ANALYSIS OF IRREGULAR MULTI- STORIED BUILDINGS WITH AND WITHOUT OUTRIGGER STRUCTURAL SYSTEM

Samadhana[1], Abdul Rashid[2], Dr. P. Srinivasa Rao[3]

[1]P.G Student, Department of Civil Engineering, JNTUH, Hyderabad, Telangana, India.
[2]Assistant Professor, Department of Civil Engineering, VVIT, Nambur, Vijayawada, AP, India.
[3]Professor, Department of Civil Engineering, JNTUH, Hyderabad, Telangana, India.

Abstract - In the current study the 8 different parameters like storey displacement, storey drift, shear force, overturning moments, modal participation factors and mode shapes are analyzed. The irregular 50 stories of total 8 structures (4 structures without Belt Truss & 4 structures with Belt Truss) with building plans of L-Shape, T-Shape, U-Shape, H-Shape are been modelled and analyzed. The belt truss is placed for 4 structures for every 5 floors interval and compared with the structures not having belt truss. The design and analysis are done as per INDIAN STANDARD IS 1893:2016 in the E-TABS -18 Software version and used for this purpose.

Key Words: outriggers, Belt truss, Storey Displacement, Storey Drift, Shear Force, Overturning Moments, Modal Participating Mass Ratios, Modal Shapes etc.

1. INTRODUCTION

The construction process is highly systematic as it includes the manufacturing of building products and the systems, the crafts people fabricate them on the building site, The contractors who get employed and harmonize the work of the craft people, the consultant who concentrate in such aspects like construction management quality control and insurance. Present days construction has become a significant factor in the industrial culture, manifestation of its variance, complication and ability to withstand natural forces tends to build a vast of varied environment to be available for the society. But from the past few years the construction has become complex. A wide range of building products and their systems which are at at most important are available at groups in the markets. The design professionals perform research and study the material properties, and their performance and co-relate them with the standard codes and enforce safety and organizes neatly to meet the user needs. The architects and structural engineers carefully design the tall high-rise buildings to withstand the lateral forces imposed by winds and potential earthquakes which is the important factor to be considered in the design process.

1.1 BELT TRUSS STRUCTURAL SYSTEM: Belt truss is a connecting and tying member between two structural member which is generally core of building and peripheral columns. The belt truss system typically engages the core with columns to increase the lateral stability and stiffness of a building. The belt truss and belt truss system are one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff belt truss and belt truss at one or more levels. The belt truss tied the peripheral column of building while the belt truss engages them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. The incorporation of a belt truss which connects the two elements together provides a stiffer component which act together to resist the overturning forces. When a belt truss-braced building deflects under wind or seismic load, the belt truss which connects to the core wall and the exterior columns, makes the whole system to act as a unit in resisting the lateral load.

1.2 Factors Affecting the Effectiveness of System

1. The stiffness and location of the Belt truss system.
2. Geometry of the tall building.
3. Stiffness of the central core.
4. Floor-to-floor height of the tall building.

1.3 Advantages of using Belt truss & Belt truss system

1. There are no trusses in the space between the core and the building exterior.
2. There are fewer constraints on the location of exterior columns. The need to locate large exterior columns where they can be directly engaged by belt truss trusses extending from the core is eliminated.
3. All exterior columns (not just certain designated belt truss columns) participate in resisting overturning moment.
4. The difficult connection of the belt truss trusses to the core is eliminated.

5. Core overturning moments can be reduced through the reverse moment applied to the core at each belt truss connection.
6. Exterior framing can consist of simple beam and column framing without the need for rigid-frame-type connection thus reducing the overall cost of the structure.
7. Reduction or elimination of uplift and net tension forces without the column and foundation system.

1.4 Objectives of the study:

To study and compare the geometrically irregular shaped 50 - Storey RCC high rise building having belt truss at every 5 floors interval with the geometrically irregular shaped RCC high rise building without any belt truss placed on the building. The design and analysis are done as per INDIAN STANDARD IS 1893:2016 in the E-TABS Software. The primary deliverables of this study are:

1. Comparison of a L- shaped 50 storey RCC building having belt truss placed at every 10-floor interval with the L-shaped 50 storey RCC building without having any belt truss on the building.
2. Comparison of a U- shaped 50 storey RCC building having belt truss placed at every 10-floor interval with the U- shaped 50 storey RCC building without having any belt truss on the building.
3. Comparison of a T- shaped 50 storey RCC building having belt truss placed at every 10-floor interval with the T- shaped 50 storey RCC building without having any belt truss on the building.
4. Comparison of a H- shaped 50 storey RCC building having belt truss placed at every 10-floor interval with the H- shaped 50 storey RCC building without having any belt truss on the building.

2. Literature Review

Bhumika [et.al] [2016] [1] studied on "Wind analysis of multi-storeyed structure with T- shape & L- shape geometry". They have studied on behaviour of high rise building against the wind forces having two irregular geometry (T- Shape & L- Shape) which located in Nagpur and analysed for 3 different storey (15th,25th, 30th) storey building in stadd pro software and analysis behaviour of various parametric coefficients such as maximum displacement, storey drift, axial force, shear force, bending moment and torsional moment has been carried out. After performing the analysis, they have noticed that the maximum displacement, bending moment, torsional moment and axial force increases as per unit length with increase in number of storeys for both T- shaped and L- shaped geometry. However, shear force is almost constant per unit length with increase in height of building in case of T- shaped plan decreases in case of L shape structure.
And concluded that the geometry of building is one of the important governing factors during analysis of behaviour high rise structure against the wind load with reference to various parametric coefficients. The structure with T-shaped plan is more sensitive to the wind loads as compared to l shaped plan and hence it is less cost effective and serviceable.

Shaikh Muffassir [2016] [2] have presented the work on " Comparative study on wind analysis of multi-storey RCC building and composite structure for different plan configuration" in their study they have investigated the comparison between RCC structure and composite structure under the wind effects with different plan configurations of square, Rectangular, U- Shaped, H-Shaped Buildings of (G+5), (G+15), (G+25) stories of a total no of 15 number of building models are designed and analysed for wind loads by using E-TABS 2015 Software. The parameters such as story displacement, story displacement, story stiffness, base reaction, maximum bending moment and tine period has been evaluated. The comparative study concluded that the composite structure is larger ductile in nature as compared to RCC structure having parameters within acceptable limit. Composite structure provides large space for utilization and economical with high durability and rapid rejection and are more susceptible to wind effect than the RCC structure. The study of different shape of composite structure conclude that H-shape and U-shape type buildings gives almost same response for (G+5) building but however at (G+15) and (G+25) the parametric response of U-shape buildings abruptly changes as compared to other shapes.

Yamini [et.al] [2018] [3] studied on "wind analysis for building using Belt truss". A [G+23] storey building of 3 different models (I) without belt truss, (ii) with the Belt truss at every 5 intervals, (iii) with the belt truss at every 4-storey interval located at Vijayawada city in Andhra Pradesh is modelled and analysed using ETABS Software for wind analysis and lateral loads for the RC frame building with belt truss. The parameters like displacements, storey drift stiffness, base shear is analysed and concluded that the optimum position of the belt truss as virtual belt truss at every 4-storey interval. When compared to other the displacement and storey drift is less and stiffness is more to the building provided with belt truss at every 4-storey interval. So, the optimum position of the stiffen girder is providing at every 4-storey interval. And concluded that the geometry of building is one of the important governing factors during analysis of behaviour high rise structure against the wind load with reference to various parametric coefficients. The structure with T- shaped plan is more sensitive to the wind loads as compared to l shaped plan and hence it is less cost effective and serviceable.

3. METHODOLOGY

3.1.1Design parameters:

The Eight different structures are considered 1. 4 structures Without belt truss and 2. 4 structures with belt truss. The structures are modelled in 3D in the commercial structural analysis and design software ETABS 2018 Version. X and Y axis are the global horizontal axis and the Z is the global vertical axis. The buildings are analysed for dead loads, live loads, earthquake loads, and their combinations. The buildings are compared for base shear, storey shear, storey displacements, story drifts, bending moment, torsional moment, storey stiffness, axial force, maximum displacement, and time period. The location of the structure is located in zone v as per Indian Standard Code. All the supports are considered to be fixed at the base. Effective lengths of the columns are considered as per the standard code of practice. Effect of rigid diaphragm for slabs is considered in the analysis.

Design codes and references

IS 456: 2000 - Plain and Reinforced Concrete.
IS 875- 1987 (1, 2,3) - Code of Practice for Design Loads.
IS 1893 (part 1):2016 - Criteria for Earthquake Resistant Design of Structures.
Is 800: 2007 - General Construction in Steel Design.
Is 16700: 2017- Criteria for Structural Safety of Tall Buildings.

3.2 Geometry Of the Model:

Details related to geometry and dimensioning of the structure is discussed here:

MODEL GEOMETRY		
1	No of stories considered	50
2	Total height of the building	150m
3.	Height of each storey	3.0m

Table 1. Geometry of the model

Element Details		
S.N. O	**Element**	**Dimensions**
1	Slabs	125 mm
2	Beams	600mm*900mm
3	Columns	1300mm*2000mm
4	Belt Truss for every 5 floors	ISLB 600
5	Wall thickness	250mm
6	Grade of concrete	M50
7	Grade of steel	Fe 500

Table 2. Element Details of Model

3.6 Static and Dynamic Analysis

Details related to static and dynamic loading are given below. Various parameters related to seismic and wind load cases are mentioned below, as they have been given as input in ETABS 18.1.1.

Static Load Cases		
1	Dead Load	as per IS 875 (Part -1) -1987
2	Live Load	as per IS 875 (Part -2) -1987
3	Earthquake in X-direction	as per IS 1893(Part -1) - 2002
4	Earthquake in Y-direction	as per IS 1893(Part- 1) - 2002
5	Wind load in X-direction	as per IS 875 (Part -3) -1987
6	Wind load in Y-direction	as per IS 875 (Part- 3) -1987

Table 3. Static Load Cases

As per the provision of is 1893 (part-1):2002, while define 'mass source' mass multiplies for live load has been kept as '0.25' as only 25% of live loads is to be considered for calculation of seismic weight for live load class up to 3kN/m^2.

Dynamic load cases		
1	Response spectra in X-direction	Auto generated as per IS 1893(Part- 1) - 2002
2	Response spectra in Y-direction	Auto generated as per IS 1893(Part- 1) - 2002

Table 4: Dynamic load cases

Parameters of wind loading as per IS 875 (PART -3) :1987		
1	Structure class	General Building Structure
2	Terrain category	4
3	Basic wind speed, V_b	44 m/s
4	Risk coefficient (K1 factor)	1.0
5	Topography coefficient (K3 factor)	1.0

Table 5: Wind Loading Parameters

PARAMETERS OF SEISMIC LOADING AS PER IS 1893 (PART-1): 2002		
1	Seismic zone	II
2	Seismic zone factor, Z	0.1
3	Importance Factor, R	1.2
4	Response Reduction Factor, R	5
5	Soil type	I

Table 6: Seismic Loading Parameters

s.no	Factor	Load Combination
1	1.5	(Dead+wall+F.F)
2	1.5	(Dead+Live+wall+F.F)
3	1.2	(Dead+Live+wall+F.F+Wind x)
4	1.2	(Dead+Live+wall+F.F-Wind x)
5	1.2	(Dead+Live+wall+F.F+Wind y)
6	1.2	(Dead+Live+wall+F.F-Wind y)
7	1.5	(Dead+wall+F.F+Wind x)
8	1.5	(Dead+wall+F.F-Wind x)
9	1.5	(Dead+wall+F.F+Wind y)
10	1.5	(Dead+wall+F.F-Wind y)
11	0.9	(Dead+wall+F.F)+1.5 Wind x
12	0.9	(Dead+wall+F.F)-1.5 Wind x
13	0.9	(Dead+wall+F.F)+1.5 Wind y
14	0.9	(Dead+wall+F.F)-1.5 Wind y
15	1.2	(Dead+Live+wall+F.F+EQ x)
16	1.2	(Dead+Live+wall+F.F-EQ x)
17	1.2	(Dead+Live+wall+F.F+EQ y)
18	1.2	(Dead+Live+wall+F.F-EQ y)
19	1.5	(Dead+wall+F.F+EQ x)
20	1.5	(Dead+wall+F.F-EQ x)
21	1.5	(Dead+wall+F.F+EQ y)
22	1.5	(Dead+wall+F.F-EQ y)
23	0.9	(Dead+wall+F.F)+1.5 EQ x
24	0.9	(Dead+wall+F.F)-1.5EQ x
25	0.9	(Dead+wall+F.F)+1.5 EQ y
26	0.9	(Dead+wall+F.F)-1.5 EQ y

Table 7: Load combination Parameters

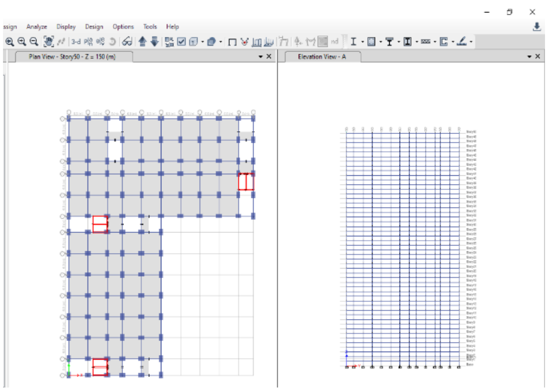

Fig:1 L-Shape structure without Belt Truss

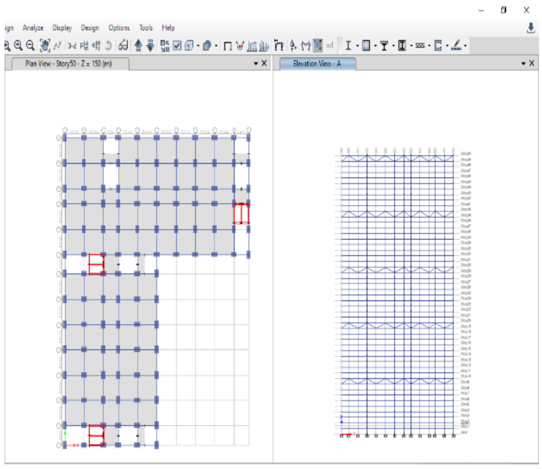

Fig:2 L-Shape structure with Belt Truss

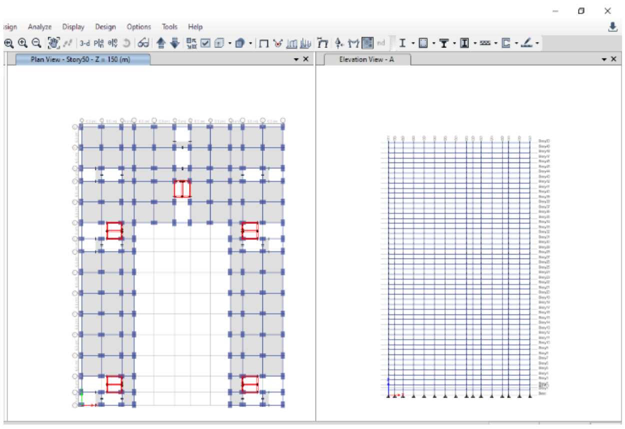

Fig:3 U-Shape structure without Belt Truss

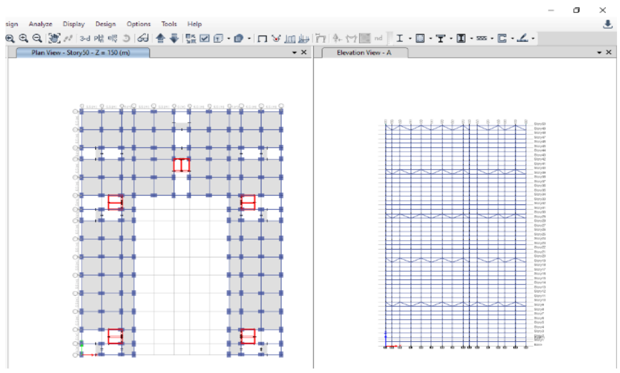

Fig:4 U-Shape structure with Belt Truss

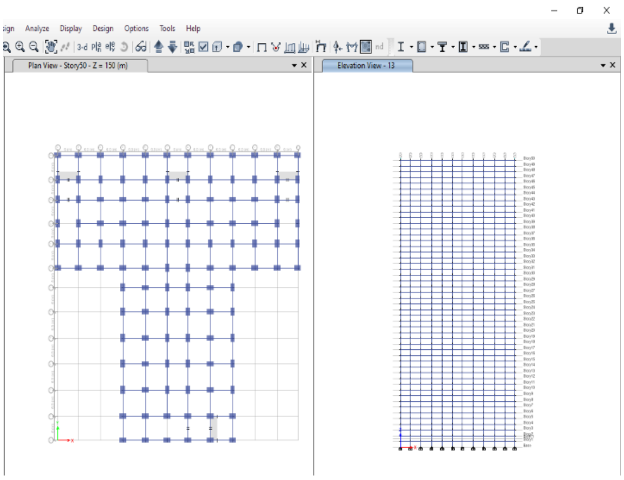

Fig:5 T-Shape structure without Belt Truss

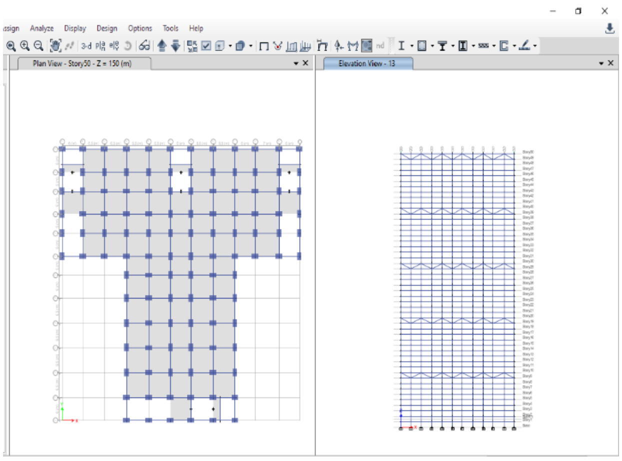

Fig:6 T-Shape structure with Belt Truss

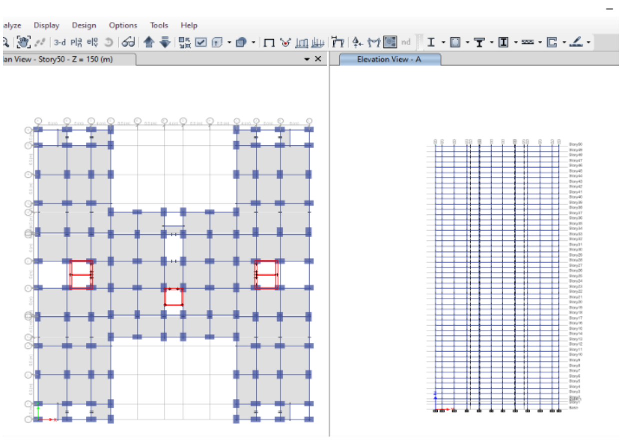

Fig:7 H-Shape structure without Belt Truss

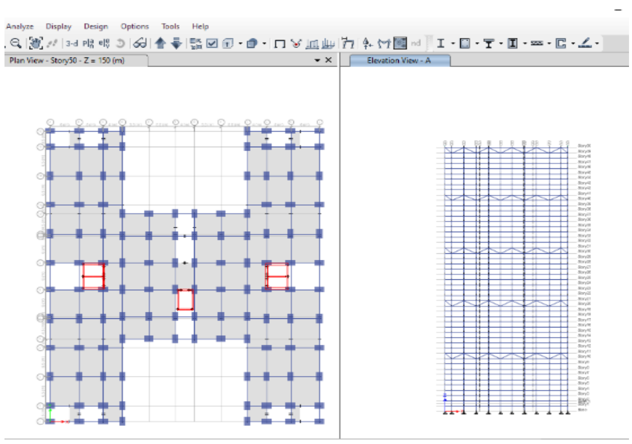

Fig:8 H-Shape structure with Belt Truss

4. RESULTS & DISSICUSSION

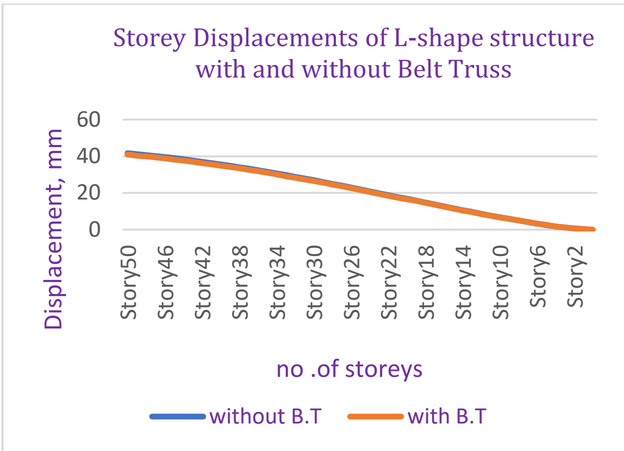

Chart 1: Storey Displacements of L-shape structure with and without Belt Truss

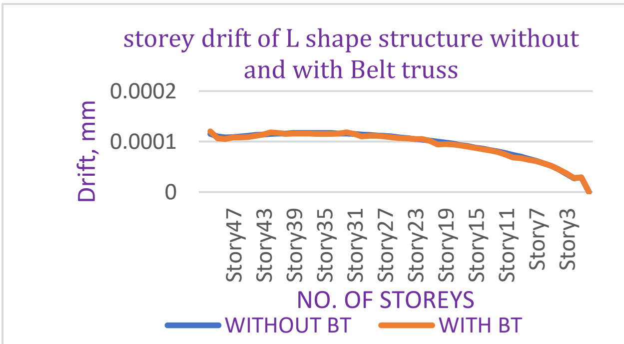

Chart 2: storey drift of L shape structure without and with Belt truss

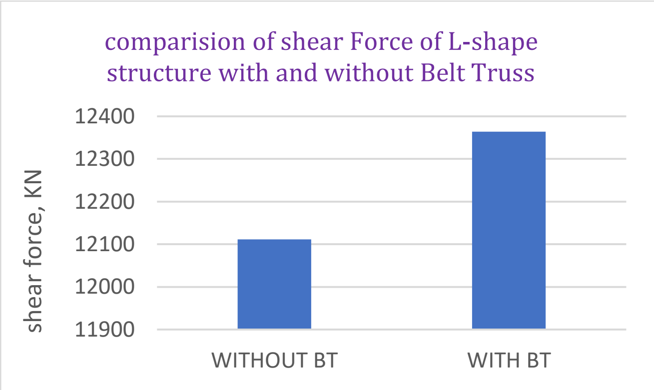

Chart 3: comparison of shear Force of L-shape structure with and without Belt Truss

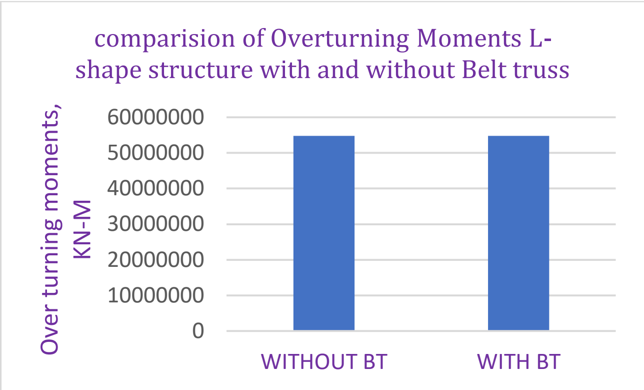

Chart 4: comparison of Overturning Moments L-shape structure with and without Belt truss

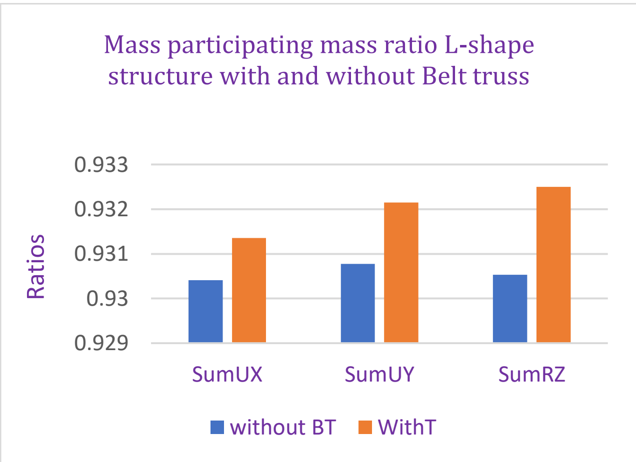

Chart 5: Mass participating mass ratio L-shape structure with and without Belt truss

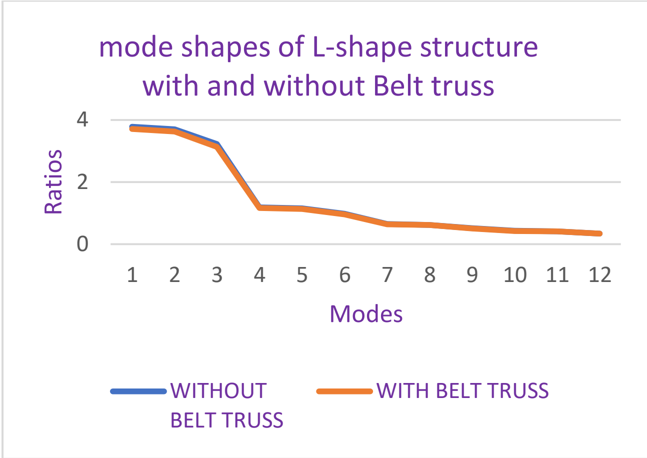

Chart 6: mode shapes of L-shape structure with and without Belt truss

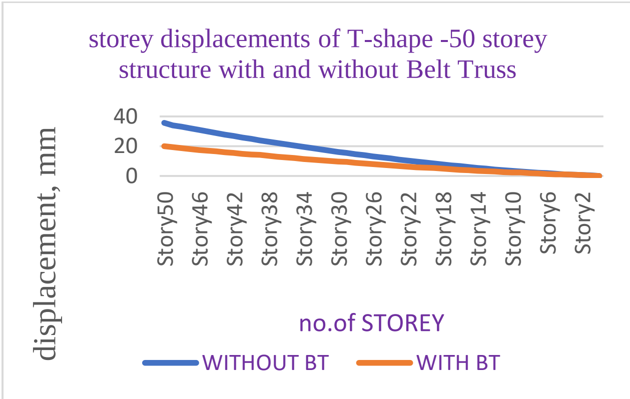

Chart 7: storey displacements of T-shape -50 storey structure with and without Belt Truss

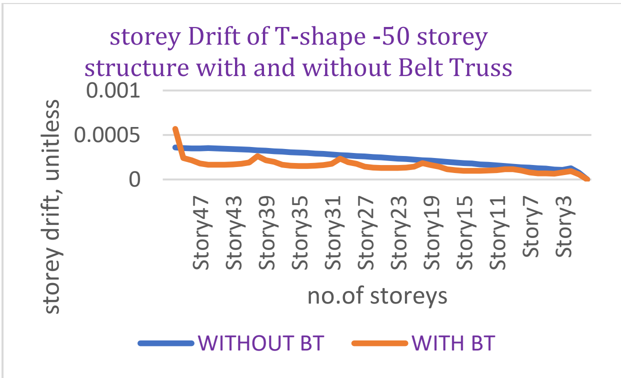

Chart 8: storey Drift of T-shape -50 storey structure with and without Belt Truss

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

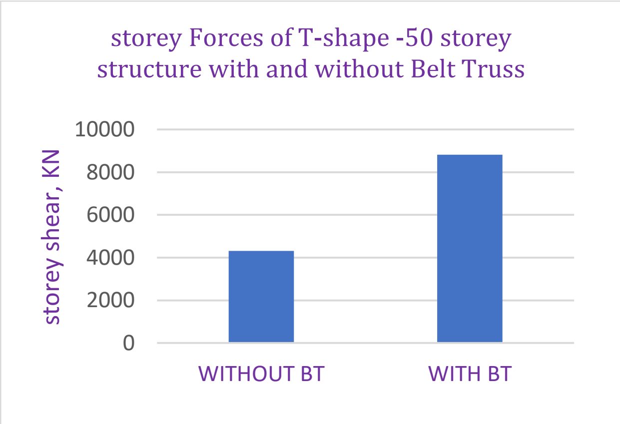

Chart 9: storey Forces of T-shape -50 storey structure with and without Belt Truss

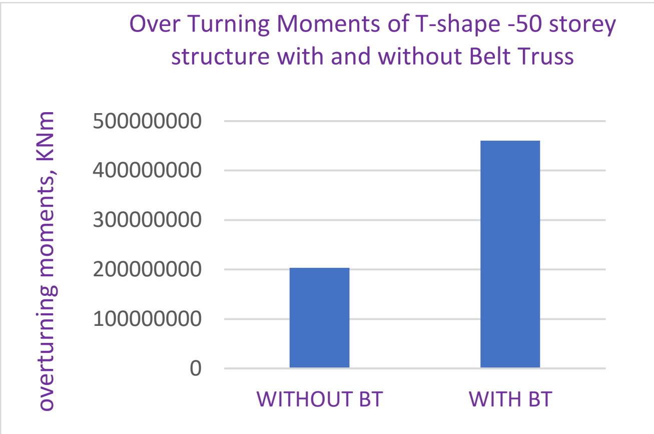

Chart 10: Over Turning Moments of T-shape -50 storey structure with and without Belt Truss

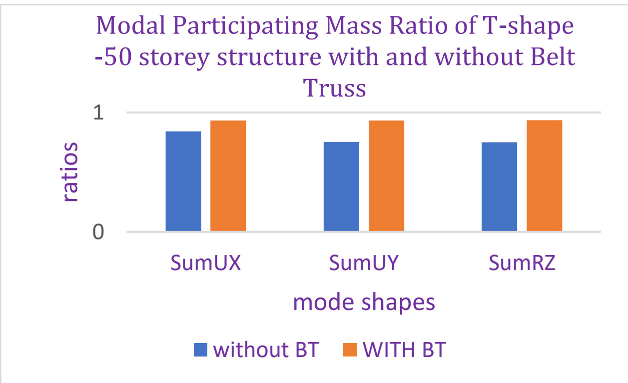

Chart 11: Modal Participating Mass Ratio of T-shape -50 storey structure with and without Belt Truss

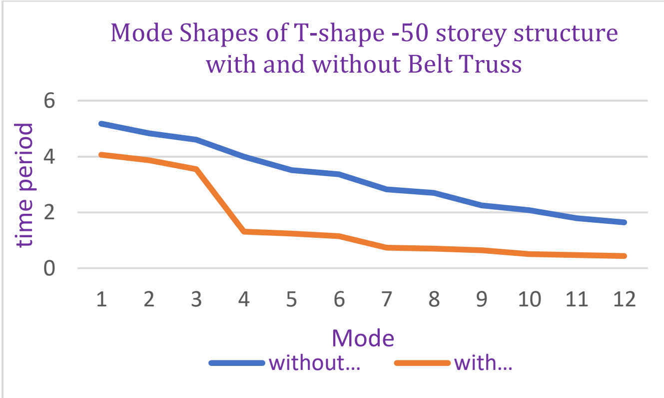

Chart 12: Mode Shapes of T-shape -50 storey structure with and without Belt Truss

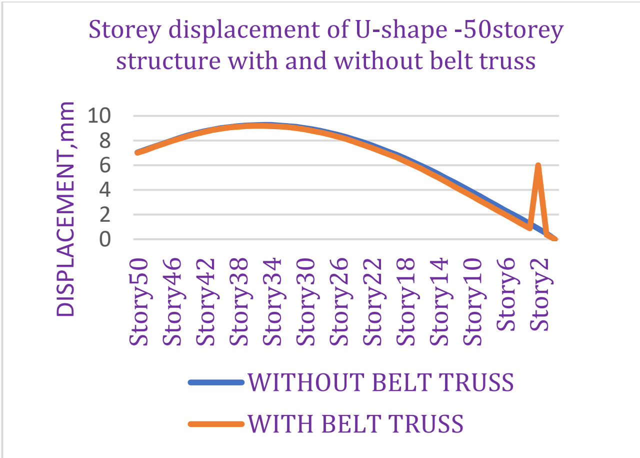

chart 13: Storey displacement of U-shape -50storey structure with and without belt truss

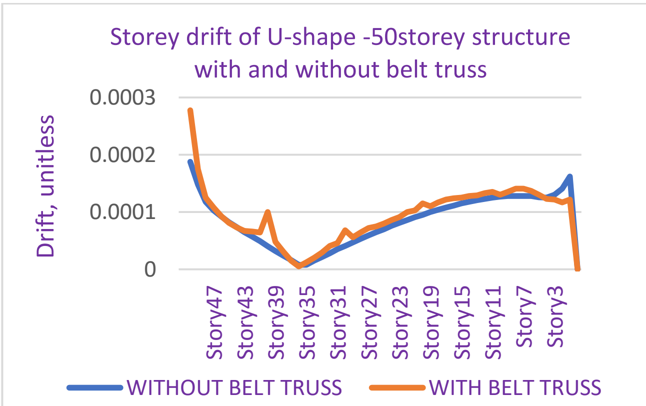

Chart 14: Storey drift of U-shape -50storey structure with and without belt truss

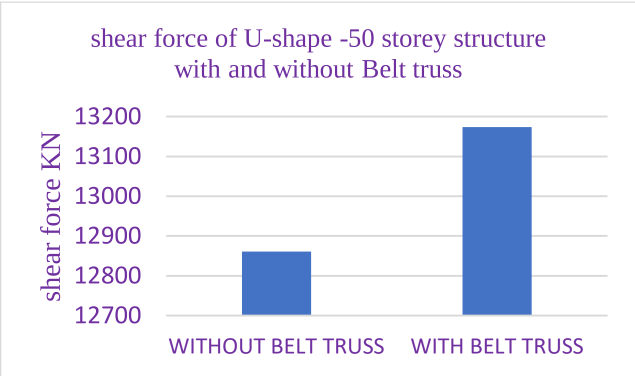

Chart 15: shear force of U-shape -50 storey structure with and without Belt truss

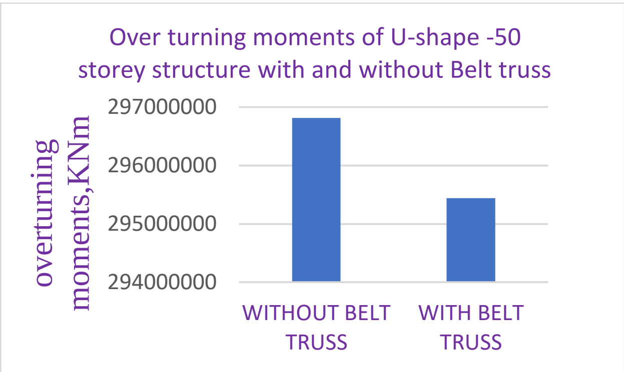

Chart 16: Over Turning Moments of U-shape -50 storey structure with and without Belt Truss

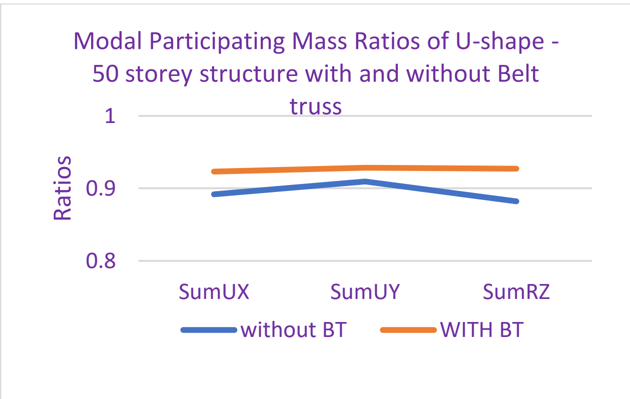

Chart 17: Modal Participating Mass Ratios of U-shape -50 storey structure with and without Belt truss

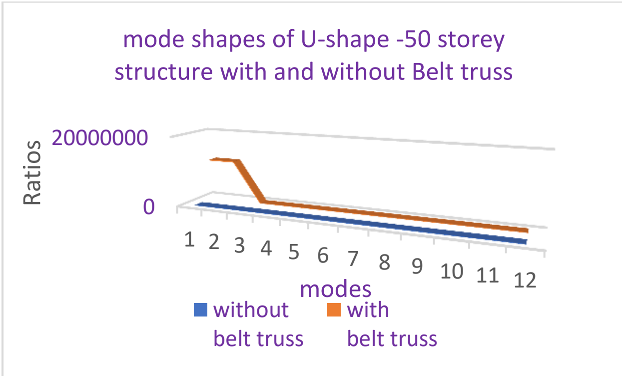

Chart 18: mode shapes of U-shape -50 storey structure with and without Belt truss

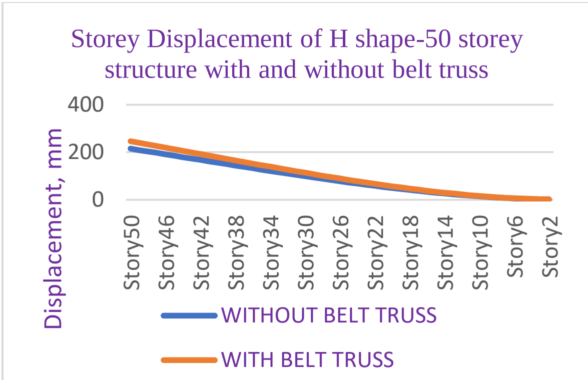

Chart 19: Storey Displacement of H shape-50 storey structure with and without belt truss

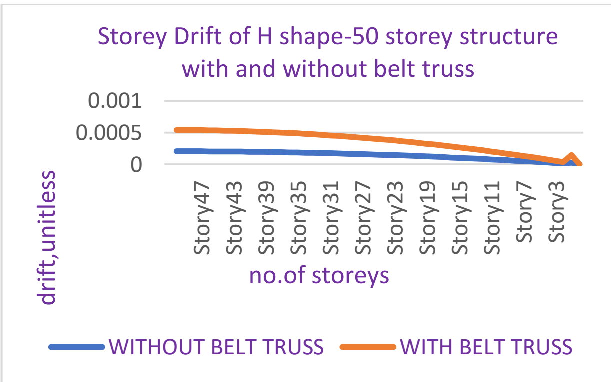

Chart 20: Storey Drift of H shape-50 storey structure with and without belt truss

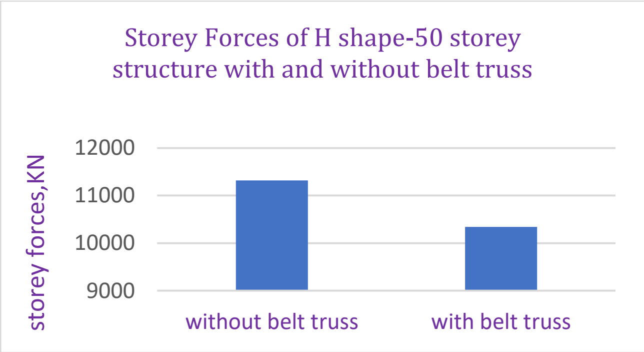

Chart 21: Storey Forces of H shape-50 storey structure with and without belt truss

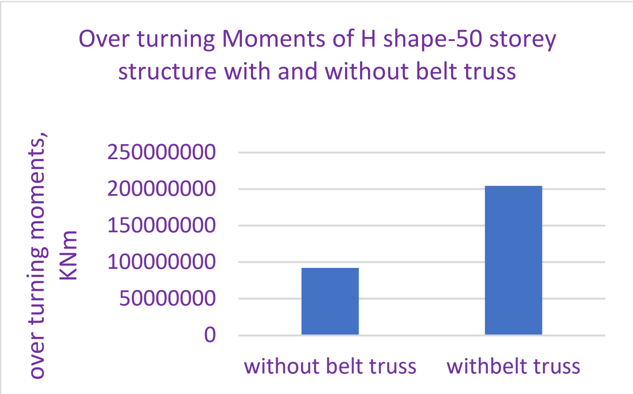

Chart 22: Over Turning Moments of H-shape -50 storey structure with and without Belt Truss

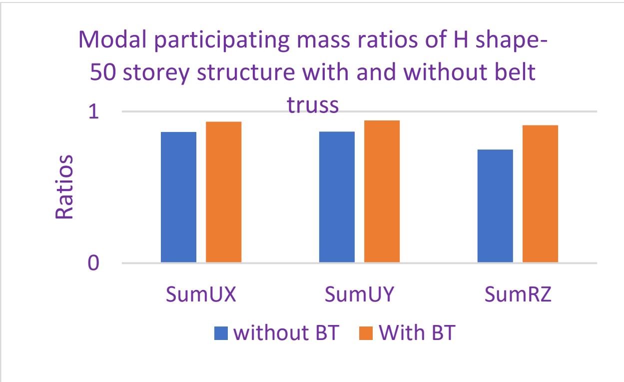

Chart 23: Modal participating mass ratios of H shape-50 storey structure with and without belt truss

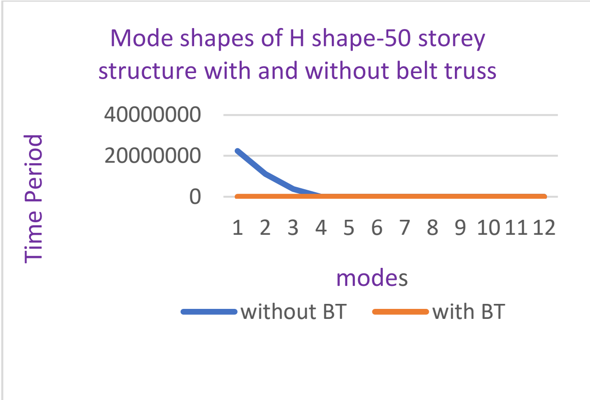

Chart 24: Mode shapes of H shape-50 storey structure with and without belt truss

5. CONCLUSIONS

5.1 L shape structure

1 In L shape structure without belt truss, the maximum deflection is 41.714 mm and 40.931 mm for structure with belt truss. The percentage of variation of deflection is 1.91 %.
2. The percentage of variation of storey drift in L shape structure with and without belt truss is 4.1 %.
3. The maximum storey shear for L shape structure without belt truss is 12111 kN and 12363 kN for structure with belt truss. The percentage of reduction in storey shear is 2.1 %.
4. The overturning moment for L shape structure with and without belt truss are 5755505 kNm and 5755505 kNm. The percentage of reduction of overturning moment is 0.04%.
5. The modal participating mass ratios for L shape structure without Belt truss are 0.93, 0.93 along the translation directions & 0.93 along the rotation direction. And for the structures with belt truss are 0.931,0.932 along the translational direction and 0.933 along the rotation direction. The percentage of reduction of Modal participating mass ratio is 0.10%,0.14% along the translation direction and 0.21% along the rotation direction.
6. The torsion is observed at 4th mode in both without and with Belt Truss according to mode shapes.

5.2 T shape structure

1. In T shape structure without belt truss, the maximum deflection is 35.799 mm and 19.928 mm for structure with belt truss. The percentage of variation of deflection is 80 %.
2. The percentage of variation of storey drift in T shape structure with and without belt truss is 37%.
3. The maximum storey shear for T shape structure without belt truss is 4309 kN and 8811 kN for structure

with belt truss. The percentage of reduction in storey shear is 51%.
4. The overturning moment for T shape structure with and without belt truss are 460448475 kNm. and 203172256 kNm. The percentage of reduction of overturning moment is 1.26%.
5. The modal participating mass ratios for L shape structure without Belt truss are 0.93, 0.93 along the translation directions & 0.93 along the rotation direction. And for the structures with belt truss are 0.923,0.928 along the translational direction and 0.927 along the rotation direction. The percentage of reduction of Modal participating mass ratio is 3.26%,2.17% along the translation direction and 4.34% along the rotation direction.
6. The torsion is observed at 4th mode in both without and with Belt Truss according to mode shapes.

5.3 U shape structure

1. In U shape structure without belt truss, the maximum deflection is 7.049 mm and 7.008 mm for structure with belt truss. The percentage of variation of deflection is 0.58%.
2. The percentage of variation of storey drift in U-shape structure with and without belt truss is 32 %.
3. The maximum storey shear for U shape structure without belt truss is 12861 kN and 13173 kN for structure with belt truss. The percentage of reduction in storey shear is 2.4%.
4. The overturning moment for U shape structure with and without belt truss are 295442794 kNm and 296816037 kNm. The percentage of reduction of overturning moment is 0.46%.
5. The modal participating mass ratios for L shape structure without Belt truss are 0.840, 0.751 along the translation directions & 0.751 along the rotation direction. And for the structures with belt truss are 0.932,0.933 along the translational direction and 0.933 along the rotation direction. The percentage of reduction of Modal participating mass ratio is9.7%,19.4% along the translation direction and 19.5% along the rotation direction.
6. The torsion is observed at 4th mode in both without and with Belt Truss according to mode shapes.

5.4 H shape structure

1. In H shape structure without belt truss, the maximum deflection is 215.248 mm and 247.001 mm for structure with belt truss. The percentage of variation of deflection is 12.8 %.
2. The percentage of variation of storey drift in H shape structure with and without belt truss is 62 %.
3. The maximum storey shear for H shape structure without belt truss is 11317.71 kN and 10342.19 kN for structure with belt truss. The percentage of reduction in storey shear is 9.42 %.
4. The overturning moment for H shape structure with and without belt truss are 92033974 kNm and 204292011 kNm. The percentage of reduction in storey shear is 1.21 %.
5. The modal participating mass ratios for L shape structure without Belt truss are 0.86, 0.86 along the translation directions & 0.74 along the rotation direction. And for the structures with belt truss are 0.931,0.94 along the translational direction and 0.908 along the rotation direction. The percentage of reduction of Modal participating mass ratio is 7.62% ,8.51% along the translation direction and 18.51% along the rotation direction.
6. The torsion is observed at 4th mode in both without and with Belt Truss according to mode shapes.

REFERENCES

[1] **Bhumika Pashine [et.al]** "Wind analysis of multi storied structure with T shape and L Shape geometry" IJEDR Volume 4, Issue 3: 2016.

[2] **Shaikh Muffassir [et.al]** "Comparative Study on Wind Analysis of Multi-story RCC and Composite Structure for Different Plan Configuration" (IOSR-JMCE), Volume 13, Issue 4 Ver. VII (Jul. - Aug. 2016).

[3] **Yamini [et.al]** "wind analysis for building using Belt truss**".** (IRJET), Volume: 05 Issue: 03 | Mar-2018.

[4] **IS 456: 2000 -** Plain and Reinforced Concrete.

[5] **Is: 875 (Part I)** – 1987: Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 1- Dead Loads

[6] **Is: 875 (Part 2)** – 1987 Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 2- Imposed Load

[7] Is: 875 **(Part 3)** – 1987 Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 3- Wind Loads.

[8] **IS 1893 (part 1):2016 -** Criteria for Earthquake Resistant Design of Structures.

[9] **Is 800: 2007 -** General Construction in Steel Design.

[10] **Is 16700: 2017-** Criteria for Structural Safety of Tall Buildings.