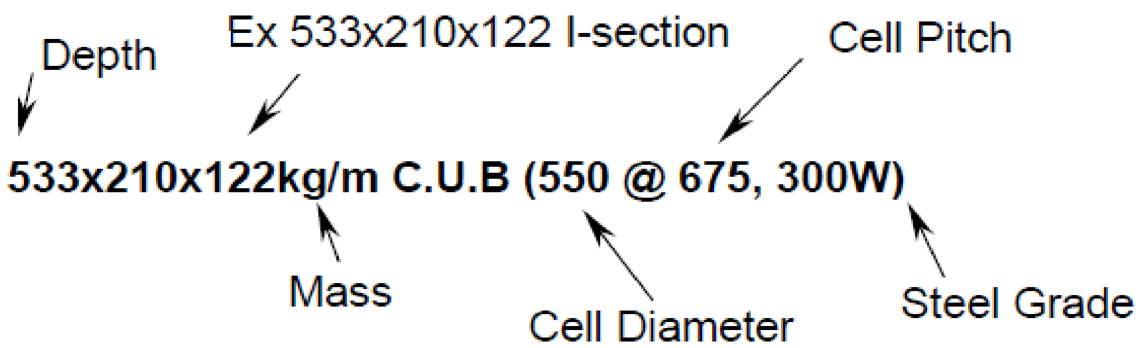
(i) The cellular beams are used in roofing of structures.
(ii) The cellular beams are used in decking.
(iii) The cellular beams are used for off-shore structures.
(iv) The cellular beams are used for car parkings.
(v) The cellular beams are used for column and façade elements.
(vi) The cellular beams are used in renovation.

1.5 Identification of cellular beam:-

The standard of identify the symmetric cellular beam as:-



The standard of identify the asymmetric cellular beam as:-



1.6 ETABS in Hybrid structures:-

*The ETBAS is an engineering software generally refers to Extended Three-Dimensional Analysis of Building System(ETABS). This software deals with the analysis of complex muliti-storey hybrid structures analysis and design.

This software gives the better static,dynamic and seismic results than the other softwares. The structure model create in ETABS is shown in figure 1.5.

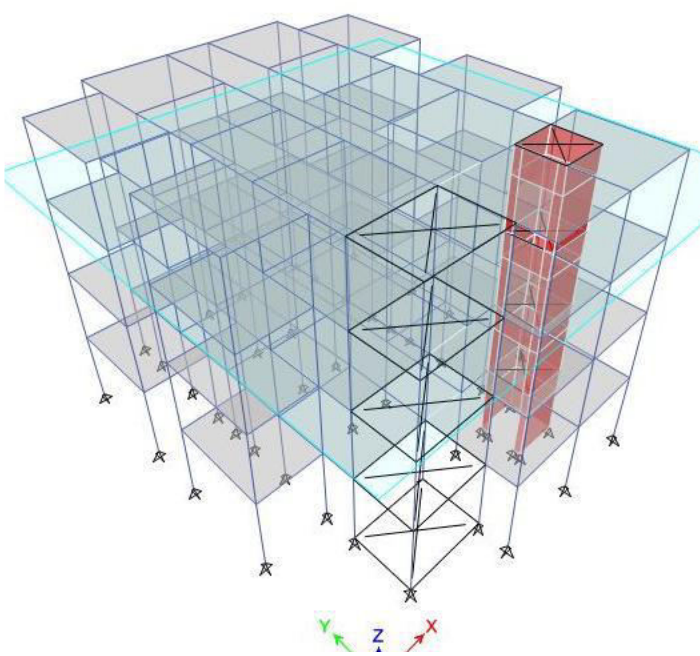


Figure-1.5 3D Model in ETABS

1.7 Features of ETABS:-

(i) ETABS can handle projects of multiple towers.
(ii) ETABS should perform static dynamic and seismic analysis of structure.
(iii) It can handle multistorey hybrid structures in very simple way.
(iv) It can perform P-delta analysis.
(v) Time history analysis curves and response spectrum curves are handle by ETABS.

CHAPTER-2.

PROBLEM BACKGROUND

2.1 Problem background:-

According to the study of past earthquakes occurred,it is seen that there is a major loss of life due to the destruction of the structures. The main reason for this destruction is the heavy masses of the structures because of the more use of the stone,bricks,concrete and steel.

So as the past experience there is a big need of introduce of resistance from the earthquake and light weight to the structures.

The common reasons comes from the study of the previous earthquakes are:-

(i) The large use of stone,brick,concrete masonary in structures.
(ii) The heavy steel reinforcemnent provided in the structures in two directions.

2.1 Socio-Economic factors:-

(i) Lack of the initiative skills and modern techniques of construction of steel-timber structures.
(ii) Lack of awareness from those factors which are helpful to maintain the economy of the structures.
(iii) Lack of investment for theproviding of high resistance techniques to the earthquake.
(iv) Lack of cement,steel and L.V.L timber in developing countries.

CHAPTER-3.

LITERATURE REVIEW

Sooria raj,(2016)

In this research paper the analysis of static response and response spectrum is done and it is seen that the use of the wood in structure as a shear wall decreases the lateral deflection. The deformation values of the seven models in this paper are analyzed and the results are:-

Table-3.1 Deformation and stress of different models

Static analysis		
Models	**Total deformation value(m.)**	**Von mises stress values(pa)**
Model 1	0.19505	6.1429e8
Model 2(OSB)	0.14187	4.1358e8
Model 3(OSB)	0.43752	9.7666e8
Model 4(OSB)	1.3126	1.2823e9
Model 5(wood)	0.13758	3.2265e8
Model 6(wood)	0.16679	6.0609e8
Model 7(wood)	0.84562	4.2421e8

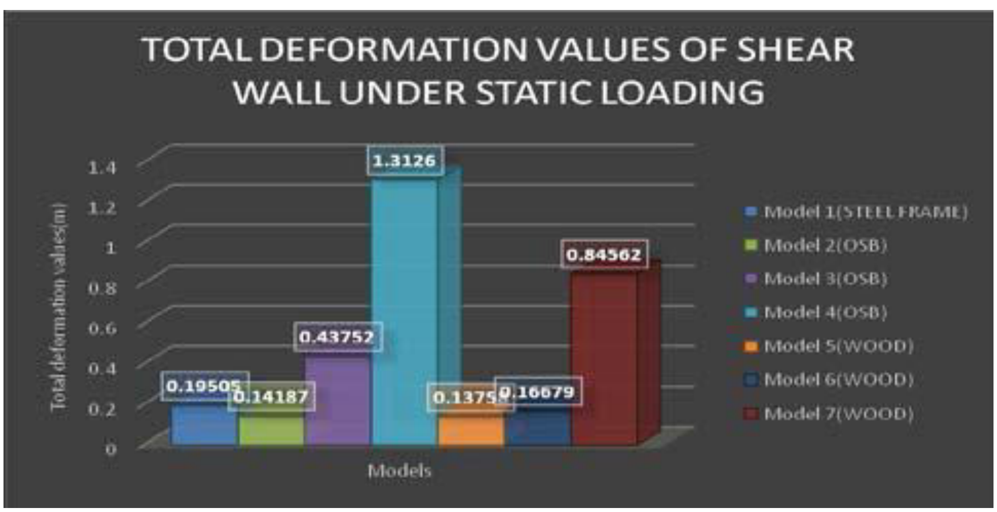


Figure-3.2 Test deformation graph of static analysis (Sooria raj,2016)

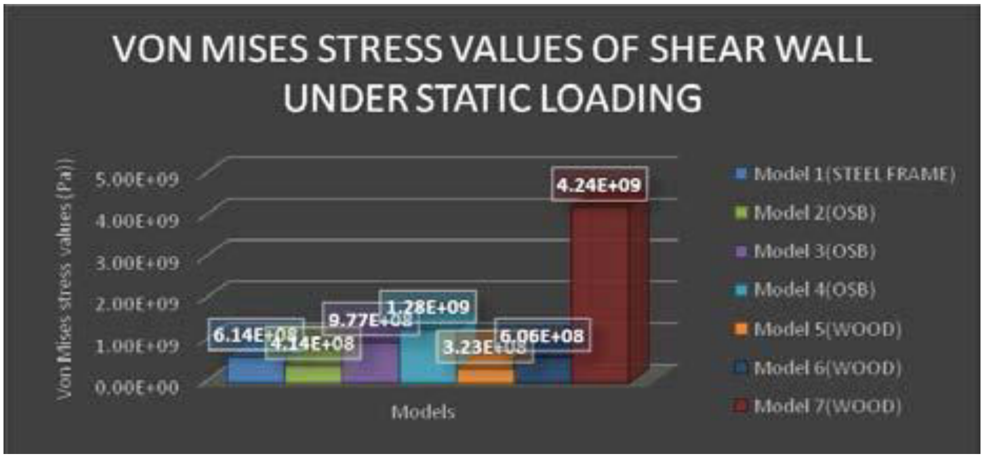


Figure-3.3 Von mises stress value graph of static analysis (Sooria raj,2016)

Table-3.4 Deformation and stress of different models

Seismic analysis		
Models	**Total deformation value(m.)**	**Von mises stress values(pa)**
Model 1(SF)	1.8402e-9	7.0828e-6
Model 2(OSB)	1.3489e-5	1.9973e-5
Model 3(OSB)	1.2284e-6	4.3915e-6
Model 4 (wood)	1.1503e-5	1.5196e-6
Model 5(wood)	2.2005e-6	6.7767e-6

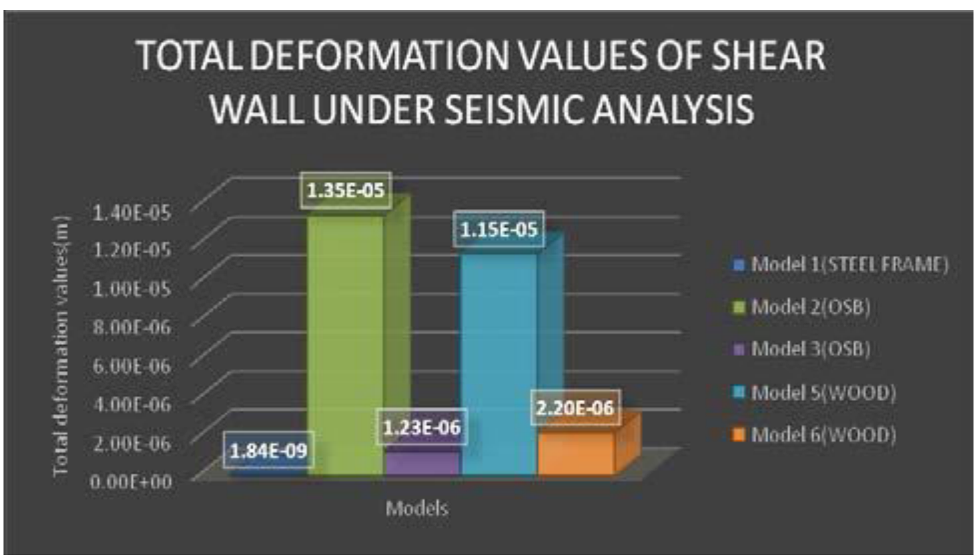


Figure-3.5 Test deformation graph of seismic analysis (Sooria raj,2016)

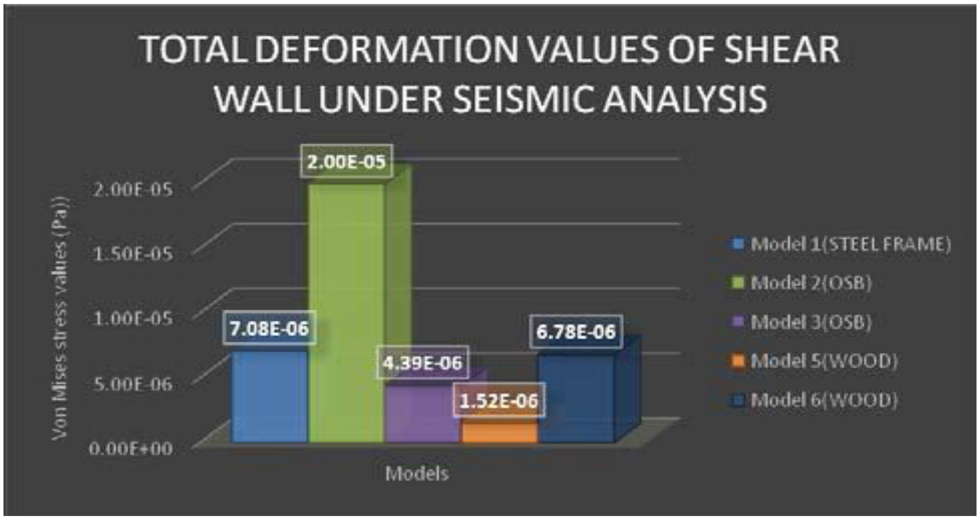


Figure-3.6 Von mises stress value graph of seismic analysis (Sooria raj,2016)

Parsad A.et.al.,(2016)

In this research paper,the glass fibre reinforced gypsum panels ar e use in place of brick masonary and concrete masonary and also proves economic because of less use of cement,steel,sand,bricks and concrete. The GFRG panels are hollow panels and they are filled by plain reinforced concrete according to their purpose.

These panels stability is also proves better for the resistance of the lateral loads,this paper deals with the response spectrum and time history analysis of structure using ETABS.

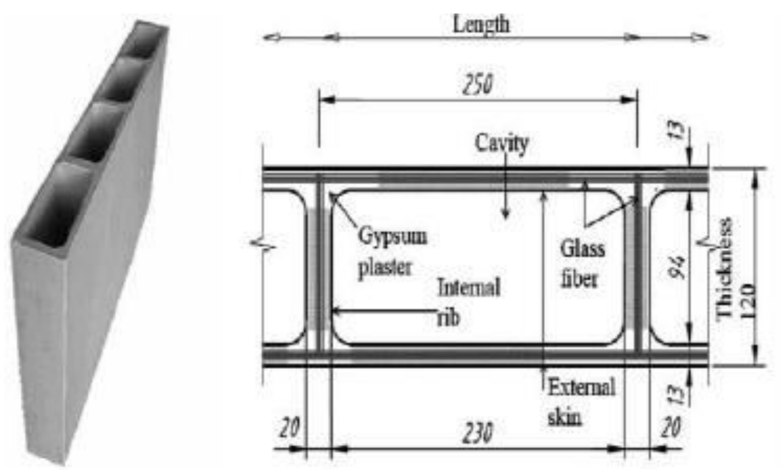
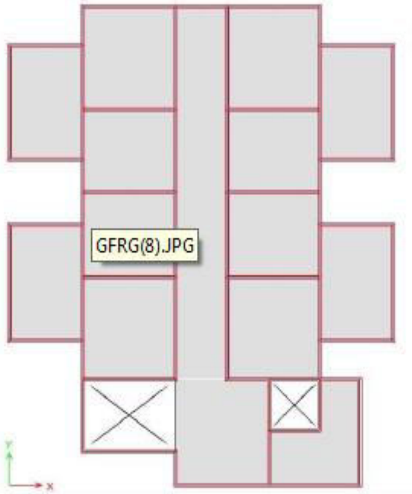


Figure-3.7 GRFG panel with cross section (Parsad A.et.al.,2016)



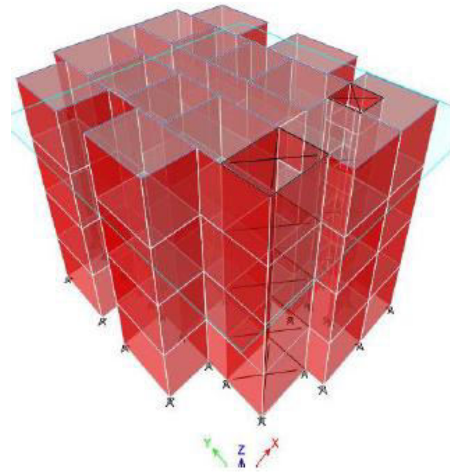


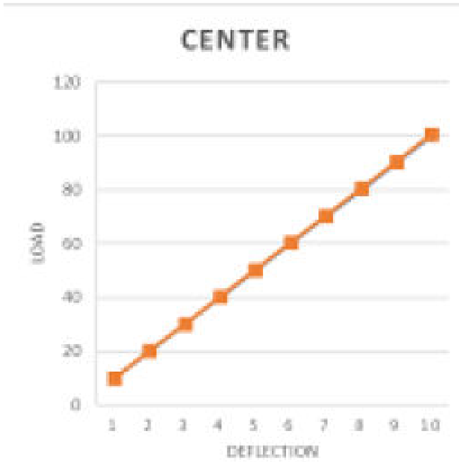
Figure-3.8 GRFG plan for structure **(b) 3D view of GREG structure**

Ajim.S.Shaikh,(2016)

The researcher spreads discussed about the structural analysis and design of castellated beam in cantilever action. In the case of simply supported beam ,the deflection occur at the mid span of the beam but in the case of cantilever action, the maximum deflection occurs at free end .

In this paper ,the experimental study should be done on the castellated beam.The graph of deflection for different cellular beam are:-

Figure-3.9 Lateral torsional buckling on(Hexagonal) **Lateral torsional buckling on(Square)**



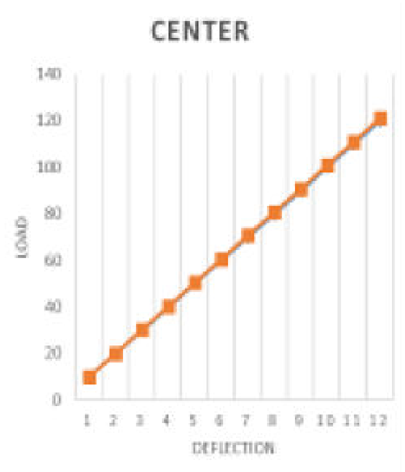


Figure-3.10 Load vs Deflection Graph for (hexagonal)

Load vs Deflection Graph for (Square)

Figure-3.11 Lateral torsional buckling on(circular)

Lateral torsional buckling on(plane)

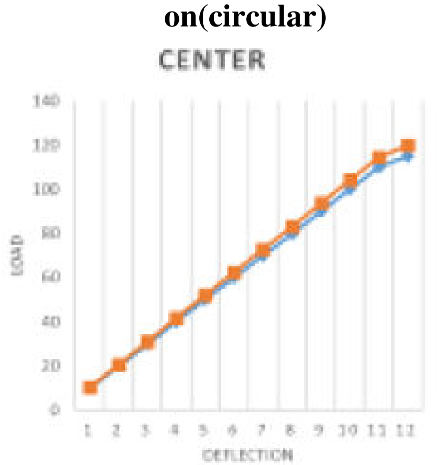


Figure-3.12 Lateral torsional buckling on(circular)

Lateral torsional buckling on(plane)

It results that maximum stress should be produced towards the edges of the opening ,which tends to buckling along web openings.

D. Moroder,(2015)

The research discuss in this paper about the importance of the diaphragm under the seismic loadings and also develop the new composition of different material diaphragm for the resistance of the seismic loads.

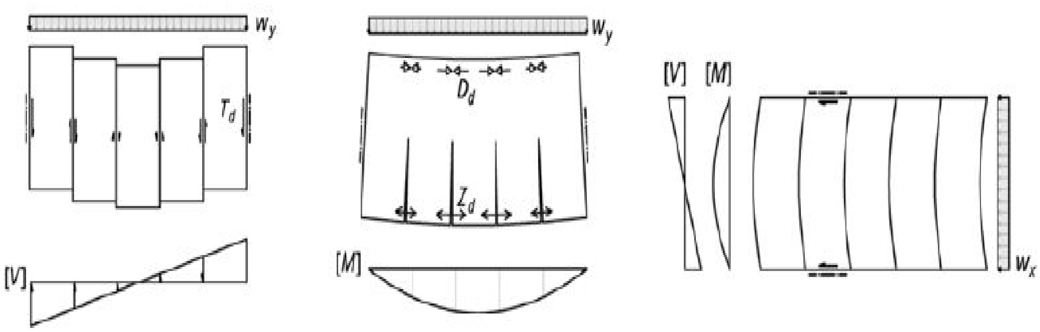
Figure-3.13 Timber frame with diaphragm with cross section (D. Moroder, 2014)

There are various types of timber material available which are used for diaphragm (LVL,CLT,structural insulated panels) in order to resist the lateral and earthquake loadings and also proves as economic rather than other timber material.

Failure mechanism:-

The figure a and b shown that that the forces are experienced and transfer by the connection between the various cord beams.

If the force is in the perpendicular direction of panel then the diaphragm is behave like c mechanism of figure 3.14.



(a) (b) (c)

Figure-3.14 Failure mechanism of diaphragm (D. Moroder, 2014)

Michael F.et. al.,(2014)

The system of “Findings the forest through the trees(F.F.T.T)”is proposed for the medium and hybrid structures.the shortcomings of timber should be ovbercome by the typical connections between the steel and wood.

In this research paper the discussion on the interdrift percentage should be discussed.the interdrift is the most basic parameter in the analysis of hybrid and multistory structures.the interdrift is the different movement of different floors to the base floor constructed in the building.

The average interstorey drift is measured by measuring the maximum interstory drift in the different floors.the percentage of the movement of floors is decreased according to the rise of the structure height because there is nor effect of vibration on the high floors.The graph of interstorey drift is given as:-

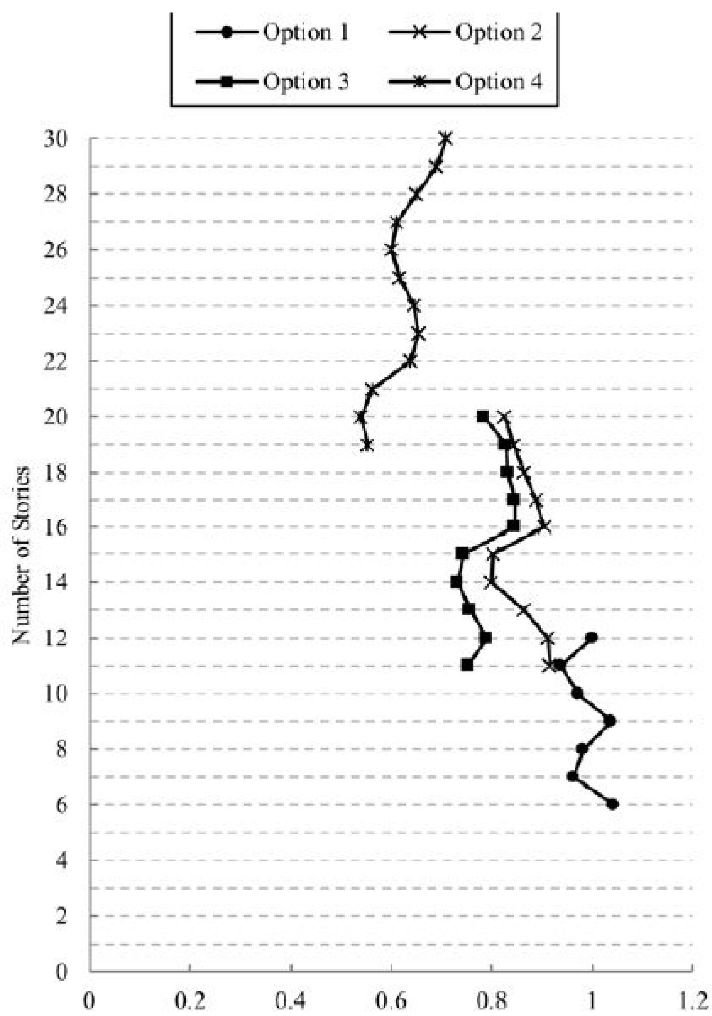


Figure-3.15 Interstorey drift percentage(Michael F.et. al.,2014)

Abhay Guleria,(2014)

In this research paper,the analysis of different shapes(rectangular shape,L-shape,C-shape and I-shape) is done by using ETABS.A structure having 32x24m and 4x4m columns center to center distance is taken in figure 3.16.

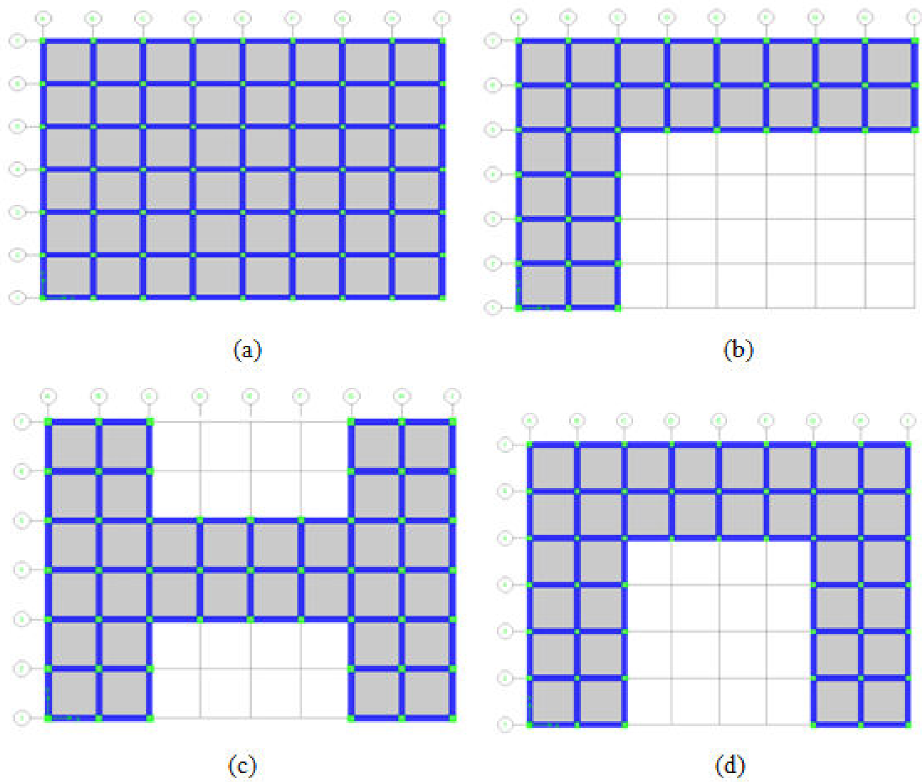


Figure-3.16 plan (a) Rectangular (b) L-shape (c) I-shape (d) C-shape (Abhay Guleria, 2014)

Results and comments:-

Table-3.17 Max B.M. and Shear Force of Beam

Forces	**Rectangular**	**L-shape**	**I-shape**	**C-shape**
B.M. My	92.99	97.38	101.54	99.74
B.M. Mz	0.11	1.56	0.64	1.12
Shear Force Fy	161.09	159.18	158.18	159.27

Table-3.18 Max B.M. and Shear Force of column

Forces	Rectangular	L-shape	I-shape	C-shape
Axial Force Fx	399.265	453.41	400.40	435.03
Shear Force Fy	88.16	87.68	91.96	90.59
Shear Force Fz	90.11	86.15	95.23	87.59
B.M. My	181.93	172.35	174.40	173.63
B.M. Mz	182.11	172.24	173.64	172.39

The graph 3.19 of overturning moment shows that as the increase in height of building,there is a decrease in overturning moment for all shape structures.

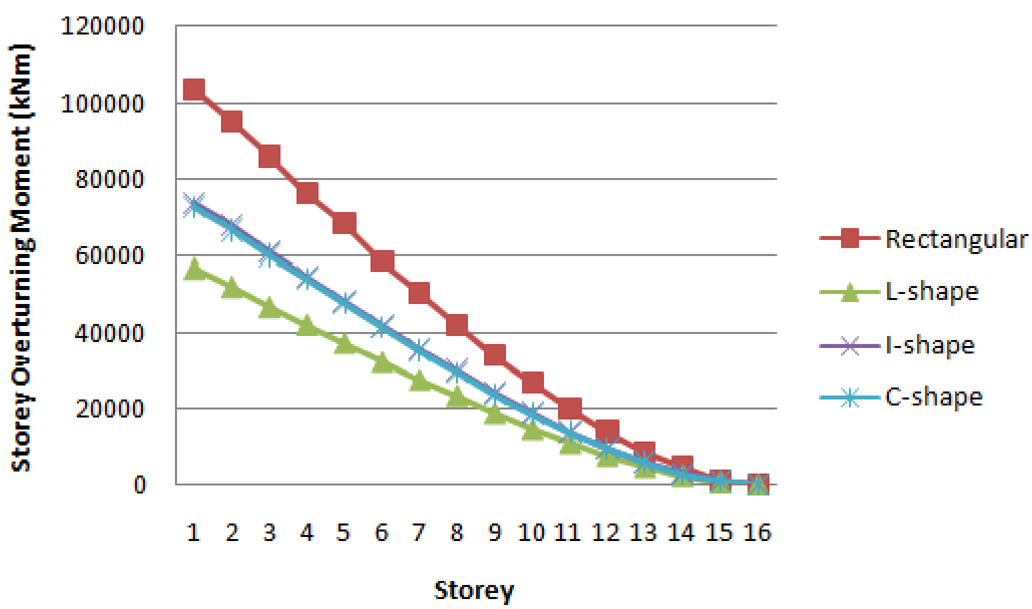


Figure-3.19 Storey height and overturning moment (Abhay Guleria,2014)

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The bar chart 3.20 shows that the storey shear of every five storey interaval. The shear decreases with an increase of height. The shear for L-shape is always less among all the shapes.

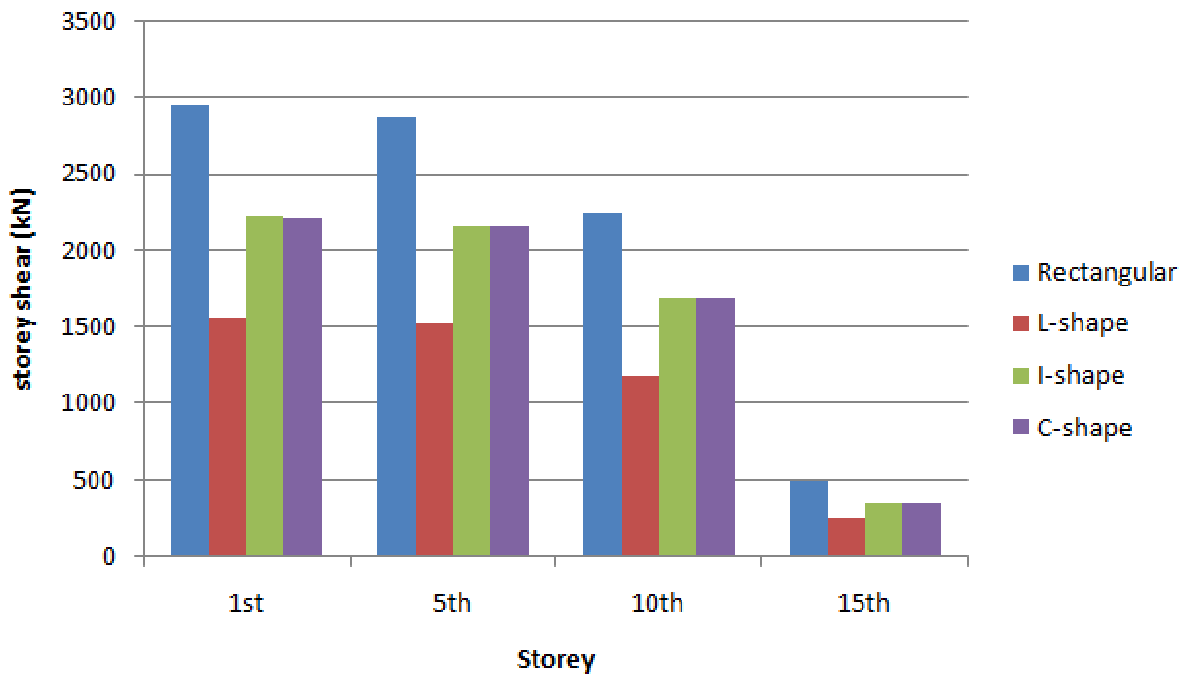


Figure-3.20 Storey height and storey shear (Abhay Guleria,2014)

In the table 3.21 there is a increase in displacement with increase in height and rectangular shape having less displacement than other shapes.

Table-3.21 Lateral displacement (mm.)

Storey	Rectangular	L-shape	I-shape	C-shape
0	0	0	0	0
1	1.37	1.30	1.27	1.37
2	3.41	3.58	3.51	3.41
3	5.95	6.29	5.85	6.05
4	8.49	9.11	8.29	8.59
5	11.12	12.03	10.93	11.32
6	13.76	15.07	13.76	14.24
7	16.78	18.32	16.49	17.37
8	19.51	21.57	19.41	20.39
9	22.24	24.72	22.15	23.22
10	24.59	27.64	24.49	25.85

11	26.83	30.46	26.93	28.49
12	28.88	32.95	28.88	30.63
13	30.15	34.91	30.34	32.49
14	31.61	36.86	31.71	34.15
15	32.39	38.16	32.78	35.02

Table-3.22 Lateral drift (mm.)

Storey	**Rectangular**	**L-shape**	**I-shape**	**C-shape**
0	0	0	0	0
1	3.9	3.8	3.8	3.8
2	7.3	7.3	7.2	7.4
3	8.1	8.4	8.1	8.4
4	8.2	8.7	8.4	8.8
5	8.2	8.9	8.5	9
6	9.5	10.04	9.7	10.03
7	9.4	10.01	9.6	10.01
8	9.0	9.8	9.3	9.9
9	8.5	9.4	8.9	9.5
10	7.9	8.8	8.3	9.0
11	7.1	8.0	7.6	8.3
12	6.2	7.2	6.7	7.4
13	5.1	6.1	5.6	6.3
14	3.7	4.8	4.3	5.0
15	2.3	3.7	3.1	3.9

The graph 3.23 between the storey drift and height tells us that there is a icrease in displacement drift with increase in heightup to 6^{th} level. After that the curve goes down as increase in height of building.

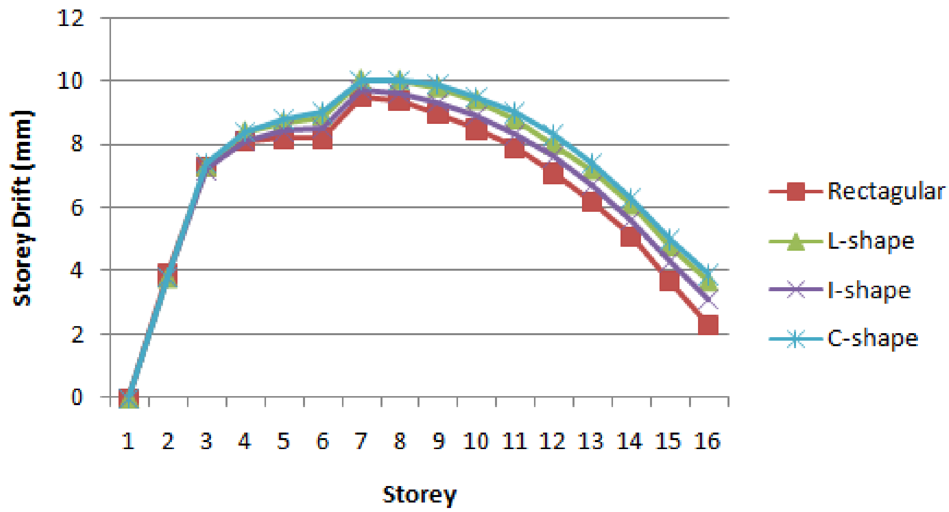
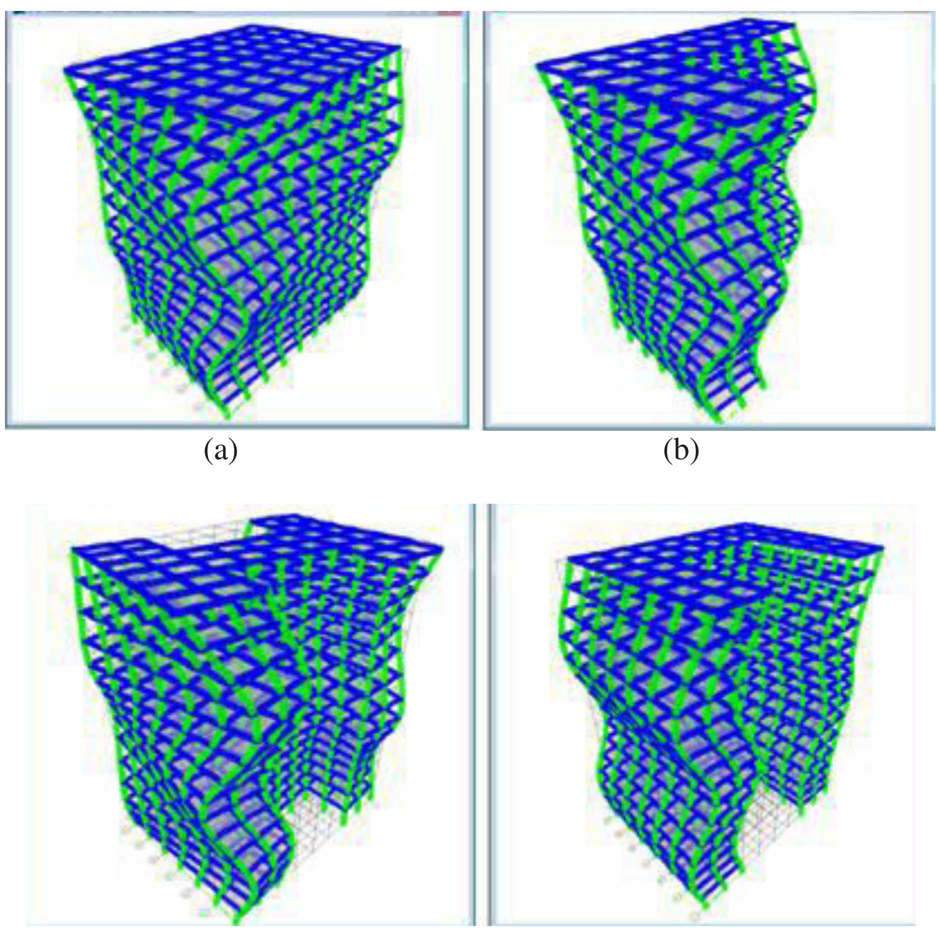


Figure-3.23 Storeydrift versus height (Abhay Guleria,2014)



(a) (b)

(c) (d)

Figure-3.24 Deformed shapes of different models in ETABS (Abhay Guleria,2014)

Hein C.,(2014)

This research paper describe the developing the new hybrid timber construction. The example of life cycle tower is taken,in which the structure of composite material(timber and concrete) is interconnected with joints and distribute the loads from timber slab to concrete beams and then to the steel columns. The timber-concrete slab system is shown in figure 3.25.

Figure-3.25 Timber-concrete slab system (Hein C.,2014)

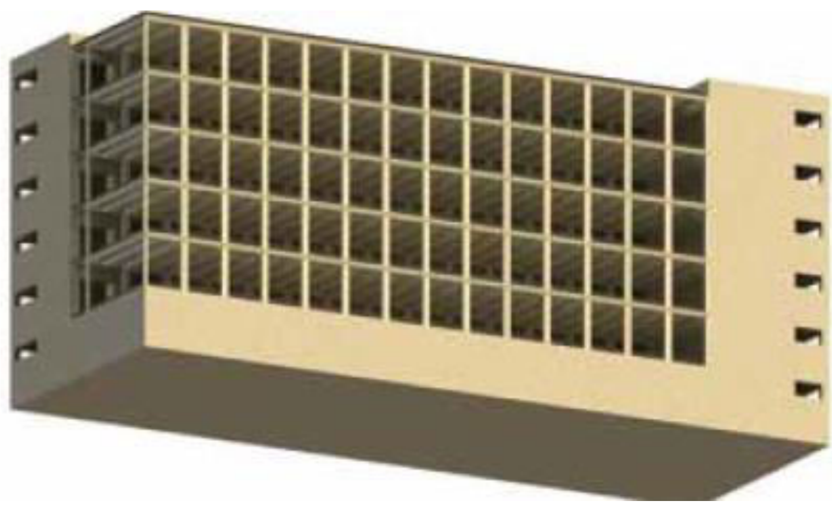


Figure-3.26 Revit model of LCT system for California (Hein C.,2014)

Nayak A.,(2013)

The bamboo's are taken as the main internal material used as a reinforcement instead of the steel reinforcement. This idea is proved economic and light weight than the steel reinforcement.

As per the research the bamboo should not take more load than the steel reinforcement becauses of the low stresses. But the performance of bamboo against the seismic action is better because of its flexibility. Before using of bamboo as reinforcemen;t,the bamboo's are cutted and then exposed to the dry atmosphere to reduces the moisture content and after that the waterproofing coating is applied over it to provide prevention from swelling when it is placed with the concrete. The properties of steel and bamboo reinforcement are:-

Table-3.27 Reinforcementof bamboo and reinforcement

	Bamboo reinforcement		**Steel reinforcement**	
No.	Diameter(in.)	Area(sq.in.)	Diameter(in.)	Area(sq.in.)
1	3/8	0.008	0.250	0.05
2	½	0.136	0.375	0.11
3	5/8	0.239	0.500	0.20
4	¾	0.322	0.625	0.31
5	1	0.548	0.750	0.44
6	2	1.92	0.875	0.60

Minjuan He,et al.,(2012)

In this paper the shear forces in the hybrid structures should be resisted by composed of steel moment-resisting frames, timber-steel hybrid diaphragms and infill wood-frame shear walls.The collaboration of steel frame and infill walls act as atimber-steel hybrid lateral load resisting systems.

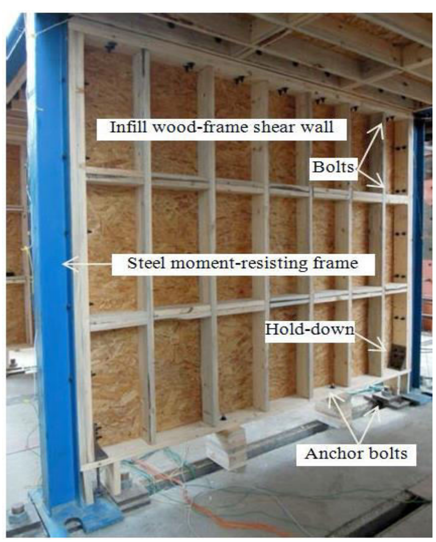


Figure-3.28 Timber-steel hybrid lateral load resisting system (Minjuan He,et al.,2012)

In the figure 3.28 the load resisting system shows that the infill walls and the steel frames should be connected by the riveted and bolted connections.the tight joints should provide more stiffness to the structures.If the shear force would not be resisted by the infill wall,the first damage occurs.at tghat conditions the lateral forces should be resisted by the steel moment resisting frames.

The researcher also verified this research on the basis of pseudo-nail model on the ABAQUS(finite element analysis software).

Minjuan He,et al.,(2012)

In this research paper,the behavior of hybrid structures under the action of lateral loads (seismic load).A particular experiment on the steel column and timer combination discussed.

The light wood frame shear wall should be jointed between the columns and beam of steel as shown in the figure and then the lateral loads is applied threw hydraulic jacks till the plastic stage of the specimen.

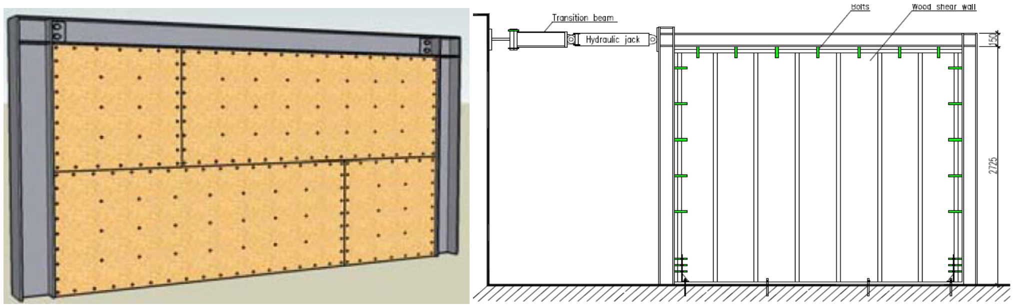


Figure-3.29 (i) Formation of lateral resistant system (ii) loading method on system (Minjuan He,et al., 2012)

This system of combination gave better lateral resistant to the lateral loads then other structures.

Panedpojaman,(2012)

This research paper describes the buckling analysis of the cellular beams.as we know there is common failure in the web the cellular beam due to buckling. The cellular beams are cutted from the center with a specified diameter and the service pipes and ducts are passes threw the wholes. So the cellular beams experienced load in their web due to these services. These beams are generally used for long span and in such structures where curved or bend roofs are provided.

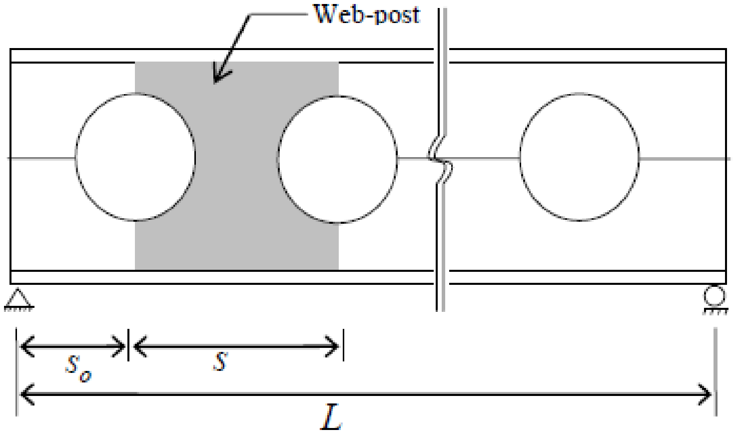


Figure-3.30 Geometry of cellular beam (Panedpojaman,2012)

The buckling in cellular beams are based upon the strut analogy. Strut analogy is defined as the diagonal stresses induced in the web of the beams as shown in figure 3.31.

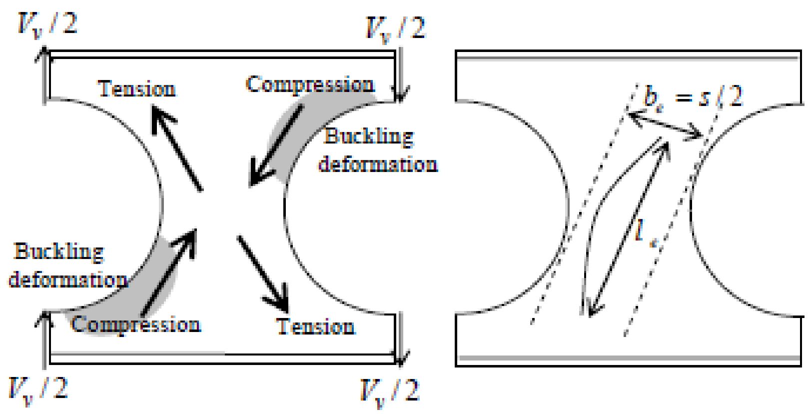


Figure-3.31 Diagonal stresses in beam (Panedpojaman,2012)

Wolfgang Winter et.al.,(2012)

This research paper describes that the promotion and increase the use of wood in the high rise residential buildings.In this paper the researcher gave the example by case study of low rise dwelling structures.

(i) Low rise dwelling (case study)

In the 1st case the 25 appartments is 4.5 storey high and build up with the concrete with the spans up to 6 meters.

The redesign of same storey structures and all parameters are same except the concrete.The timber is used instead of concrete and the results show the cost effectiveness of the structure in the case of timber structures.

A. Nadjai et.al.,(2011)

In this research paper the researcher describes the performance of the steel cellular beams under the action of fire.he takes the example of the long span unprotected cellular beam of 15 m.the supporting floor system resting on the cellular beams.the beams and the floor systems are designed to carry the overall static load,when the structure is subjected to the fire.

This floor system is generally depends upon the bailey method.according to this method.

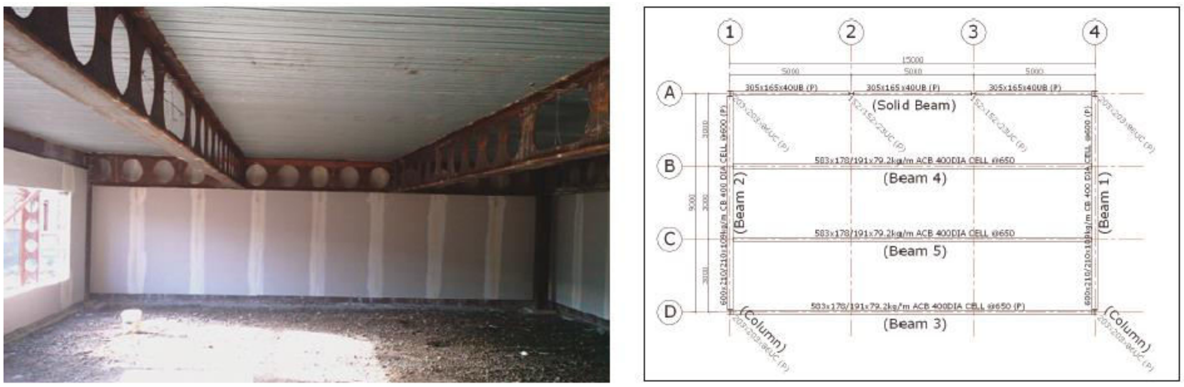


Figure-3.32 Test compartment with long unprotected cellular beams

Steel structural layout (A. Nadjai et.al.,2011)

The Bailey method allows a number of steel beams, within a given floorplate,to be left unprotected by indentifying only those beams that actually require applied fire protection and utilising the inherent strength of the system through membrane action within the composite floor system.

Figure-3.33 Beam connections before protection applied to the primary beam

(A. Nadjai et.al.,2011)

Figure-3.34 Fibre and plasterboard protection used inside the compartment (A. Nadjai et.al.,2011)

Figure-3.35 Vertical static load (A. Nadjai et.al.,2011)

Table-3.36 Load criteria for cellular beams and supporting floor system

Description kN/m2	**Characteristic Load (kN/m2)**	**Load Factor at FLS**	**Design Load at FLS**
Partition	1.0	1.0	1.0
Services and finishes	0.5	1.0	0.5
Live load	3.5	0.5	1.75
Total load			3.25

The relation of temperature with time is shown in curve 2.37 of cellular beams. The curve explains that the temperature of 900 c is achived at the 52-62mintues. The Ozone V2 model gave a maximum temperature of 951°C at 62min.

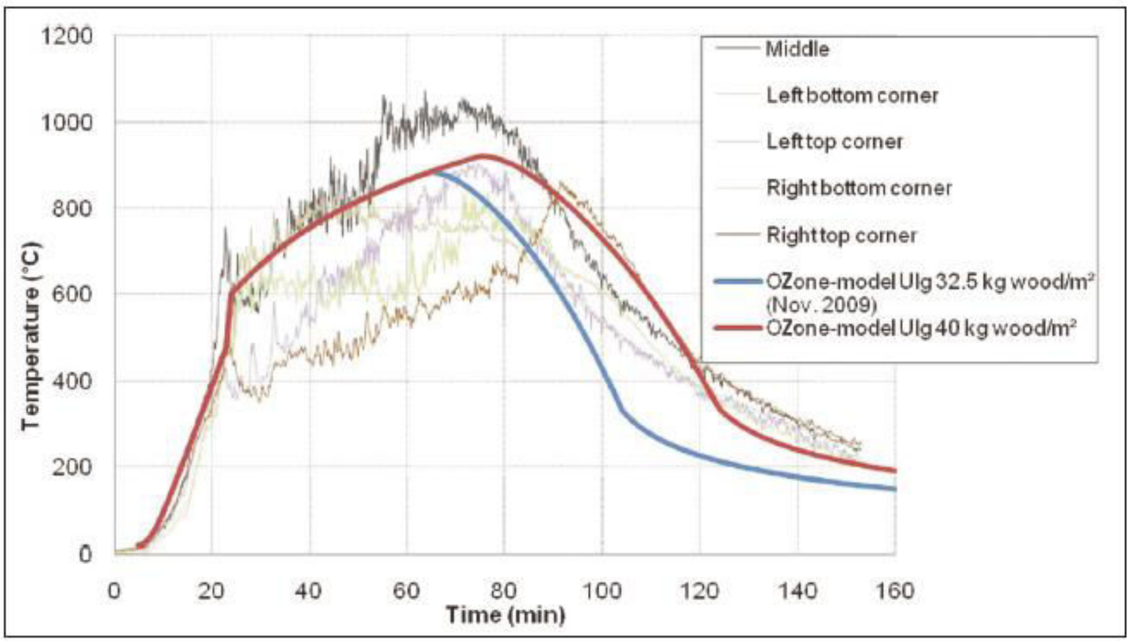


Figure-3.37 Design parametric fire curve, OZone model and measured atmosphere temperatures (A. Nadjai et.al.,2011)

Figure-3.38 Behavior of cellular beams under fire action (A. Nadjai et.al.,2011)

El-Hadi Naili,(2011)

This paper describe the study about the modeling and analysis of different beams specimens having different openings in their web (like circular and elongated web openings).
The researcher take the three specimens of beams as shown in figures having different section properties.

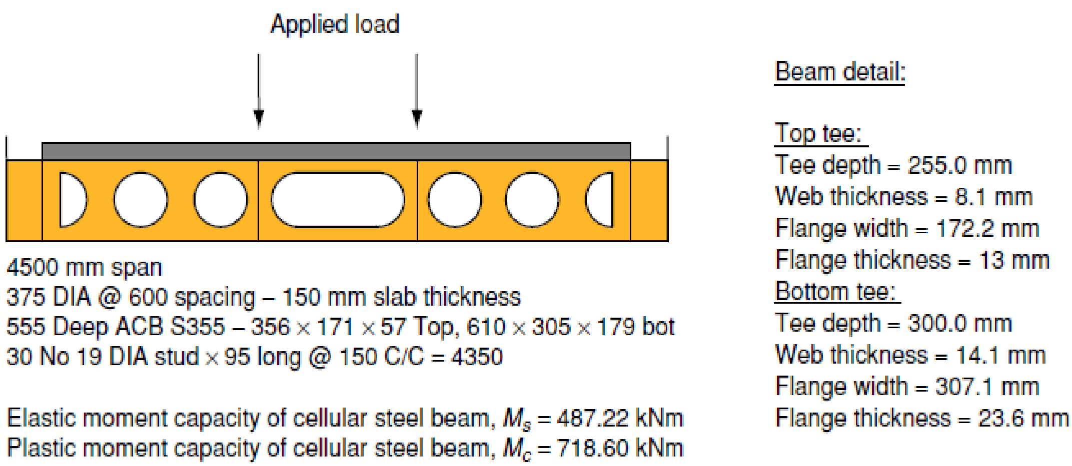


Figure-3.39 Details of asymmetrical cellular beam(1) with two point loads (El-Hadi Naili,2011)

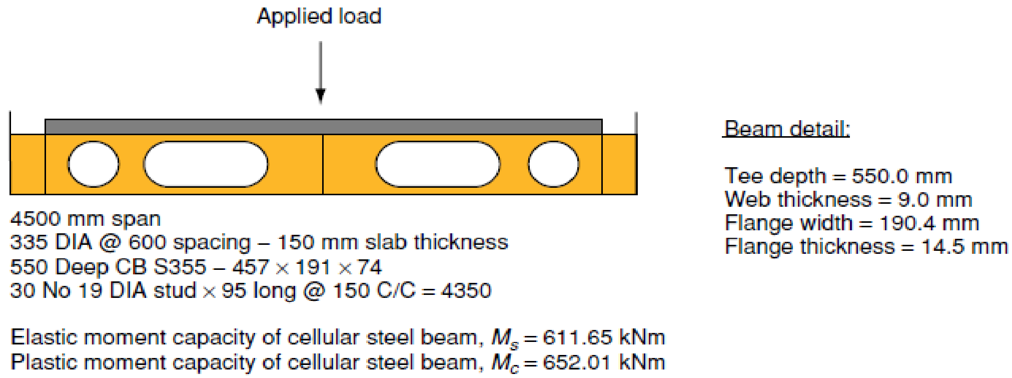


Figure-3.40 Detail of asymmetrical cellular beam(2) with one point load (El-Hadi Naili,2011)

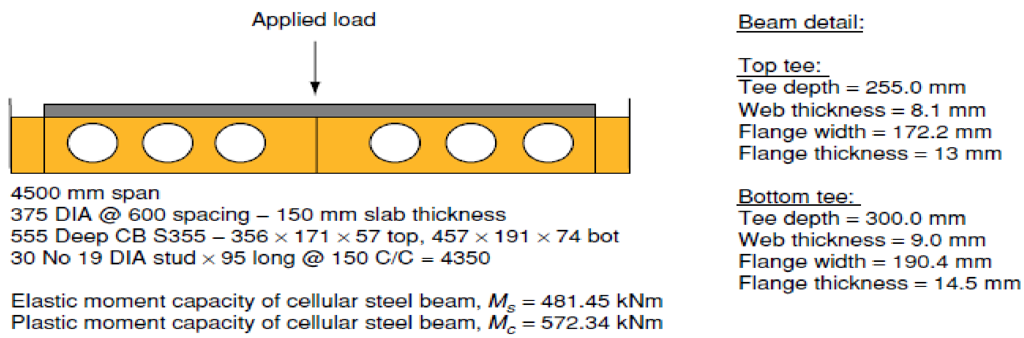
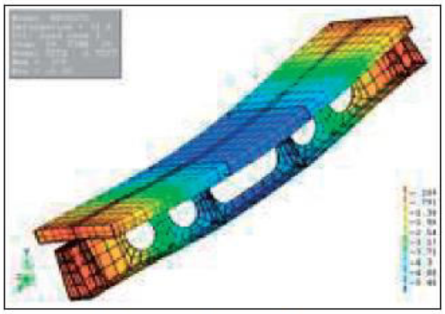


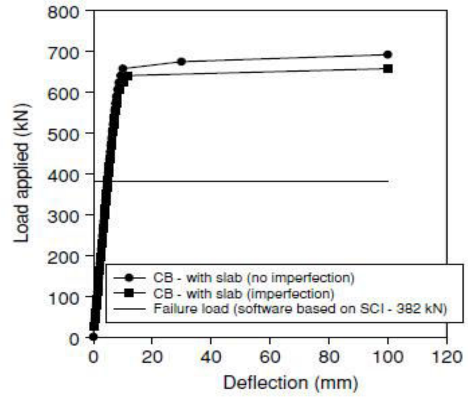
Figure-3.41 Detail of asymmetrical cellular beam(3) with one point load (El-Hadi Naili,2011)

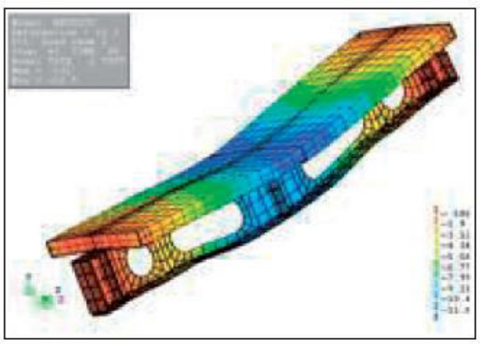
Table-3.42 Software results of cellular beams

	Vierendeel bending	**Web post buckling**	**Horizontal shear**	**Failure load (KN)**
Beam 1	90%	51%	102%	382
Beam 2	102%	35%	44%	245
Beam 3	111%	73%	88%	432



(a) Deflected shape of beam 1A





(c) Deflected shape of beam 2A

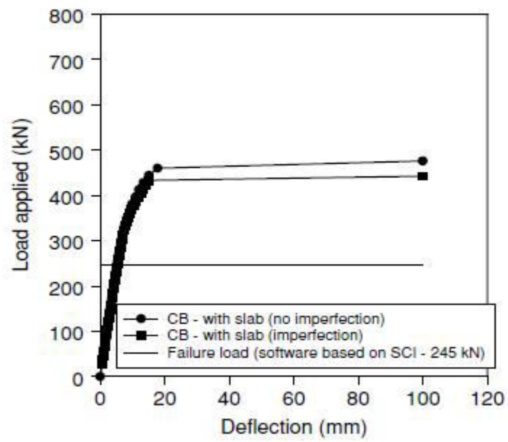
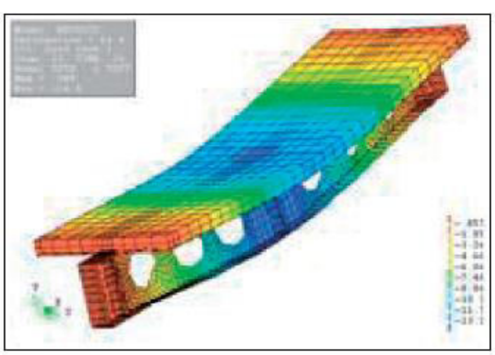


Figure-3.43 Loading versus Deflection and failure loads of composite cellular Beam 1 and 2 (El-Hadi Naili,2011)



(a) Deflected shape of beam 3A

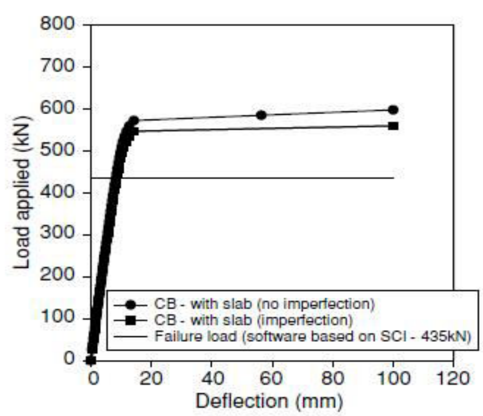


Figure-3.44 Loading v/s Deflection and failure load of composite cellular Beam 3 (El-Hadi Naili,2011)

Muller A.,(2010)

In this research paper,the structural design for the energy efficient hybrid timber houses in $Europe discussed.The timber used in the modern structural design proves better for the structure and consumes low energy and efficient sustainable structures.
The private and Government sector used timber for the accomplishment of the economic requirements.

In 19th century there is a less use of timber because of two reasons.But now a days,these two reasons are eliminated.

(a) (b)

Figure-3.45 (a)Traidational block building (b)Modern timber building in Stenhausen (Muller A.,2014)

The researcher studies about the two approaches in this paper:-

(i) **Fire approach:-**In the fire approach, to provide the protection to the building or to resist fire,there is need of installation of sprinkler system in structure.These systems are able to fight against the fire case.

(ii) **Sound insulation approach:-**The ceilings of different partations in arartments are systematically separated by providing light weight and non load bearing intermediate walls in order to eliminate sound transfers in horizontal direction.

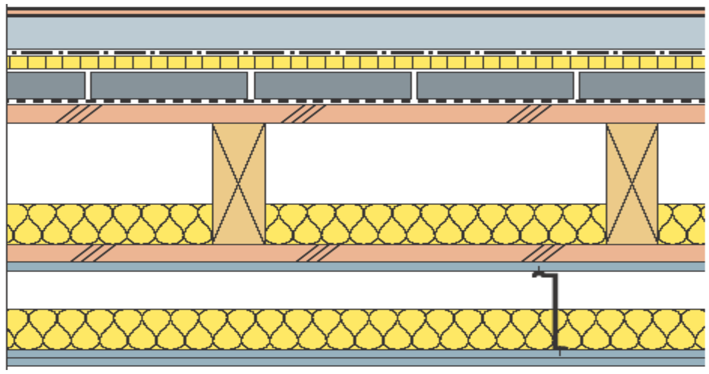


Figure-3.46 Separation of ceiling to avoid sound transfer (Muller A.,2014)

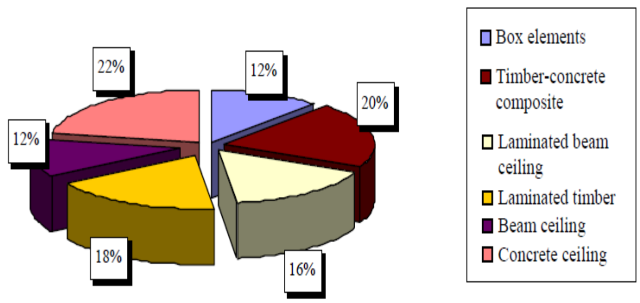


Figure-3.47 Pie chat of using different material in hybrid structures (Muller A.2014)

Timber-concrete and cross laminated timber are best combination to provide sound insulation and fire protection.

Kamyar T.,Et.al,(2010)

This paper describes the economical factors of the hybrid structure.according to the structure the loads on the structure should be analyzed by the combination of streel between the two planks of wood.

The deformation and deflection is equal to the frame combination and load is shared according to flexural rigidity.

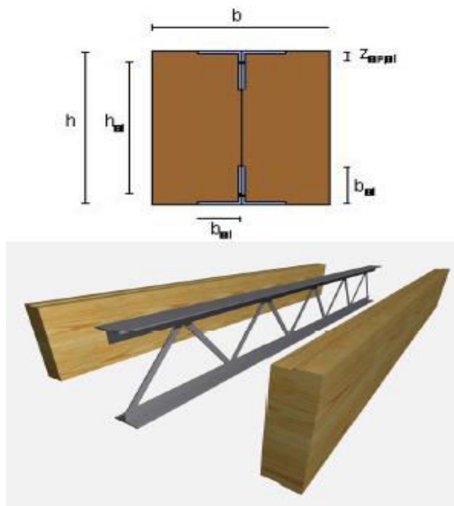


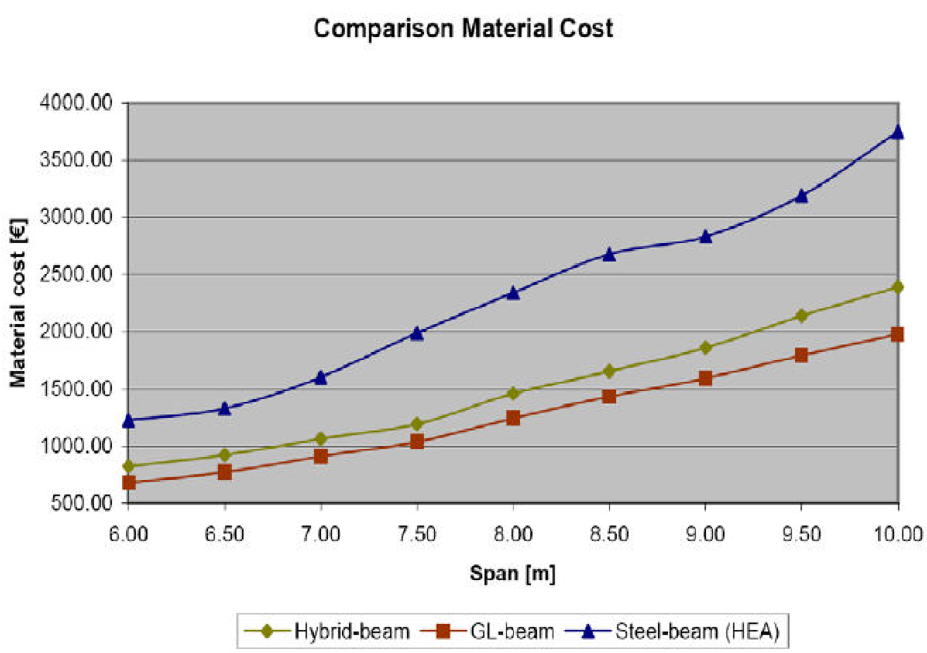
Figure-3.48 Timber steel hybrid beam (Kamyar T.,Et.al,2010)

The use of timber steel in structures results many differences than the single material (like steel).

The graph of material cost and the weight of different three materials are shown different results as:-

The glue laminated and hyrid beam having less cost than the steel beam in graph (i).

There is a very small difference in weight among three material but G.L and hybrid beam having low weight than the steel beam.



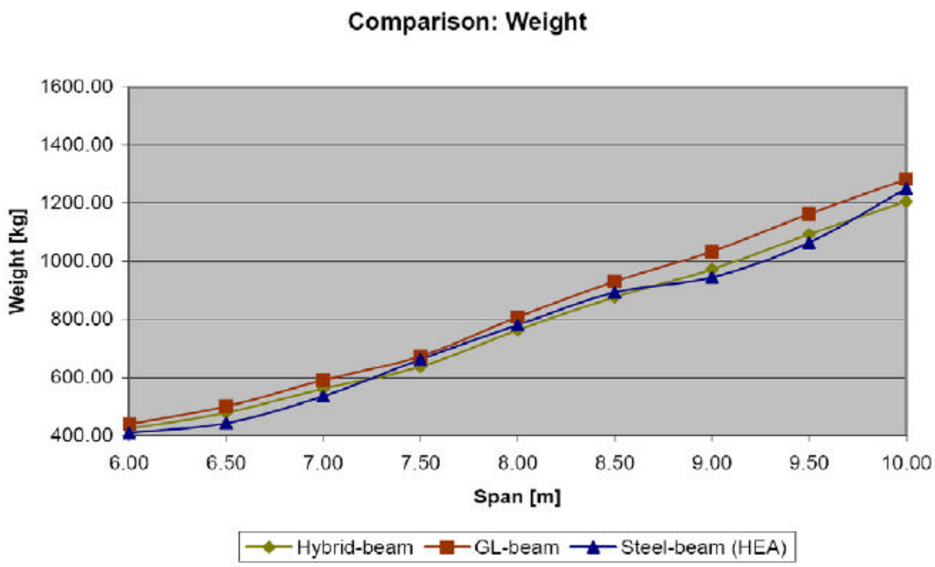


Figure-3.49 comparison in material,cost and weight (Kamyar T.,Et.al,2010)

Vuiyee et.al.,(2009)

The behavior of the composite cellular steel-concrete beams at different temperatures is discussed in this paper.as we know the web post buckling is the main failure in the composite beams.In the case of fire the lower portion of the beam flange,web is more exposed than the upper portion of the beam to fire. So there is a occurance of non uniformity of the distribution of temperature.

The F.E.A model is the best representation of failure in the composite cellular beams.

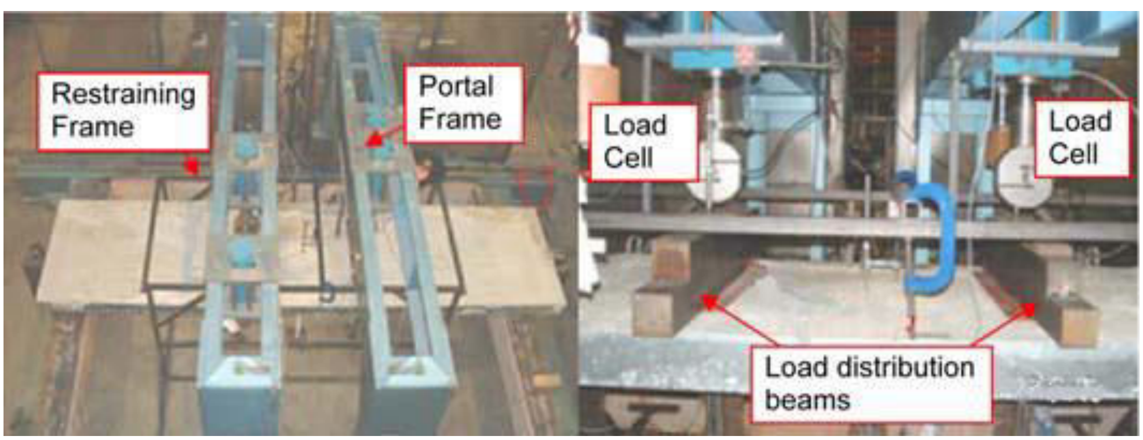


Figure-3.50 Experiment set up (Vuiyee et.al.,2009)

Table-3.51 Cross-section and load on beams

Cellular beam					
Type	**Beam Size**	**Opening**	**Web-post width**	**Spacing**	**Applied Load**
A	Symmetric beam 575×140×39 kg/m	8×375 mm	125mm	500mm	2×90 kN
B	Asymmetric beam 630×140/152×46 kg/m	6×450 mm	180mm	630mm	1×210 kN

The relation of stress strain in concrete shows that the concrete behaves as elastic material til its reaches its cracking mode,after that the tensile stress is decreased linearly to zero. The concrete tensile strength and Poisson's ratio are assumed as 10% of its compressive strength and 0.2 respectively.

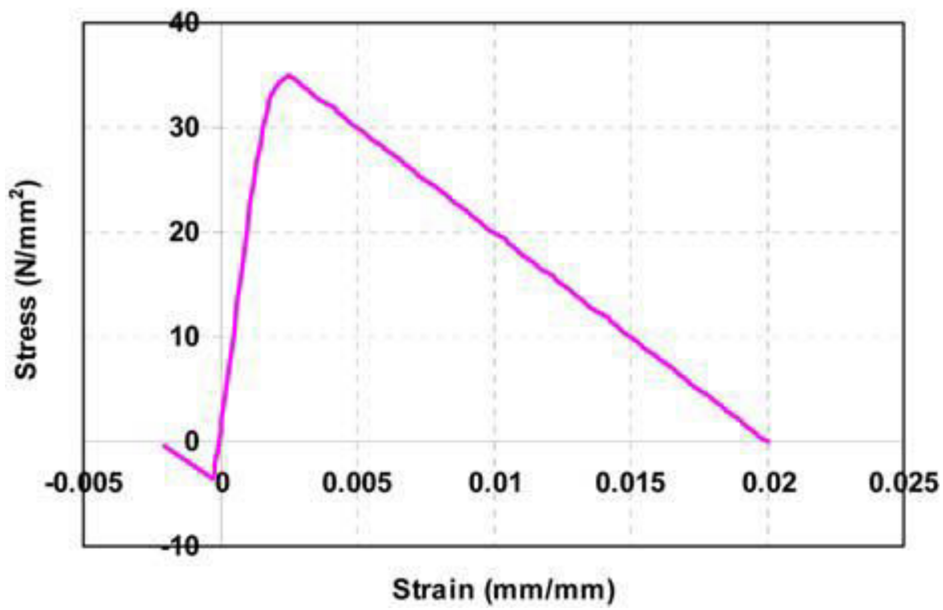


Figure-3.52 Stress strain curve of concrete (Vuiyee et.al.,2009)

The relation of stress strain in steel shows that the state of elastic-plastic with strain hardening,

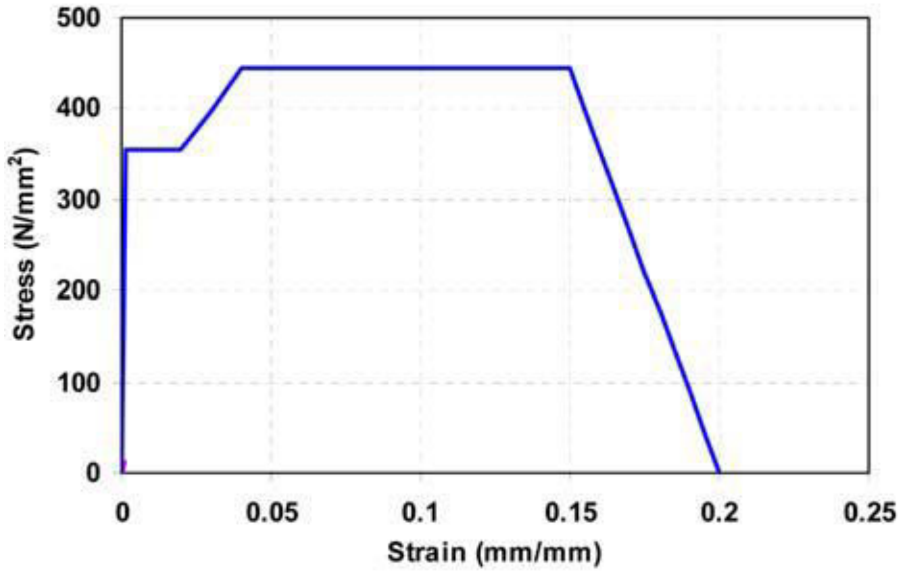


Figure-3.53 Stress strain curve of steel (Vuiyee et.al.,2009)

The graph 3.54 of temperature-time tells us that the strength and of beams is decreased with the increase in temperature.because the temperature should be always rise as the increase of time.

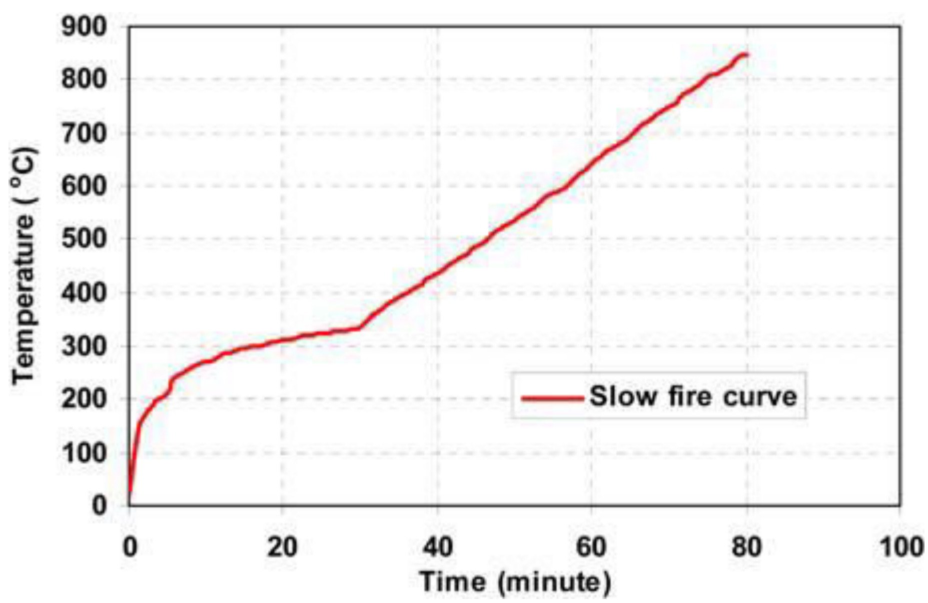


Figure-3.54 Time-temperature graph (Vuiyee et.al.,2009)

Buchanan A et. al.(2008)

This research paper deals with the latest and new developments systems in the multistorey prestressed timber structure in new Zealand.but these type of system should should not be constructed yet.The researcher describes about the maximum use of the new timber and new technology,maintain better living environment,increase the performance of the building and provide resistance to the seismic and lateral loading on structures.

The moment resisting frame are constructed,which makes a connection betwwn the walls and beams under the seismic structural system.these system helps in cost effectiveness in structures and depends upon the inelastic displacements.

The timber frames and walls system are extended from the precast concrete concept.For this purpose the L.V.L type of wood should be taken for the timber frames. Figure shows the conceptual solution for a hybrid beam-column timber connection, based on the combination of post-tensioning and internal dissipaters.

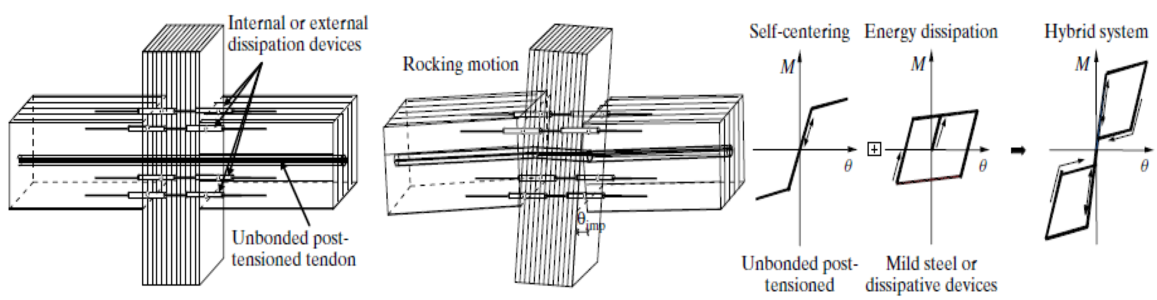


Figure-3.55 L.V.L timber frame with hysteresis behavior (Buchanan A et. al.,2008)

This experimental insvestigation based upon the quasi-static cyclic tests and pseudo dynamic tests.

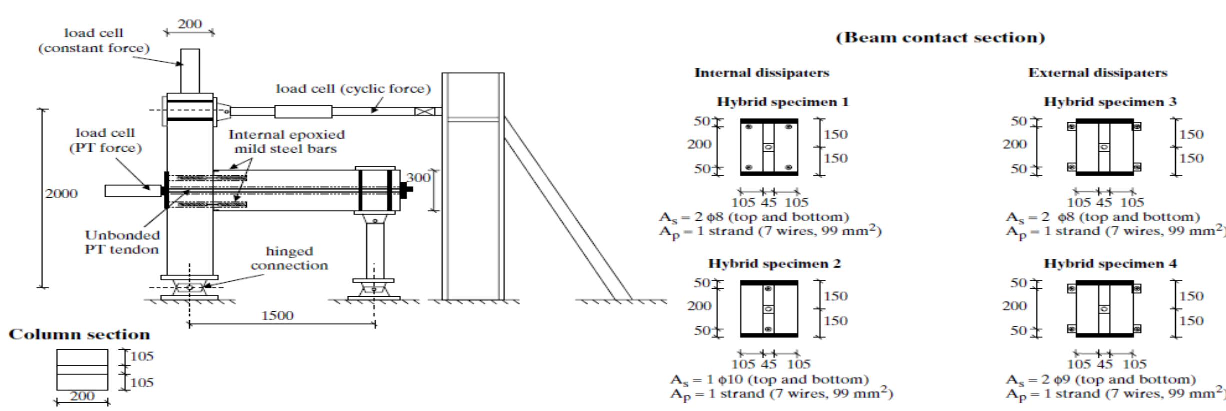


Figure-3.56 Test set up for beam column joints with dissipaters (Buchanan A et. al.,2008)

Floor solution:-

The composite floor system is the new technique of the floor system because of its strength and stiffness.The composite floor system having less weight than the concrete and only timber floor and these systems are used for the span of (6-10 m).The stiffness and strength of this system reduces the deflection and sensitivity of the vibrations.The L.V.L composite system of floor is experimented in developed building of new Zealand.

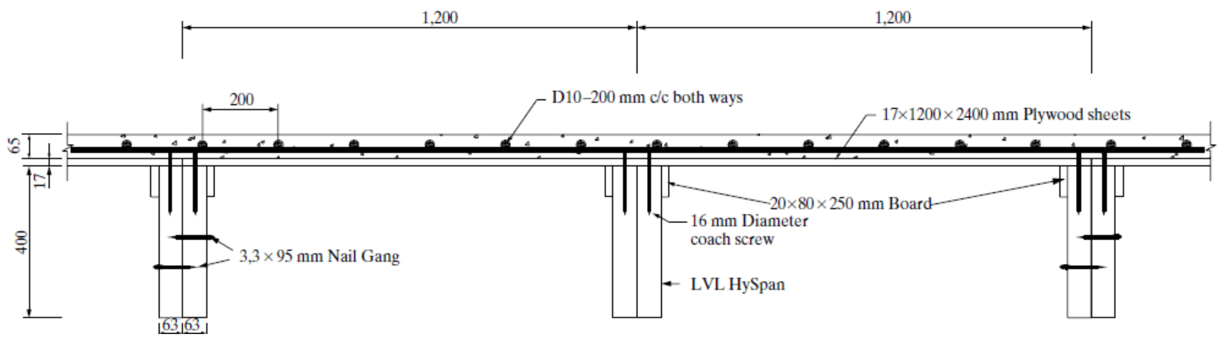


Figure-3.57 Cross section of L.V.L composite floor system in new zealand (Buchanan A et. al.2008)

Bing .J,(2008)

The elastic analysis and non linear elesto plastic analysis is done in this paper for highbrid structures.

(i) Elastic analysis:-

(a) **Response spectrum analysis-**The two models are taken to perform this spectrum analysis by using SATWE and ETABS. The different results of first six periods and the upper displacement and interdrift of the structure in x and y direction and overturning base shear is shown in table-1,2,3

Table-3.58 The first six order periods of structure (sec)

No.	**1**	**2**	**3**	**4**	**5**	**6**
SATWE	6.5093(ty)	5.4096(tx)	4.7910(rz)	1.6910(tx)	1.6050(ty)	1.4316(rz)
ETABS	6.5564(ty)	4.9029(tx)	4.7436(rz)	1.6475(ty))	1.5922(tx)	1.4352(rz)

Table-3.59 Maximum top displacement and inter-storey drift

	Upper displacement (mm)		**Inter-storey drift**	
Direction	X	Y	X	Y
No.	1	2	3	4
SATWE	173.8	241.9	1/1085	1/798
ETABS	139.3	221.6	1/1244	1/798

Table-3.60 Base shear and base over-turning moment

	Base shear (kN)		**Base over-turning moment (kN·m)**	
Direction	X	Y	X	Y
SATWE	25859	25055	3644395	3240375
ETABS	25990	24363	3781019	3257016

(b) **Elastic time history analysis-**In this analysis the artifivial wave is compared with the three different kind of past earthquakes. The figure shows the four ground motion accelerations and ther is also a curve in figure 7 which tells us that the average acceleration of specturum analysis is just similar to the different kind of four earthquakes.

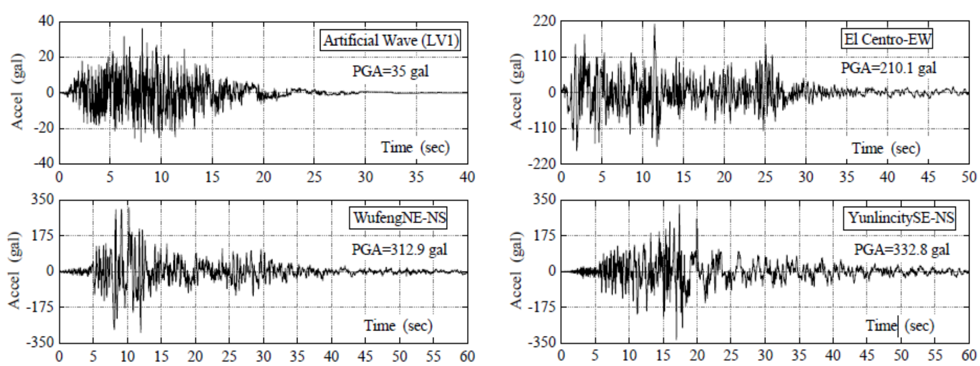


Figure-3.61 One wave and three earthquake ground motions (Bing .J,2008)

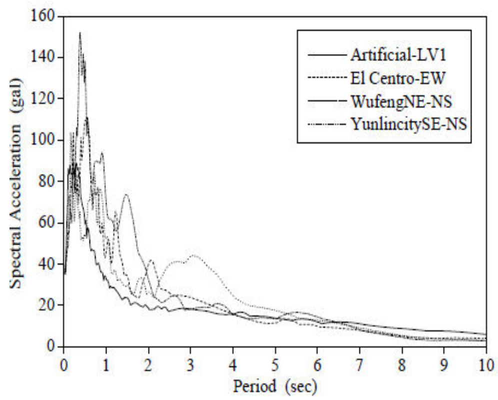
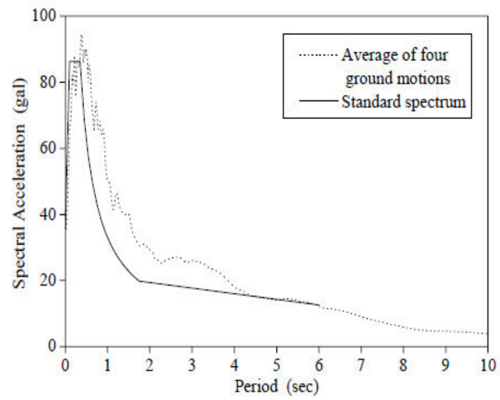


Figure-3.62(a)Acceleration response of individual earthquakes



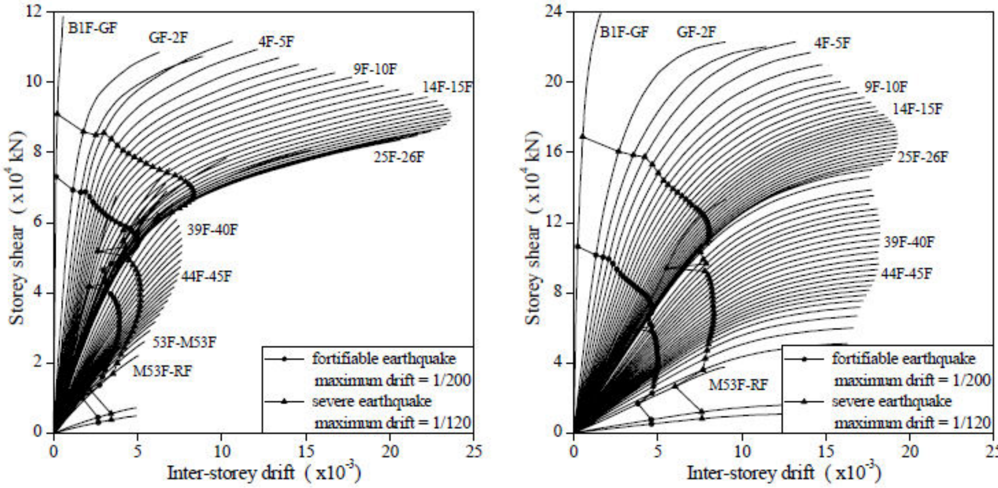
(b) Average Acceleration response

Table-3.63 Response of dynamic analysis

Input ground motion		**Artificial wave**	**EI-Centro-EW**	**WufendNE-NS**	**YunlincitySE-NS**
Base shear	X	19845	28165	19315	19729
	Z	24932	24620	27801	21782
Base overturning moment(Kn.m)	X	2408350	2120070	2605770	2464880
	Z	2870820	2357630	3325710	2664480
Inter-storey drift	X	1/1069	1/1237	1/1032	1/977
	Z	1/1171	1/1399	1/928	1/909

(c) <u>Non linear analsis:-</u>

According to this analysis y directional ductility is far better than the x-direction because of its solid shear walls.



(a) X-direction **(b) Y-direction**

Figure-3.64 storey performance curve (Bing .J,2008)

The analysis of the two peakl ground acceleration is done by comparing theartificial wave with the earthquakes and their response are:-

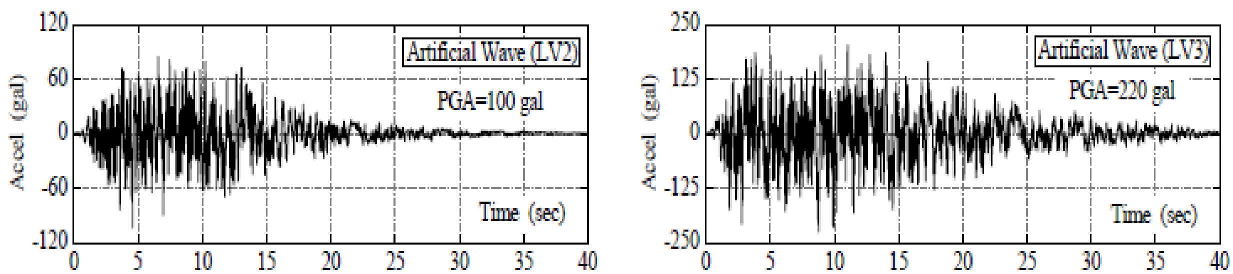


Figure-3.65 Artificial waves and earthquakes (Bing .J,2008)

<u>J.Schneider,(2008)</u>

In this research paper the failure of connection and joints in the (CLT)timber under the action of of cyclic loads are discussed.

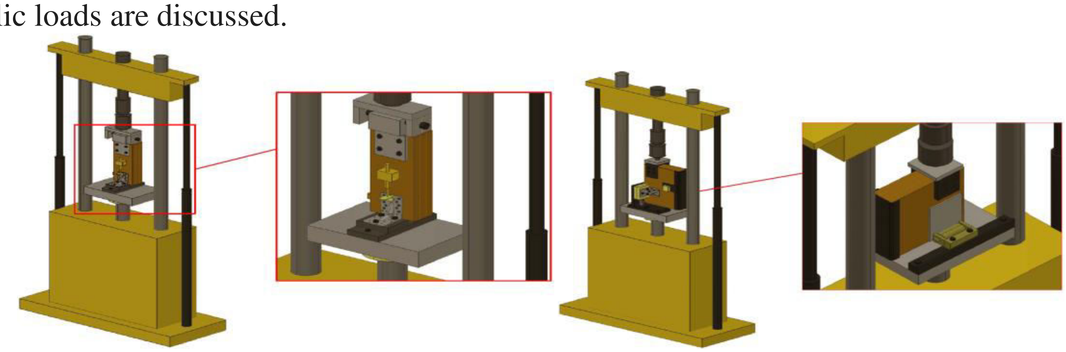


Figure-3.66(a) Parallel load **(b) Perpendicular load**

(J.Schneider,2008)

Results-The hysteretic response for both of the test are formed as under cyclic loads.

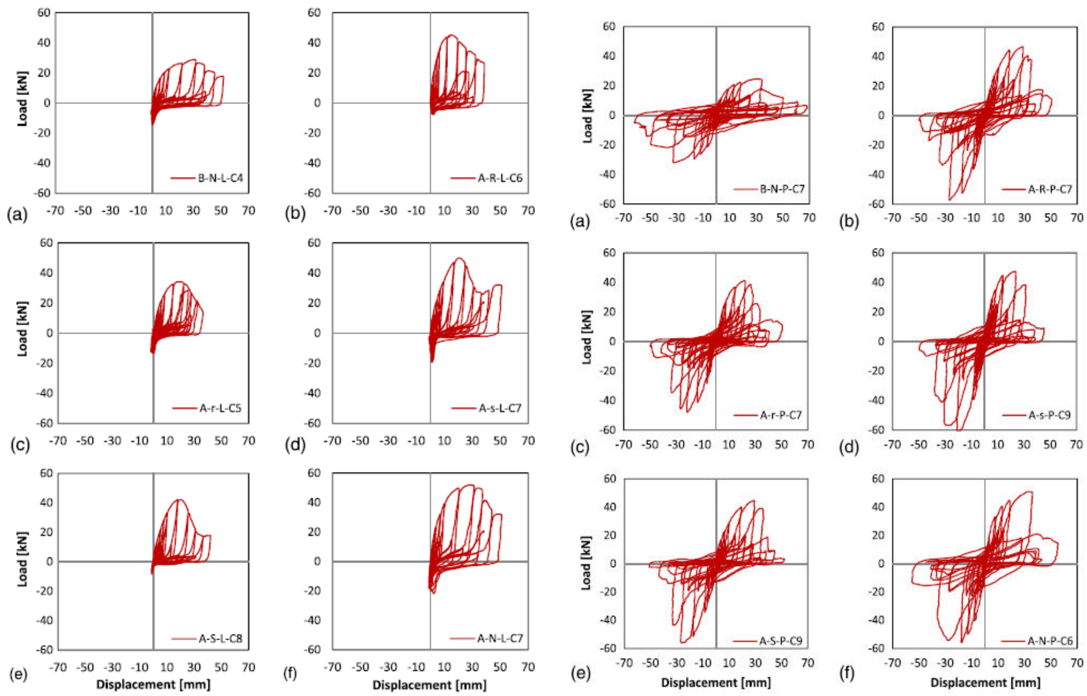


Figure-3.67 (a) Parallel response (b) Perpendicular response

(J.Schneider,2008)

T.Smith et.al, (2007)

The researcher discussed in this research paper about the seismic response of hybrid L.V.L coupled wall with quasi-static and pseudo dynamic tests

The lateral forces always disturbues any structures,which results in displacements and collapse of structures.so at the time of design of hybrid structures,an opportune calibration ratio of (1.2-1.5) is taken.the two factors first is unbounded post tensioned tendons and second is dissipation devices installed in structures.these two factors helps in reducing the lateral displacement of structures by effective beam-to-column,column-to-foundation or wall-to-foundation connections.

Unbonded post tensioned solutions:-

The graph of lateral force and drift is shown with the maximum of drift level of 2.5%.because the drift level prevents the tendons from yielding.the hysteresis loop shows the non linear behavior because the stiffness after the yielding points increase the moment due to elongation of tendons.

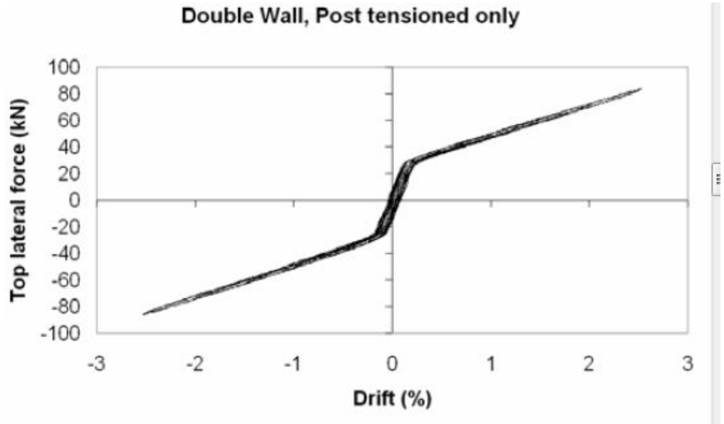


Figure-3.68 Hysteresis loop curve at the level of 2.5% (T.Smith et.al, 2007)

A. Palermo,(2005)

This paper deals with the seismic design of the multistorey buildings using laminated veneer lumber(L.V.L).

There are many advanteges of the L.V.L type timber than the solid timber and glue laminated timber because of their low mass,flexibility,and potential to carry load.so it is used for the design of seismic of multistorey buildings.the L.V.L timber makes a ductile connections between the walls and the steel frames.the moments should be resisted by these two parameters.
The whole process is based upon the static cyclic tests of exterior beam-column joint of the expected high seismic performance of the proposed solutions for LVL seismic resisting systems.

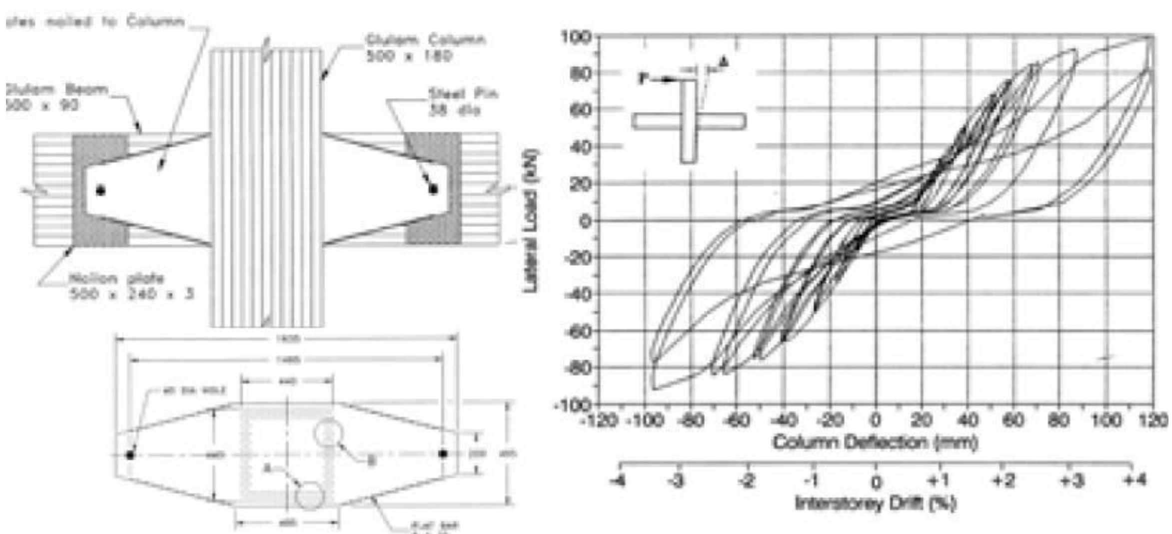


Figure-3.69 Hysteresis loop of multiple nailed connections (A. Palermo,(2005)

(a) Moment resisting connections in timber buildings:-

The hysteresis loop curve for multiple nailed connection are shown in figure.is describes that the moments coming from the slab to the steel frames and walls should be resisted according to the connections provided in the structures like riveted,bolted,welded etc.the curves also depends upon the connections.

(b) Hybrid L.V.L systems:-

In this system the L.V.L timber should be largerly preferred then than the solid timber and the glue laminated timber.the main reason that the L.V.L having the 3mm trhick veneer and it is also free fronm the defects like knot.
a "controlled rocking" motion occurs in hybrid jointed ductile connections
for a typical hybrid frame beam-column as shown in figure

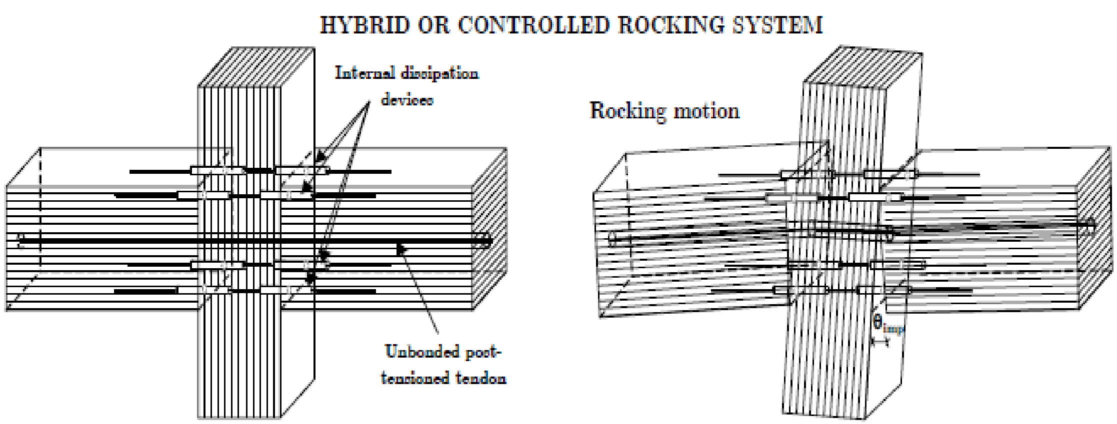


Figure-3.70 Application of Hybrid Concept to LVL frame systems (A. Palermo,2005)

Gurksyns K.et.al.(2005)

This research represents the sleeved connection in composite timber-concrete floors by the interconnection between the timber joist and the concrete floor. By this research,it is seen that the sleeved connection between the oriented strands boards and the concrete slab increases the stiffness and strength of the joint.

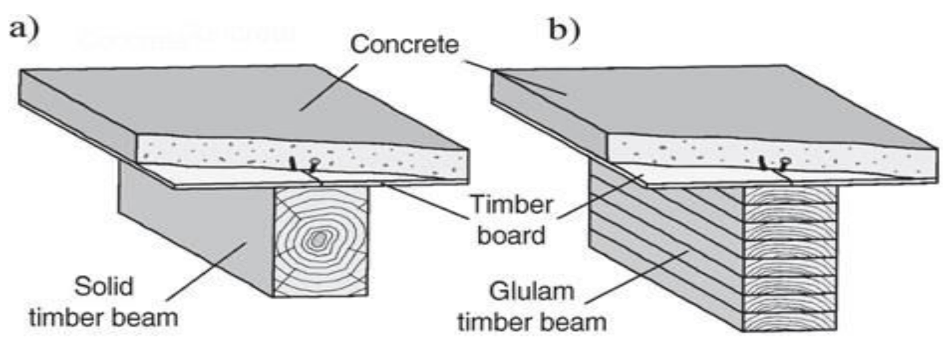


Figure-3.71 TCC joisted floors (Gurksyns K.et.al.2005)

Hiroshi Isoda,(2002)

In this paper the researcher discuss about the high performance,development and investigations in the timber hybrid structures.

(i) Joints between members:-

The first finding is about the different joints connection in the timber, reinforced concrete and timber hybrid structures.the new type of material should be used to provide more stiffness to the structure.

The carobon fibre type of material is used to maintain the joints between members.

(ii) Joints between structures:-

The second investigation is about the joint between the structures.according to this fact there is a need to develop the dual type of structures and then provide a joint between them to resist the ground motions.

(iii) Floor systems:-

There are different type of wooden material for used in hybrid structures slabs and roofs such as timber beams with plywood, timber beams with reinforced concrete slab, timber deck, and timber deck with reinforced concrete slab.

(iv) Dual structures:-

As the research,it is found that the dual structures are more feasible the single type of structure.the model of dual structures is shown in figure.thereinforced concrete core system, reinforced concrete shear wall and timber frame system, and system of timber frames surrounded by steel frames.these dual structures are helpful to solve out the problems for high performance pf the hybrid structures.

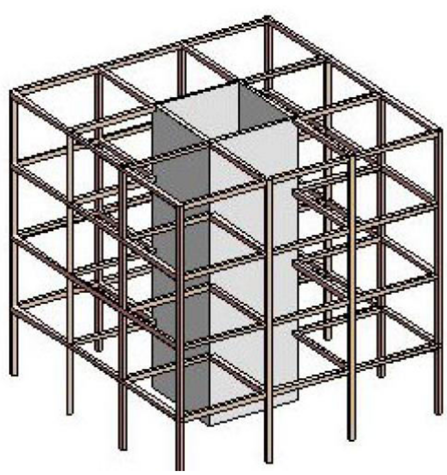


Figure-3.72 R.C core and timber frame (Hiroshi Isoda,2002)

Haibei Xiong et.al.

In this research paper, the researcher describes about the seismic behavior of the wood-concrete hybrid structures to resist the ground vibrations of the 3strorey wood concrete structures with the help of shake of table.

The researcher take the example of five specimens of different specification and properties with different stiffness ratio between a wood frame and concrete frame and then conduct a shaking test on it.

The whole results of this research implies that,the seismic motions make larger effect on the structures,those having less stiffness ratio.

The five specimens having the stiffness ratio between the 2.1-12.1 are taken.the all details are given in the table 3.73.

Table-3.73 Specimens configurations and different stiffmess ratio

Specimen no.	**Opening size at the 2nd storey (m.m)**	**r.c frame and brace type**	**Stiffness (KN/m.m)**	**Stiffness (KN/m.m)**	**Stiffness ratio R.C/W.F.C frame**
			R.C frame	W.F.C frame	
M1	1220	Only R.C frame,no brace	10.0	4.8	2:1
M2	3660	Only R.C frame,no brace	10.0	2.4	4:1
M3	1220	R.C frame with brace,type 1	20.0	4.8	4:1
M4	3660	R.C frame with brace,type 1	20.0	2.4	8:1
M6	3660	R.C frame with brace,type 2	30.0	2.4	12:1

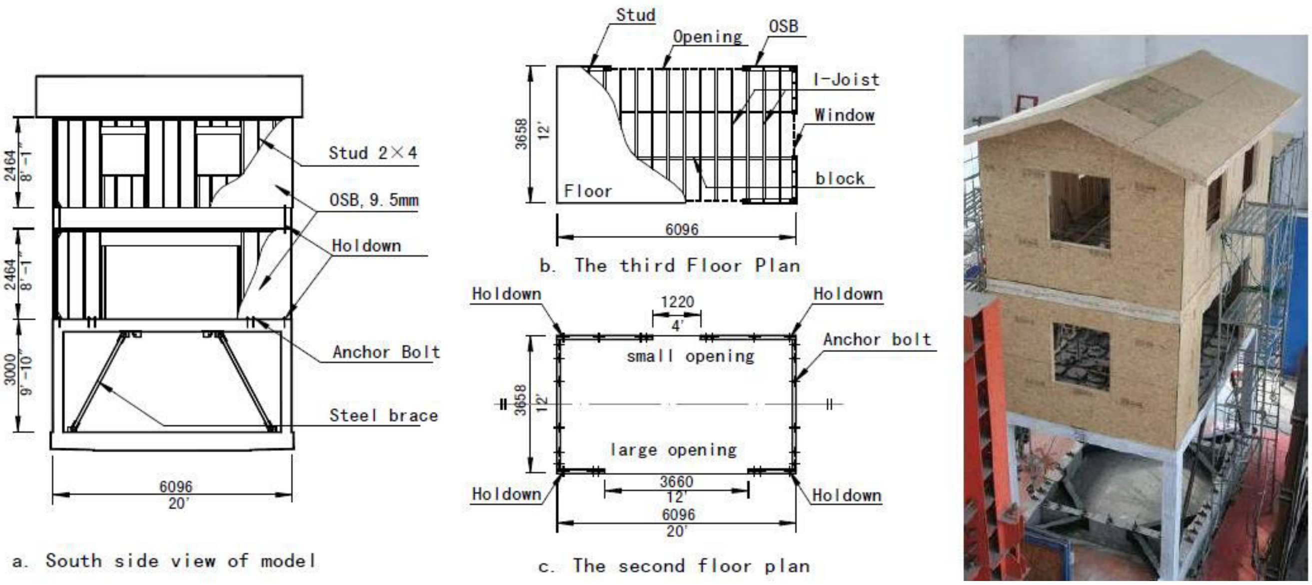


Figure-3.74 Diagram and photo view of wood-concrete hybrid structure (Haibei Xiong)

After applying the loads on roof and slabs the three earthquakes are applied on structure in three steps and the peak ground accelerations are 0.1g,0.2g,0.3g,0.4g,0.5g.the results of different parameters are noted.

Dynamic properties results-as the graph shown the relation between natural frequency and the damping ratio of structures and give the mode shapes.higher the openings in structure lower the natural frequency and higher the damping ratio.

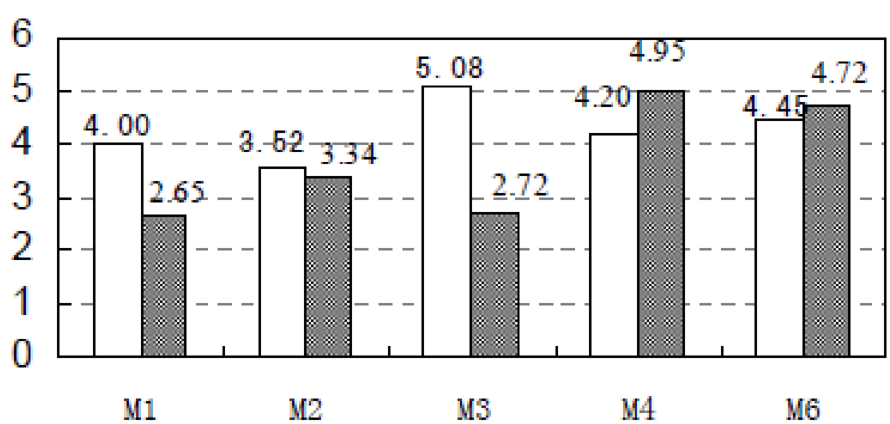


Figure-3.75 Relation of natural frequency and damping ratio.

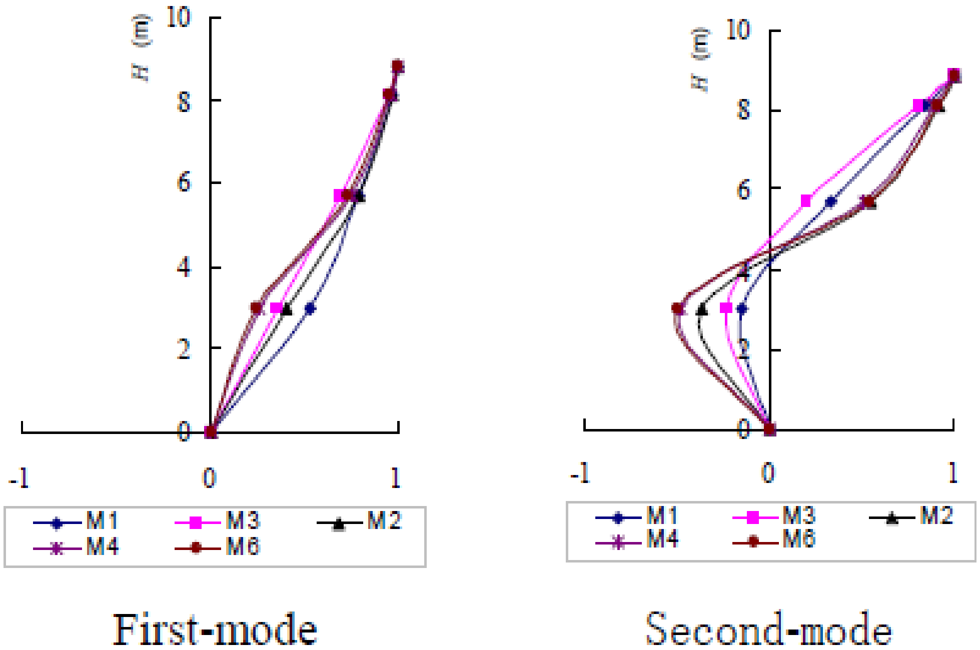


Figure-3.76 Comparison between two mode shapes (Haibei Xiong)

These two shapes shows that large stiffness in structure having large flexible shape.

Acceleration response:-

The different acceleration graphs of different storey shows that the amplification should be greater with the increase in height.

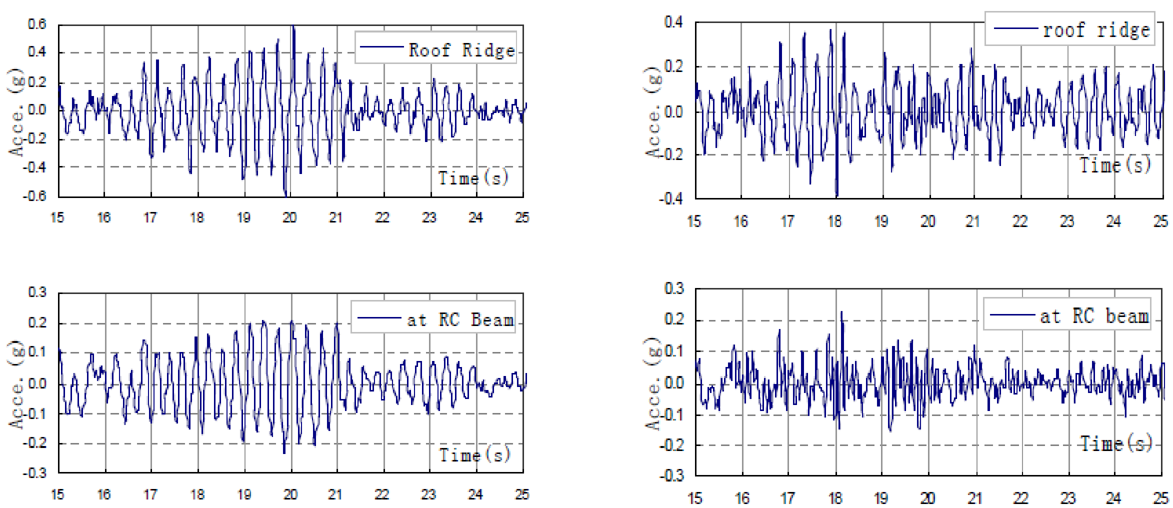


Figure-3.77Acceleration graphs (Haibei Xiong)

Displacement properties:-

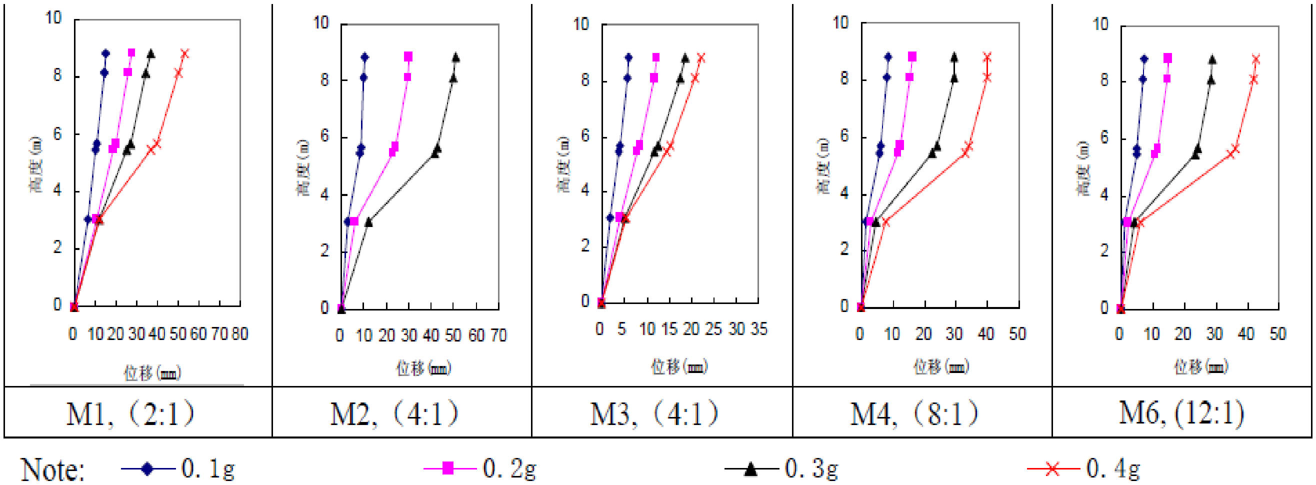


Figure-3.78 Displacement graphs of each storey (Haibei Xiong)

VASSART O.

This paper based on the web post buckling in cellular beam under fire.The results of finite element method prediction and the real result provide good agreement in terms of failure mode,load deflection and ultimate loads.the web post buckling is the most common failure in the cellular beam under the action of fire.

The researcher done experiment on web post buckling of cellular beam by developing the cold condtions to the beams and then the beams should be experienced by the different elevated temperatures.

The finite element model is created by the SAFIR software and then the cellular beam is exposed to different cold conditions and after that the behavior of the cellular beam is simulate under the action of fire temperature.

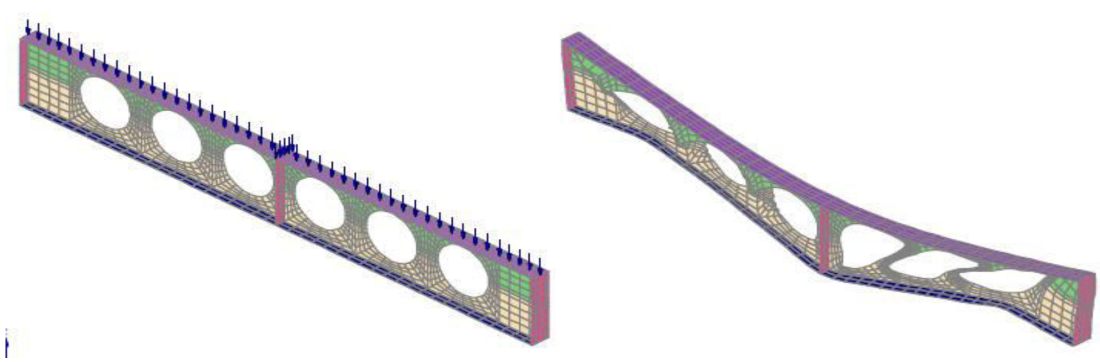


Figure-3.79 (a) Initial shape **(b) Deformed shape**

The results of finite element model shows that the numerical model gives a high accurate result of the mechanical behavior of the cellular beam in different cold and high temperatures conditions as shown in figure.

The figure 3.79 shows the web post buckling of cellular beam under elevated temperature.

The comparison of critical temperature between the finite element model by SAFIR and the analytical model given in figure 3.80 and it shows that all the results are on safe side.

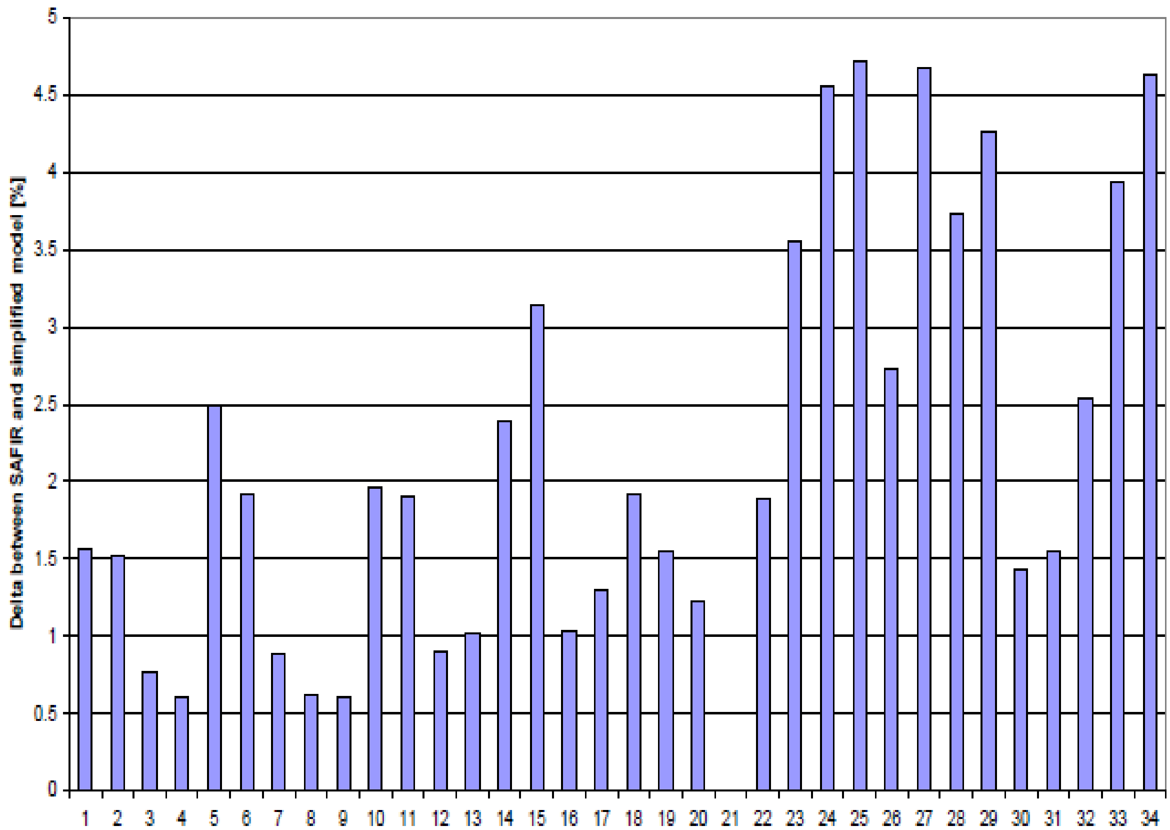


Figure-3.80 critical temperature between the FEM and the analytical model (VASSART O.)

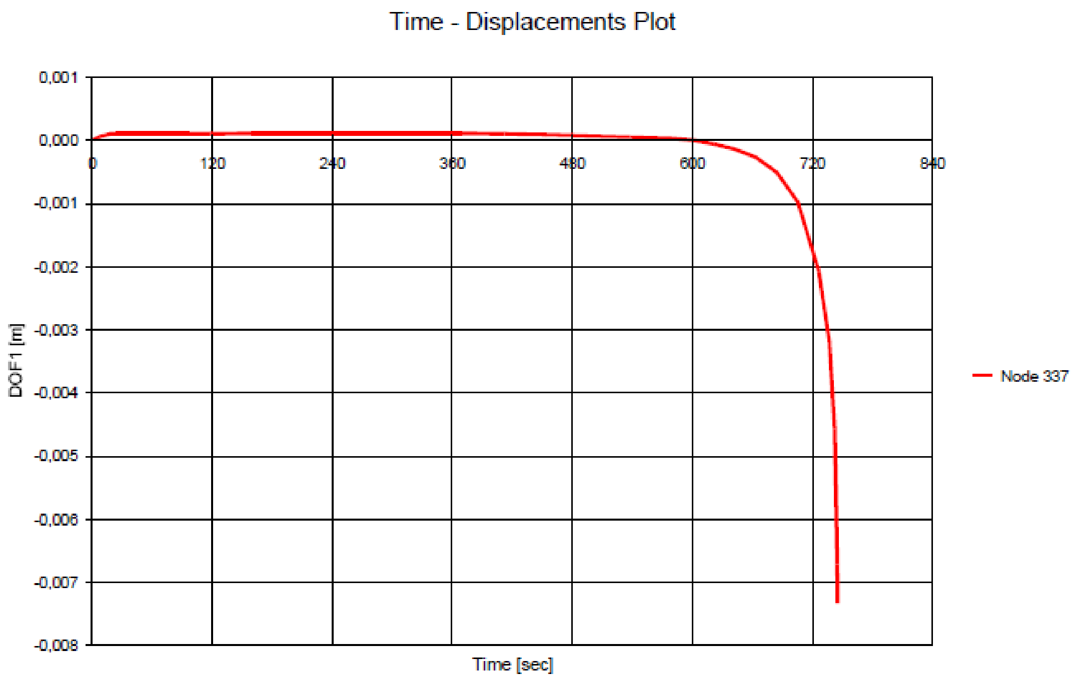


Figure-3.81 Lateral displacement versus time of heating curve (VASSART O.)

The lateral displacement evolution versus time heating shows that when the displacement is high,then the beam reached to its critical temperature.

Stephen John et.al.

In this paper,the cost effectiveness should be achieved by the various and alternative solution to the structural system.The only use of timber in hybrid structures instead of concrete is not always proved cost effective.sometimes there is a need of use of concrete and steel according to the conditions.

So in that case the cost effectiveness should be maintained by using the different kind of material according to their need. The study on new building Christchurch demonstrate the merits of different materials.

According to this research paper the one material is used as the main component like timber,concrete and steel and the researcher compared the cost comparisons of that different material building with common type of building.

The new Nelson and Marlborough Institute of Technology (NMIT) Arts and Media complex in Nelson is the example, where the L.V.L timber is used as main component and other parameters like beam ,column and shear walls are made up of different materials.The NIMT design for cost effectiveness is the best example for different material used in hybrid structures.

Case study:-

The case study of Christchurch is taken, which is damaged in the earthquake (2011). This building is designed with four stories and comparison is done with the concrete and steel structural building.the flexibility is also proved to the building as the earthquake of (ricter 7-7.9) should be resisted.The architect sketch of this building is shown in figure 3.82.

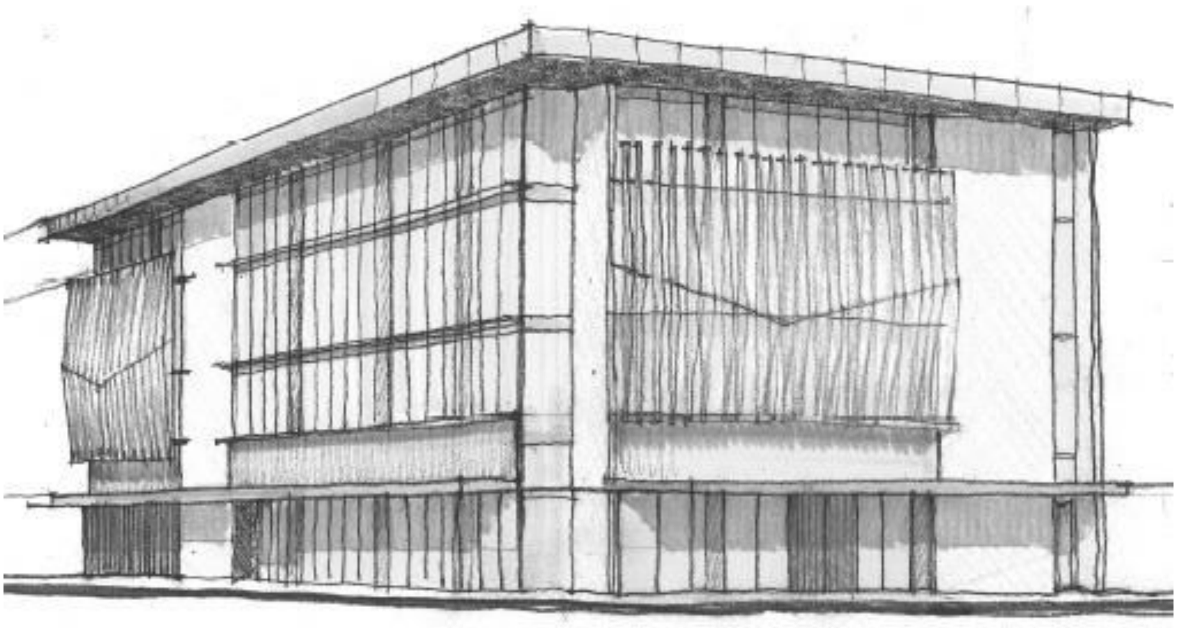


Figure-3.82 Architect sketch of building at 190 Hereford Street Christchurch (Stephen John et.al.)

Elements of different material of building:-

(i) Purlin -Laminated veneer lumber (L.V.L)
(ii) Refters –Bolted L.V.L
(iii) Upper floor –cross laminated timber (CLT)
(iv) Columns and floor beams – Bolted LVL
(v) Shear walls –post tensioned LVL
(vi) Foundation system –screw piles

Prof. DDI Wolfgang Winter

The development of different construction methods for hybrid structures under the lateral loadings are discussed in this paper.The main purpose of this paper is to develop the diagonal bracing rather than the semi rigid joints between the horizontal and vertical members in structures.

The hybrid structures having large openings in front side and there are more chances,the structure should be effected by the lateral loading due to the rise of structure.So the idea of diagonal bracing in structures should be provided in order to reduces the effect of the lateral loading.

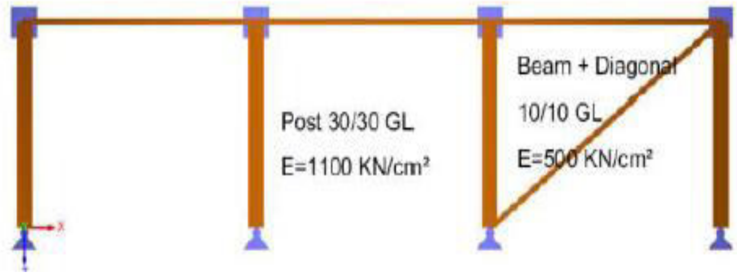


Figure-3.83 Diagonal bracing system (Prof. DDI Wolfgang Winter)

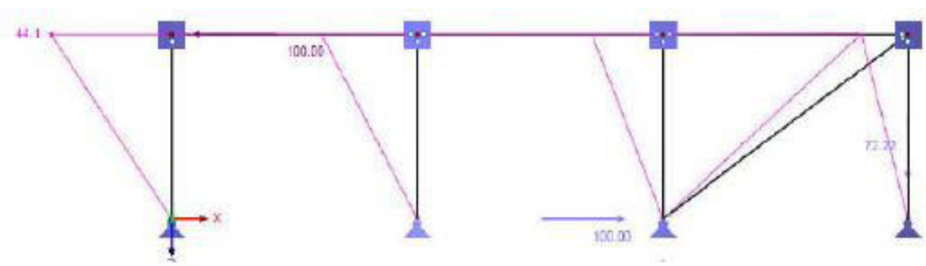


Figure-3.84 Displacement for diagonal bracing system (Prof. DDI Wolfgang Winter)

In the figure 3.84 the displacement for the diagonal bracing system is 44mm.

Figure-3.85 Rigid connection system (Prof. DDI Wolfgang Winter)

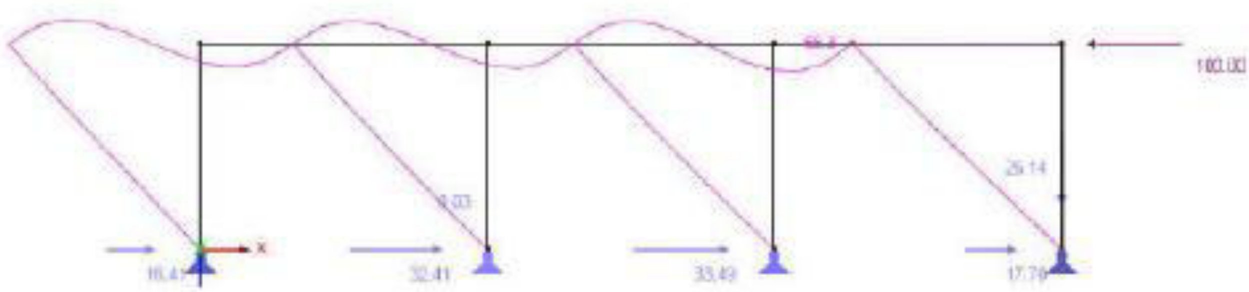


Figure-3.86 Displacement for rigid connection system (Prof. DDI Wolfgang Winter)

In the figure 3.86 the displacement for rigid connection system is 66mm.so it is seen that the results with the bracing system is more better than the rigid connection.
There are two elements of Birdcage system.

- **<u>Vertical elements:-</u>**

  (i)Wall elements and anchorage systems
  (ii)Steel reinforced timber hybrid columns

- **<u>Horizontal elements:-</u>**

  (i)Shear stiff floor
  (ii) Steel reinforced timber hybrid beams

CHAPTER-4.

SCOPE OF STUDY

4.1 Scope:-

This research is generally depends upon the economy and light weight of the hybrid structure. the timber is the feasible and cheap material than the concrete and other material. So when the timber is used in construction the cost of project will be reduced.

Hope this material will be used in future to get better and stable structure.

- The steel-timber combination in hybrid structures achieved light weight of structures.
- There are less effect of vibrations from the earthquakes on steel-timber structure.
- Cellular beams are provide better strength to the structures due to stresses induced in it.
- Cellular beams are used in large span places.So there is a large area to use due to the less intermidiate column under structures.
- These beams are also used for the architectural purpose (curved beams in airports).

CHAPTER-5.

OBJECTIVES OF RESEARCH

5.1 Objectives of study:-

- To analysis the mulistorey structure and compare it with other combination of material structure.

- To get the less lateral effects of the lateral loads on the building.

- To get fesible and stable structure with the duration of time.

CHAPTER-6.

RESEARCH METHODOLOGY

6.1 Method of Resrarch:-This research is generally based upon the static and dynamic analysis of the structure. As we know, there are many kinds of softwares,which are use for static,dynamic and other analysis.

In this research the analysis should be done by the software STADD Pro V8i.

But ETABS is a latest and advanced software to handle the complex hybrid structure in a very simple way and provide better results than the other software analysis.

The two structure should be analysed by the STADD Pro V8i and compare their results so that which structure is more stable and feasible.

- Steel Structure
- Steel-Timber Structure

Each structure have ten stories.

CHAPTER-7.

EXPERIMENTAL PROGRAMMES

7.1 General

In the experiment, the software STADD.Pro V8i is used to analyse the steel structure and steel with timber structure. The plan of the structure is 59.74m*50.29m. The height of each floor is taken as 3.65m and the structure have ground floor plus 10 storey. The foundation depth is taken as 4m.

Table-7.1 Detail of Structure

Type of structure	Hospital building	
Plan width	59.74m*50.29m	
Storey	10	
Floor height	3.65m	
Foundation depth	4m	
Column	Channel section	
	ISMC 400	Double profile
Spacing between channel section	250mm	
Beam	I-section	
	ISMB 300	Single profile

Static and dynamic analysis will be done on steel structure and steel with timber structure.

Table-7.2 Various Analysis

Static analysis	Dynamic analysis
Seismic analysis	Response spectrum analysis
Wind analysis	Time –history analysis
Pushover analysis	

Currently, the seismic analysis is done on Both the steel structure and steel with timber structure under the conditions of IS 1893-2002/2005 specifications, which are given in table-7.2.

Table-7.3 Seismic detail

Zone	IV
Response reduction factor	Special RC moment resisting frame (S.M.R.F)
Importance factor	Important building
Type of soil	Medium
Structure type	Steel frame building
Damping ratio	5%
Time period in X-direction	0.43 seconds
Time period in Z-direction	0.49 seconds

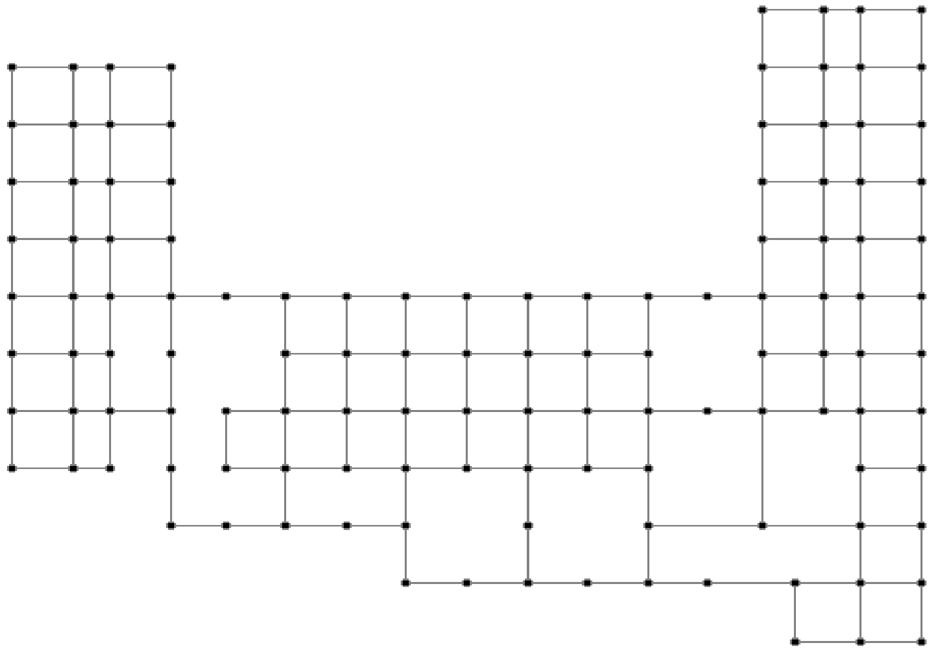


Figure-7.1Placement of column and beam

CHAPTER-8.

RESULTS AND DISCUSSIONS

8.1 Base Shear Results:-

The seismic analysis is done by the STADD Pro V8i and it is seen that there is a big difference between the base shear of steel structure and steel with timber structure. The base is reduced to near about 50%.

Table-8.1 Base Shear

Direction	Steel Structure (KN)	Steel-Timber Structure (KN)
X-Direction	38057.92956	19925.16456
Z-Direction	38057.92956	19925.16456

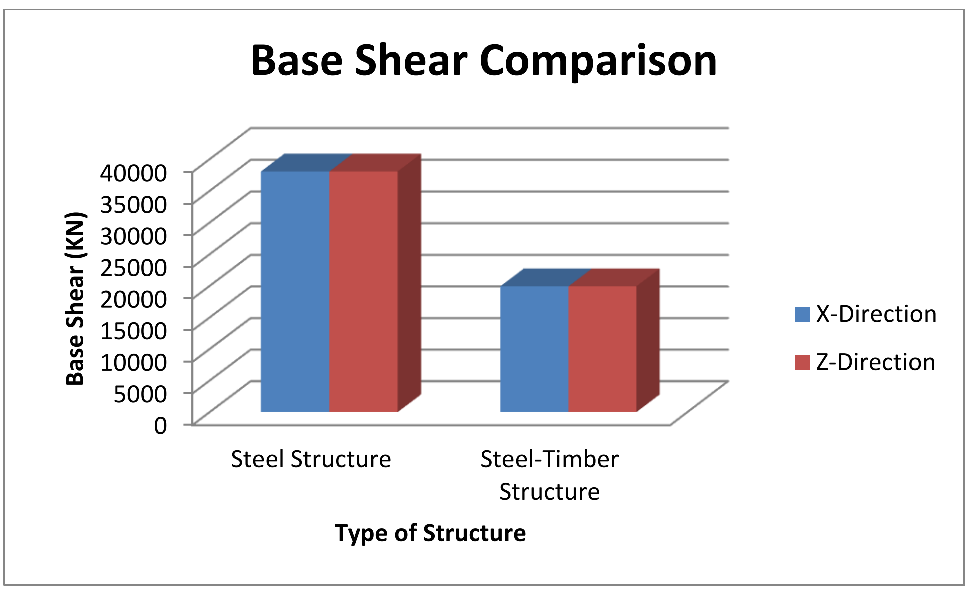


Figure-8.1 Comparison of Base shear

8.2 Overturning Moment Results:-

In these results,the overturning moment of steel with timber structure in X-direction is increased to some extent than the steel structure but moment of steel with timber structure in Z-direction is decreased than the steel structure.

So there is a greater difference between the net overturning moment in Z-direction of steel with timber structure,which is reduced as comaparison to the steel structure.

Table-8.2 Overturning Moment

Direction	Steel Structure (Knm)	Steel-Timber Structure (Knm)
X-Direction	**1760.9227**	**1818.4443**
Z-Direction	**1717.6243**	**1581.2658**

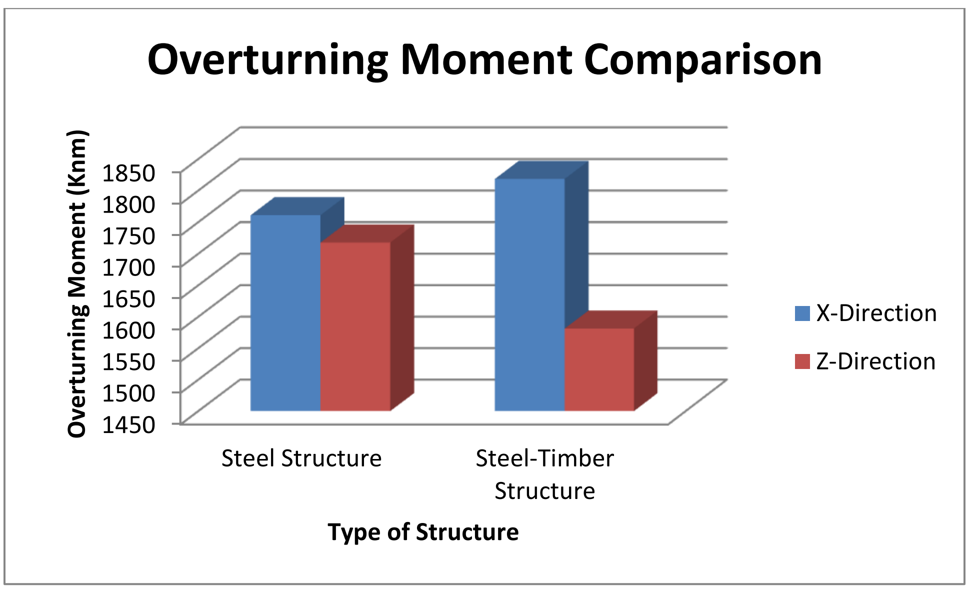


Figure-8.2 Comparison of Overturning Moment

8.3 Maximum Node Displacement:-

8.3.1 Steel Structure:-

Table-8.3 Maximum Node Displacement

Steel Structure		
Direction	**Node**	**Displacement (mm)**
Max X	1524	2480.914
Max Y	1555	71.010
Max Z	1532	2139.528

	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	1524	12 GENERAT	**2480.914**	61.069	-146.324	2485.976	-0.002	-0.016	-0.020
Min X	1524	18 GENERAT	**-2476.418**	-91.527	148.296	2482.542	0.002	0.015	0.019
Max Y	1555	18 GENERAT	-2474.170	**71.010**	-77.630	2476.406	-0.002	0.014	0.018
Min Y	1532	5 GENERATE	5.295	**-113.257**	-5.394	113.509	0.004	-0.001	0.001
Max Z	1532	13 GENERAT	53.757	-69.262	**2139.528**	2141.324	0.004	-0.024	0.002
Min Z	1532	19 GENERAT	-49.576	1.202	**-2137.537**	2138.113	-0.002	0.023	-0.002
Max rX	484	17 GENERAT	20.782	-9.837	462.652	463.223	**0.057**	0.063	-0.000
Min rX	484	15 GENERAT	-20.607	0.796	-462.668	463.128	**-0.057**	-0.063	0.001
Max rY	1569	19 GENERAT	-47.571	-3.311	-1685.387	1686.062	-0.016	**0.218**	0.001
Min rY	1569	13 GENERAT	53.582	-17.423	1686.085	1687.026	0.016	**-0.219**	-0.002
Max rZ	688	14 GENERAT	-1142.588	-33.982	29.916	1143.485	0.001	0.031	**0.055**
Min rZ	696	12 GENERAT	1142.390	-34.350	3.491	1142.912	0.000	-0.030	**-0.055**
Max Rs	1524	12 GENERAT	2480.914	61.069	-146.324	**2485.976**	-0.002	-0.016	-0.020

Figure -8.3 Summary of Node Displacement

8.3.2Steel-Timber Structure:-

Table-8.4 Maximum Node Displacemnt

Steel-Timber Structure		
Direction	Node	Displacement (mm)
Max X	1555	1276.656
Max Y	1115	18.651
Max Z	1485	1146.824

	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	1555	16 GENERAT	1276.656	-39.959	-18.497	1277.415	0.000	-0.002	-0.008
Min X	1555	14 GENERAT	-1287.066	10.750	17.166	1287.225	0.000	0.002	0.008
Max Y	1115	18 GENERAT	-844.138	18.651	-64.122	846.775	-0.002	0.003	0.019
Min Y	1532	5 GENERATE	-0.698	-123.591	-3.013	123.630	0.003	-0.000	0.001
Max Z	1485	13 GENERAT	17.841	-35.668	1146.824	1147.517	0.004	-0.005	0.001
Min Z	1485	19 GENERAT	-17.366	1.748	-1145.053	1145.186	-0.004	0.004	-0.000
Max rX	518	13 GENERAT	6.790	-6.239	384.388	384.498	0.034	0.030	-0.000
Min rX	518	19 GENERAT	-6.750	-6.048	-384.287	384.393	-0.034	-0.030	0.000
Max rY	1569	19 GENERAT	-13.529	-5.532	-1023.128	1023.233	-0.008	0.069	0.000
Min rY	1569	13 GENERAT	18.533	-15.239	1023.153	1023.435	0.008	-0.070	-0.001
Max rZ	607	14 GENERAT	-365.337	-7.742	-37.198	367.308	-0.002	-0.004	0.034
Min rZ	607	16 GENERAT	364.593	-4.580	37.293	366.524	0.002	0.004	-0.034
Max Rs	1524	14 GENERAT	-1286.861	-45.774	94.524	1291.139	0.001	0.002	0.008

Figure-8.4 Summary of Node displacement

8.4 Beam End Forces:-

8.4.1 Steel Structure:-

Table-8.5 Beam End Forces

Steel Structure		
Direction	**Beam**	**Force (KN)**
Max FX	3848	13351.680
Max FY	751	1829.963
Max FZ	718	1836.324

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	3848	8 GENERATE	1653	**13351.680**	152.394	1004.582	0.021	2048.125	-232.737
Min Fx	3871	18 GENERAT	101	**-9566.881**	-1244.372	249.380	-0.008	-689.716	-2010.697
Max Fy	751	12 GENERAT	355	6578.324	**1829.963**	-54.641	0.022	97.471	3351.824
Min Fy	751	18 GENERAT	355	-3764.245	**-1823.174**	34.585	-0.022	-63.165	-3339.615
Max Fz	718	19 GENERAT	322	-480.914	-386.337	**1836.324**	-0.051	-3355.048	-702.330
Min Fz	718	13 GENERAT	322	6747.669	404.909	**-1837.974**	0.051	3360.624	735.096
Max Mx	3802	15 GENERAT	32	2618.167	-17.384	-66.498	**0.347**	-255.099	0.431
Min Mx	3802	17 GENERAT	32	-249.354	19.211	66.479	**-0.347**	255.152	4.349
Max My	718	13 GENERAT	322	6747.669	404.909	-1837.974	0.051	**3360.624**	735.096
Min My	718	19 GENERAT	322	-480.914	-386.337	1836.324	-0.051	**-3355.048**	-702.330
Max Mz	438	12 GENERAT	111	7663.395	1820.741	-27.987	0.017	47.650	**3358.583**
Min Mz	438	18 GENERAT	111	-4548.291	-1815.356	15.077	-0.017	-26.598	**-3348.706**

Figure-8.5 Summary of Beam End forces

The table 5.5 shows that there is a maximum shear forces for beam no. 3848, 751 and 718 in X,Y and Z direction in the case of steel structure.

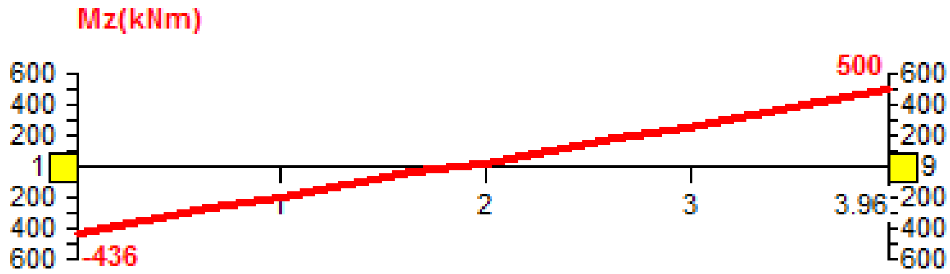


Figure-8.6 Beam graph of steel structure

8.4.2 Steel-Timber Structure:-

Table-8.6 Beam End Forces

Steel-Timber Structure		
Direction	**Beam**	**Force (KN)**
Max FX	3848	13391.705
Max FY	478	711.076
$Max FZ	750	480.203

All / Summary / Envelope

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	3848	5 GENERATE	1653	13931.705	6.581	14.587	-0.000	17.673	-8.402
Min Fx	3794	18 GENERAT	24	-3145.211	-252.723	-23.567	-0.004	24.880	-220.390
Max Fy	478	14 GENERAT	325	-0.337	711.076	-4.239	0.006	5.381	843.455
Min Fy	478	12 GENERAT	333	3.591	-709.617	4.304	-0.006	5.015	841.737
Max Fz	750	19 GENERAT	354	1915.468	219.831	480.203	-0.012	-886.760	401.303
Min Fz	751	13 GENERAT	355	1961.435	185.093	-488.304	0.012	901.983	337.047
Max Mx	359	15 GENERAT	32	1623.585	-3.018	32.320	0.124	-217.358	-6.003
Min Mx	359	17 GENERAT	32	564.102	9.198	-32.310	-0.124	217.423	15.822
Max My	3799	17 GENERAT	1604	1510.060	37.090	377.044	0.004	1064.723	-57.725
Min My	3799	15 GENERAT	1604	3183.576	-35.959	-377.739	-0.005	-1065.897	56.355
Max Mz	3859	14 GENERAT	1664	-588.631	-408.327	-1.739	-0.022	8.994	1162.899
Min Mz	3851	12 GENERAT	1656	-423.468	408.611	-18.271	0.025	-49.158	-1163.126

Figure-8.7 Summary of Beam End forcess

The table shows that there is a maximum shear forces for beam no. 3848, 478 and 750 in X,Y and Z direction in the case of steel structure with timber.

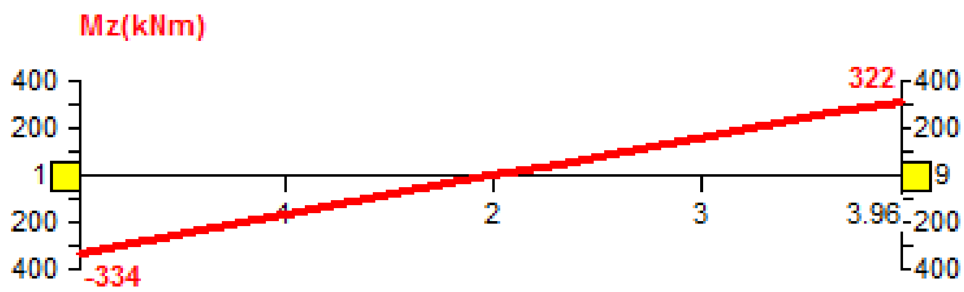


Figure-8.8 Beam graph of steel-timber structure

8.5 Lateral Load Effect:- The lateral load effect of each storey is given in table 4.5 and the results shows that the lateral load is increased with the each level of structure. The lateral load for every storey of steel with timber structure is less than the lateral load effect as compare to the steel structure.

Table-8.7 Lateral Load Effect

	Steel Structure		**Steel-Timber Structure**	
Storey level	**Lateral load (X) (KN)**	**Lateral load (Z) (KN)**	**Lateral load (X) (KN)**	**Lateral €load (Z) (KN)**
0	75.081	75.081	42.689	42.689
3.650	274.475	274.475	155.989	155.989
7.300	598.874	598.874	340.351	340.351
10.950	1048.239	1048.239	595.733	595.733

14.600	1622.572	1622.572	922.137	922.137
18.250	2321.87	2321.87	1319.561	1319.561
21.900	3146.136	3146.136	1788.006	1788.006
25.550	4095.398	4095.398	2327.976	2327.976
29.200	5169.599	5169.599	2937.976	2937.976
32.850	6368.768	6368.768	3619.485	3619.485
36.500	7692.904	7692.904	4372.014	4372.014
40.150	5644.019	5644.019	1503.737	1503.737

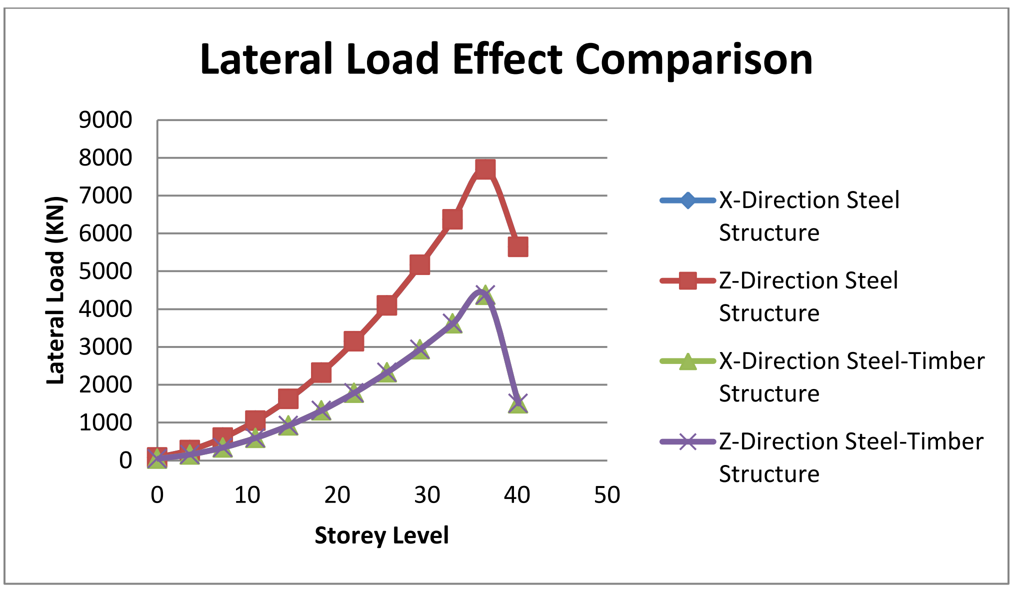


Figure-8.9 Comparison of Lateral Load Effect

CHAPTER-9.

CONCLUSION

The conclusion of the above analysis is given below:-

(i) From the results, it can be seen that the base shear in the steel structure is greather than the steel-timber structure. The base shear in steel-Timber structure is reduced to 47.64% than the steel structure.

(ii) The base shear value is equal in X-direction and Z-direction for both the structure because of its approximate same time period in both direction.

(iii) The overturning moment have more difference in both structures because of the different response of material during the earthquake.

(iv) The lateral forces of earthquake should more effected the steel structure than the steel-timber structure.

(v) It is also seen that the node displacement in the steel structure is more than the steel-timber structure.

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