ORIGINAL RESEARCH PAPER

Engineering

OPTIMIZATION OF OUTRIGGER AND BELT TRUSS SYSTEM IN VERTICALLY IRREGULAR STRUCTURE

KEY WORDS: outrigger and belt truss, vertical irregularity, deflection, drift, storey shear, static analysis.

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ABSTRACT

Today's greatest challenge for any structural engineer is to design lateral loading resistant structures. Outrigger and belt truss are prominent lateral load resisting system in tall slender buildings. Outriggers are rigid horizontal structure connecting a building core to distant columns. The present work is to study the behaviour of outrigger and belt truss placed at different levels of the building are subjected to wind and earthquake loads. 3D models of outrigger and belt truss system with octagonal plan configuration was considered for the analysis of the structure. In this study, attempt has been made to study the effect of outrigger and belt truss system with vertically irregular building. To achieve this objective, the vertical irregularities structures with 30 stories 7X7 bay from 1st to 10th floor, 5x5 bays from 11th to 20th floor, 3x3 bays from 21st to 30th floor with outriggers and belt truss at different stories were analysed. The depth of outrigger and belt truss is equal to the height of typical storey and maintained in all models. ETABS 2016 used for modelling and analysis to evaluate the performance of vertical irregularities of outrigger structure. The optimised value was obtained by considering the various factors such as storey displacement, storey drift, base shear and overturning moment, are examined using linear static analysis. Compare the results of analysis of octagonal structures with symmetric structure were done. Compared to Bare frame the outrigger and belt truss reduces 25.86% and 33.33% of deflection and drift in the structure.

I. INTRODUCTION

C Construction of a high-rise structure is a complicated affair with lateral loads playing a dominant role in the design of structure it requires need the of lateral load resisting system. With evolution in technology, various load resisting systems arrived from the normal load-bearing structures to moment resisting frames to bracing to the shear wall to some more modern structures like core out-trigger and tube in tube, diagrids...etc each has their own pros and cons.

Outriggers are rigid horizontal structure i.e. truss or beam which connect core wall and outer column of building to improve building strength and overturning stiffness. Outriggers have been used in tall building for nearly half century, but innovative design principle has been improving its efficiency. Outrigger may be extended to both side of central core or core building with outrigger extending to other side column.

II. A) OBJECTIVES

Based on the literature review presented later, the salient objectives of the present study have been identified as follows:

a) Comparing the present study (octagonal shape) with symmetric plan layout.
b) To optimise the outrigger and belt truss system in the vertically irregular structure.
c) To study the performances of building with the vertically geometric irregularity.
d) To perform the equivalent static analysis of vertically irregular structure against earthquake and wind loads.

B) SCOPE OF THE STUDY

i. To perform parametric studies of storey displacement, storey drift, base shear, and overturning moment of vertical irregular building with outrigger systems.
ii. Reinforced 30 storey framed structure is considered in this study.
iii. Both irregular RCC building with the symmetric plan and irregular RCC building with asymmetric is considered for the comparative study.
iv. The Vertical irregularity was studied.
v. The Outriggers are introduced at two levels in the building.
vi. The Linear elastic analysis was done on the structures.
vii. Parameters kept constant in the analytical study are height and Outrigger location for the different cases of building.
viii. The Column was modelled as fixed to the base.

C) METHODOLOGY

The steps undertaken in the present study to achieve the above-mentioned objectives are as follows:

a) Carry out extensive literature review, to establish the objectives of the research work.
b) Select an exhaustive Symmetric vertically geometric irregular RCC building frame model of 90m height (30 stories) having 7x7 Bay spacing of 5.5m.
c) Modeling of the selected structure by using ETABS software.
d) Performing the Equivalent static analysis and results are analysed.
e) For the same structure provide "Outrigger and Belt Truss" system in different positions and find out the optimum position for this system.
f) Performing the analysis for optimum position for the selected structure and comparison of analysis result.
g) Validation of results.
h) Modifying the selected structure to an asymmetric plan (octagonal shape) with outrigger and belt truss system.
i) Performing the analysis and comparison of results.

III. STRUCTURAL MODELLING

A) SELECTION OF PARAMETERS

This thesis is a comparative study between different plan layouts. Five types of parameters are selected:

- Model heights
- Model plan layout(Square and Octagonal)
- Vertical geometric irregularity
- Mass irregularity
- Belt-truss and outriggers configuration

B) STRUCTURAL ELEMENT PROPERTIES

Element	Description
Slab	150mm thick
Beams	All the beams are 230mm wide and 450mm deep,

Columns	1st and 2nd storey 800 x 800mm 3rd to 5th storey 700 x 700mm 6th to 10th storey 600 x 600mm 11th to15th storey 500 x 500mm 16th to 30th storey 400 x 400mm
Core wall or shear wall	Reinforced cement concrete (RCC)with Thickness – 300 mm
Belt Truss and outriggers	(300x300)mm with Belt truss

TABLE 1: ELEMENT PROPERTIES

C) LOAD CONSIDERATIONS

The Live loads used in the models are for hotel occupancy as per IS-875-Part 3 (1987) is given below,

Live load-3KN/m^2
Floor finish-1KN/m^2
Mass Source Definition
Dead Load- 1 KN/m^2
Floor Finish- 1 KN/m_2
Live Load- 0.25 KN/m^2
Wind load: (IS: 875(Part 3) -1987) – Bhuj
Design Speed – 50 m/s
Terrain Category – 3

Class – B
Diaphragms – Rigid
Earth Quake Load: (1893(Part 1): 2002) – Bhuj
Zone V – 0.36
Importance factor – 1
Type of soil – Medium Soil
Reduction Factor – 5

D) MODEL DIMENSIONS

The study is based on three dimensional RC building with a setback is considered. The model considered for this study is a 90m high rise reinforced concrete building frame. The building represents a 30storeyed hotel building. The plan area of the structure is (38.5 X 38.5) m with columns spaced at 5.5m center to center in longitudinal and transverse direction respectively. The plan layout for all the models is shown in Fig1.

E) MODEL VALIDATION

For verification of software a 30 storey building example is taken from *IOSR Journal of Mechanical and Civil Engineering* (*IOSR-JMCE*) .The results of which are compared with the results of ETABS 2016.

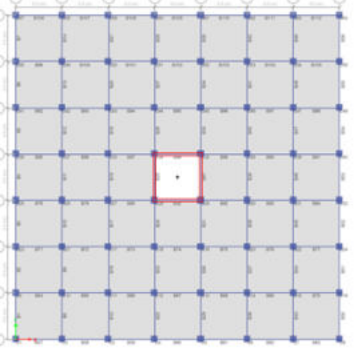


Fig 1: Plan layout

The table 2 shows the model validation of above plan layout analysis result of deflection of bare frame with core and compared with the computer generated results of Etabs 2016.

The validation percentages were within the acceptable limits of 5-10%, which was also indicative of correct input parameters in the models.

Difference = {(Journal result–Etab output)/ journal result} x100

Storey	From journal	Etabs	Difference
30	330.84	326.7	1.26722
29	313.914	313.3	0.19598
28	285.875	299.7	4.6129
27	262.735	286.1	8.1667
26	250.48	272.4	8.047
25	238.109	258.6	7.9238
24	225.634	244.7	7.7916
23	213.075	230.7	7.6398
22	200.459	216.7	7.4947
21	187.819	202.8	7.3871
20	175.257	188.9	7.2223
19	162.882	175.2	7.0308
18	150.515	161.7	6.9171
17	138.227	148.2	6.7294
16	126.071	134.9	6.5448
15	113.989	121.8	6.413
14	102.307	109.1	6.2264
13	90.871	96.7	6.0279
12	79.781	84.7	5.8076
11	69.112	73.2	5.5847
10	58.984	62.3	5.3226
9	49.795	52.4	4.9714
8	41.026	43	4.5907
7	32.869	34.2	3.8918
6	25.377	26.3	3.5095
5	18.661	19.2	2.8073
4	12.814	13	1.4308
3	7.852	7.8	0.66667
2	3.957	3.8	4.13158
1	1.251	1.2	4.25

Table 2: Deflection of bare frame +core Model validation for 30 storey

F) PROBLEM STATEMENT

In present work in order to compare the response of outrigger and belt truss in vertically irregular building with octagonal plan layout of dimension 38.5m x38.5m is modeled and analyzed in ETABS 2016 Non Linear Version software. Equivalent static analysis is performed on the structure.

In present work total 9 models are prepared. Two models of G+29 storey buildings, which include determination of optimum position of outrigger and belt truss system, provision of mass irregularity in the optimum position, and different outrigger configuration models are studied and analysed.

The plan of present study is given below, in that beams are represented as B1,B2,B3…and columns are represented as C1,C2,C3…respectively.

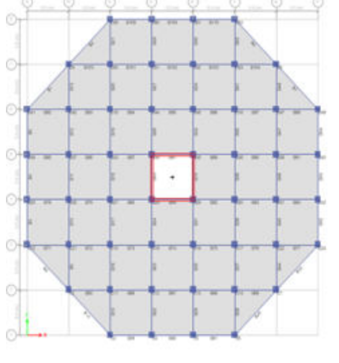


Fig 2: Plan of the building

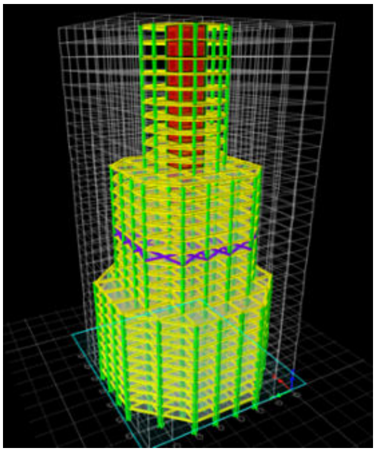


Fig 3: 3D Model of building with 1st outrigger position

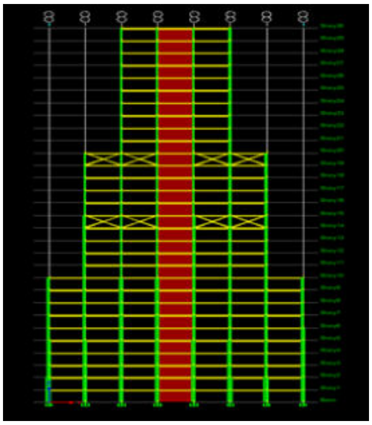
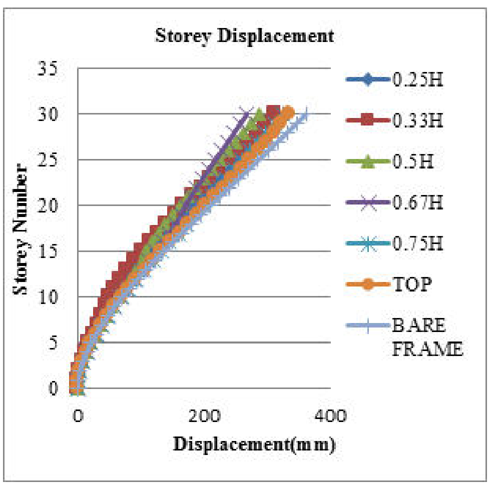


Fig 4: Elevation of model with 2nd outrigger position

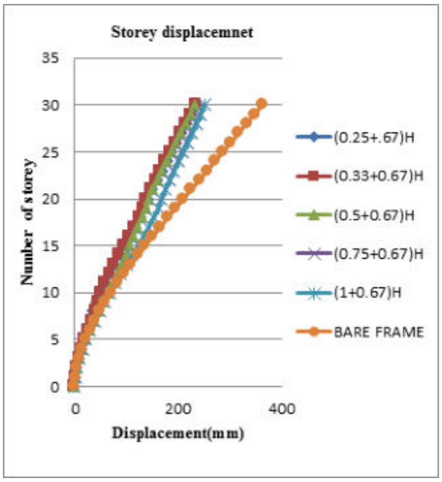
Here Braced concrete outrigger and belt truss is considered and are connected the building core to distant columns these columns are connected by belt truss.

IV. RESULTS AND DISCUSSIONS

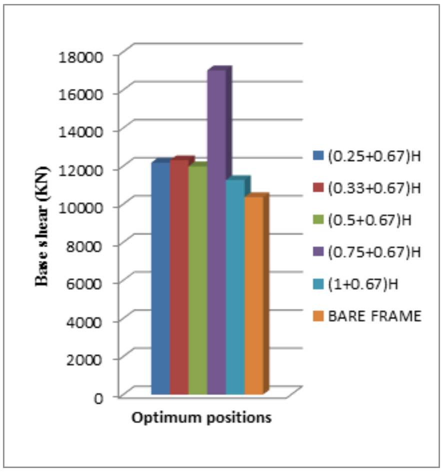
The storey displacement is reducing when outrigger and belt truss system is used in the multi storey building. The outrigger and belt truss system increases the stiffness of irregular building than in the regular building. The graph 1 shows that storey displacement of vertical irregular building with outrigger and belt truss system is provided at different locations.'''



Graph 1: Deflection for 1st position of outrigger and belt truss

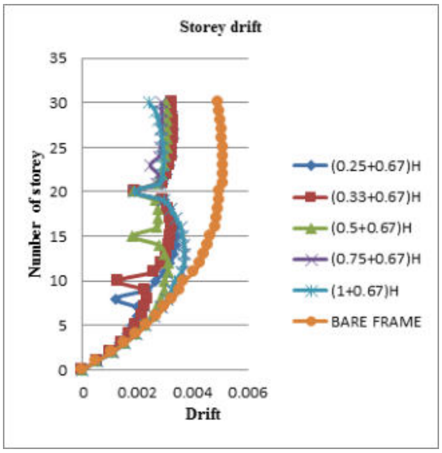


Graph 2: Deflection for 2nd position of outrigger and belt truss



Graph 3: Base shear for 2nd position of outrigger and belt truss

The base shear increasing at the 0.75 times the height of the building than the bare frame. (graph 3)



Graph 4: Storey drift for 2nd position of outrigger and belt truss

The storey drift is also decreasing with increasing the number of storey. The graph 4 shows the minimum drift is occurred at the outrigger and belt truss at top position. The bare frame has high drift than the building with outrigger and belt truss.

V. CONCLUSION

From the results depicts that Outrigger and belt truss one of the lateral load resisting system used in the multistory buildings. Outrigger and belt truss system is increase the stiffness of vertically irregular building than the regular structure. Vertical irregular structure the abrupt changes in the geometry reduces the stiffness of the building.

1. Compared to Bare frame analysis the outrigger and belt truss reduces 25.86% and 33.33% of deflection and drift in the structure.
2. The analysis result shows that the controlling of deflection and drift are achieving at 0.67h is the 1st optimum position and at 0.5h is the 2nd optimum position of outrigger and belt truss.
3. According to the equivalent static analysis results, the storey displacement getting reduced at the second optimum position of outrigger than the 1st position, this gives 13.38% reduction at the top storey.
4. Base shear of vertical irregular structure is increasing gradually when the outrigger position changes. The second position of outrigger i.e., at 0.75h a credible rise in the base shear occurred then decreased. Because the stiffness is increasing at this stage.

VI. REFERENCES

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