IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"SEISMIC ANALYSIS OF OUTRIGGER BRACED SYSTEMS IN HIGH RISE BUILDING"

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ABSTRACT

In the present study an investigation has been perform to examine the behaviour of various alternative 3D models using software for reinforced concrete structure with central core wall with outrigger and without outrigger by varying the relative flexural rigidity from 0.25 to 2.0 with step of 0.25. Also the position of outrigger has been varied along the height of the building by considering a parameter relative height of outrigger from 0.975 to 0.4. The parameters discussed in this study include variation of bending moments, shear force, lateral deflection, peak acceleration of the core; inter-storey drifts for static and dynamic analysis for a 3-dimensional model for various values of relative rigidity and relative height. From the analysis of the results obtained it has been found that performance of the outrigger is most efficient for relative height of the outrigger equal to 0.5.

Keywords: Storey Displacement, Storey Drift and Base Shear

1.0 INTRODUCTION:

The major factor that affects the design of tall structures is its sensitivity to the lateral load. One of the important criteria for the design of tall buildings is lateral drift at top. The acceptable drift limit (top deflection in tall building) for wind load analysis (according to the IS-875-part3 (1987)) is 1/500 of the building height. The acceleration is also an important factor which actually brings about the feel of drift to human perception.

The use of core-wall system has been a very effective and efficient structural system used in reducing the drift due to lateral load (wind and earthquake loads). However, as and when the height of the building increases, the core does not have the adequate stiffness to keep the wind drift down to acceptable limits. For such tall structures a structural system known as outriggers may be introduced. Outriggers are deep, stiff beam which connects the central core to the exterior most columns which helps in keeping the columns in their position in turn reducing the sway. This system helps in reducing the movement of the core when compared to the system with freely standing core without outriggers. The restrain caused by the outrigger reduces the lateral drift at top. The stiffness of the structural system increases by 20 to 30 percent by introducing the outrigger structural system. The use of outriggers in high-rise buildings started about 5 decades ago.

1.1 CONCEPT OF OUTRIGGER:

The outrigger concept was originally derived from sailing canoe which runs on wind pressure during its journey in sea. Sometimes even in the high storm these sailing ship withstand to its position. Similarly, tall building can withstand to high lateral load by introducing outrigger in structure. If we compare the element of sailing ship and building then Central core wall of building behave like a vertical mast of the sailing ship. And outrigger beam or truss is act like a Spreader. Similarly, peripheral columns are representing the shrouds of sailing ship. This Phenomenon has a great potential to be employed in tall buildings.

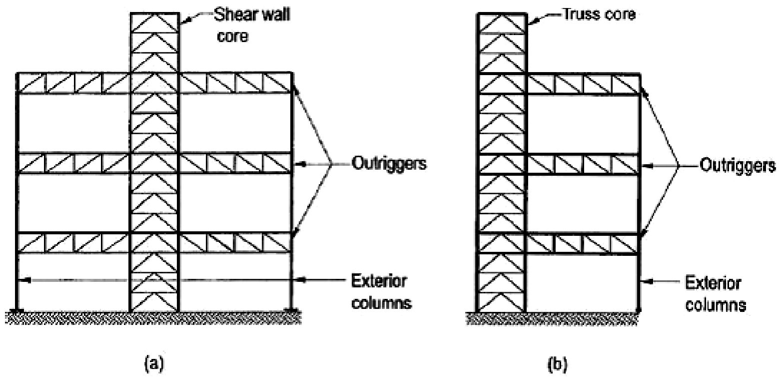


Fig.1.1

(a) Outrigger system with a central core (b) Outrigger system with offset core

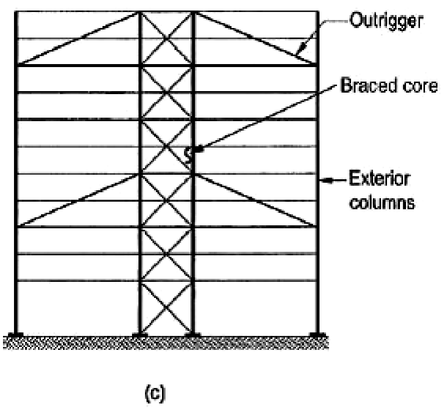


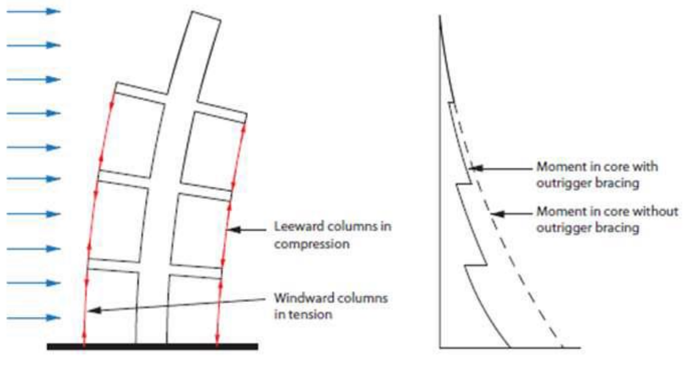
Fig.1.2 Diagonals acting as outriggers

1.2 BEHAVIOUR OF OUTRIGGER

The provision of outrigger structural system comprises of central core wall (i.e. lift shear wall)

Connected to the peripheral columns by single or double storey deep beam in case of RCC structure or sometime steel truss of that particular storey height is provided. This deep beam or steel truss is commonly referred as outrigger. The working principle of outrigger structural system is very simple. When lateral loading either wind or earthquake load applied on the structure the rotation of central core wall is reduced due to the originating of axial forces in peripheral columns. Specifically, Tensile force is developed in windward columns and similarly

Compressive force will develop in leeward columns. The result is the bending moment at a specific location where outrigger beam is provided is drastically reduced. As shown in fig.2. For restraining the rotation of outriggers peripheral columns are also connected. This can be possible by connecting the all peripheral columns with steel truss which is generally referred as belt truss or sometime single or double storey deep wall around the structure. Sometime it referred as “belt wall”.



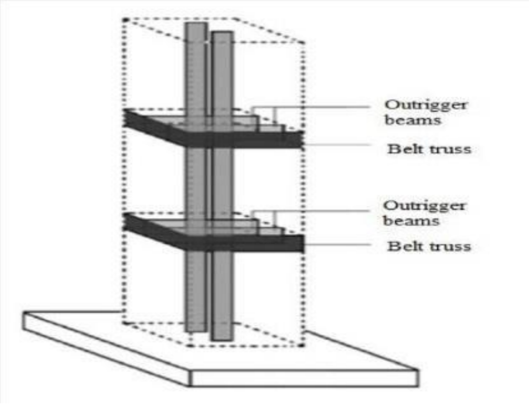


Fig.1.3 Behaviour of Outrigger **Fig.1.4 Building with outrigger & belt truss central**

2.0 OBJECTIVES:

1. To perform a parametric study which include Storey Displacement, Storey Drift and Base Shear?
2. To perform seismic analysis of high rise building models by response spectrum method using software.
3. To determine the optimum location of belt-truss and outriggers arrangement by comparison of results seismic actions.
4. To study the behavior of high rise RCC building structure provided with steel outriggers along with belt truss system subjected to seismic forces.
5. To analyse the effect of outriggers with X- type, V-type V inv- type bracing systems of high rise building

2.1 NEED FOR PRESENT STUDY:

❖ Several studies were carried out on structure by taking shear wall, bracings systems as a lateral load resisting for seismic analysis.

❖ In several studies outrigger system were used as a lateral resisting system

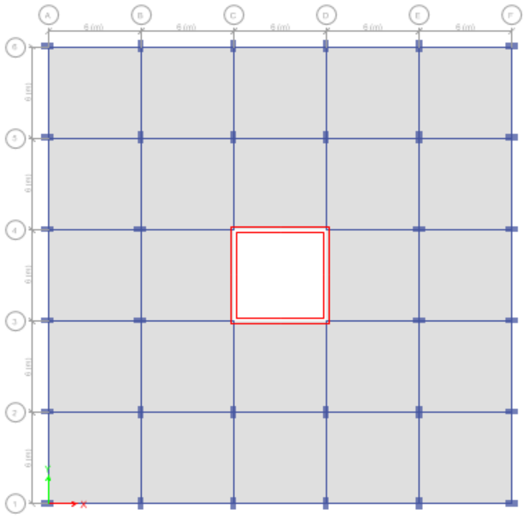
3.0 METHODOLOGY:

In high-rise buildings, lateral loads induced by earthquake are often resisted by a system of coupled shear walls. To make the building structure more ductile and to provide sufficient stiffness outrigger beams between the shear walls and external columns is used.

In this study, the analysis of G+60 storey steel building with outrigger structural system subjected to seismic forces is proposed to be carried out. For the analysis, steel outriggers are proposed to be used in the form of X- type, V-type and V inv bracings along with belt truss system. The optimum location of outriggers in the high-rise building is to be concluded.

3.1 MODEL DETAILS:

For the study of seismic response, a high-rise structure of G+60 storied building with outrigger structural system is considered. The modelling and analysis of work is proposed by using ETABS software. ETABS is powerful and completely incorporated research software for design and analysis of building structure. The floor plan of G+60 storied building is shown below Fig.



PLAN

3.2 Properties of steel

Yield strength of steel – 250N/mm2 mild steel
Modulus of elasticity of steel Es – 200000Mpa

3.3 Dimension of model

Plan dimension – 0.3 X 0.2m
Storey height – 0.25m
Number of storey – 4no
Total height – 1m
Size of bracing – 20X20X3 Size of beam – 20X20X3
Size of column – 20X20X3

3.4 Properties of L section of size 20X20X3mm (from steel table)

Center of gravity = Cxx = Cyy = 0.59cm
Distance of extreme fibre = Exx = Eyy = 1.41cm
Moment of inertia
Ixx = Iyy = 0.4cm4
Iuu = 0.6cm4
Ivv = 0.2cm4
Radii of gyration
Rxx = Ryy = 0.58cm
Ruu = 0.73cm
Rvv = 0.37 cm
Modulus of section
Zxx = Zyy = 0.3cm4
The folowing figure show the model of steel frame and bracing structure for the validation purpose and the result were obtained.

- Model 1- Conventional frame model without outriggers
- Model 2- Model with V-type braced outriggers located at 30^{th} and 60^{th} storey
- Model 3- Model with X-type braced outriggers located at 30^{th} and 60^{th} storey
- Model 4- Model with V-inv type braced outriggers located at 30^{th} and 60^{th} storey
- Model 5- Model with V-type braced outriggers located at 20^{th} and 40^{th} and 60^{th} storey
- Model 6- Model with X-type braced outriggers located at 20^{th} and 40^{th} and 60^{th} storey
- Model 7- Model with V-inv type braced outriggers located at 20^{th} and 40^{th} and 60^{th} storey
- Model 8- Model with V-type braced outriggers located at 15^{th} and 30^{th} and 45^{th} and 60^{th} storey

- Model 9- Model with X-type braced outriggers located at 15th and 30th and 45th and 60th storey
- Model 10- Model with V-inv type braced outriggers located at 15th and 30th and45th and 60th storey
- Model 11- Model with V-type braced outriggers located at 12th and 24th and 36th and 48th and 60th storey
- Model 12- Model with X-type braced outriggers located at 12th and 24th and 36th and 48th and 60th storey
- Model 13- Model with V-inv type braced outriggers located at 12th and 24th and 36th and 48th and 60th storey
- Model 14- Model with V- type braced outriggers located at 10th and 20th and 30th and 40th and 50th and 60th storey
- Model 15- Model with X- type braced outriggers located at 10th and 20th and 30th and 40th and 50th and 60th storey

4.0 RESULTS & DISCUSSIONS:

Displacement results: Table 4.1: Maximum lateral displacement

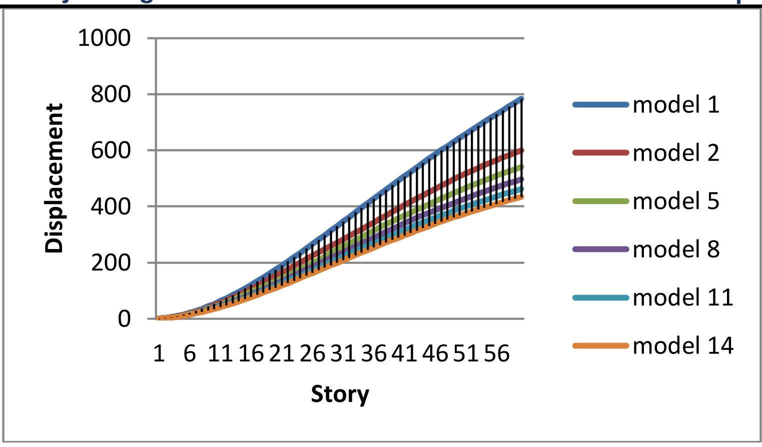
Model No.	V type Maximum displacement at top storey (mm)	Percentage reduction (%)
Model 1	782.9	
Model 2	600.2	23.33%
Model 5	541.8	30.79%
Model 8	498.5	36.32%
Model 11	464.2	40.70%
Model 14	436.1	44.29%

Table 4.2: Maximum lateral displacement

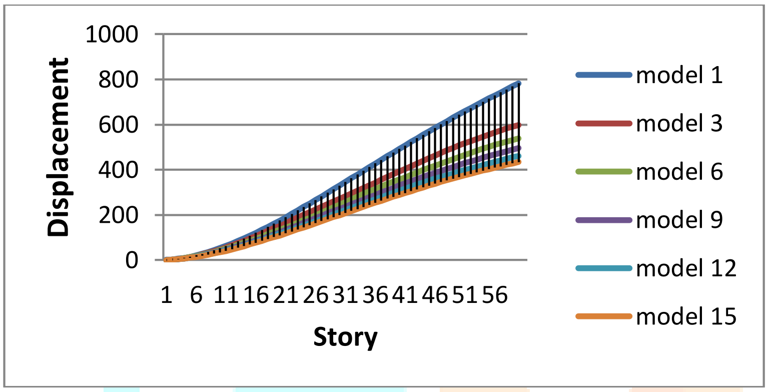
Model No.	V inv type Maximum displacement at top storey (mm)	Percentage reduction (%)
Model 1	782.9	
Model 4	599.3	23.45 %
Model 7	540.5	30.96%
Model 10	497	36.51%
Model 13	462.4	40.93%
Model 16	434.1	44.55 %

Table 4.3: Maximum lateral displacement

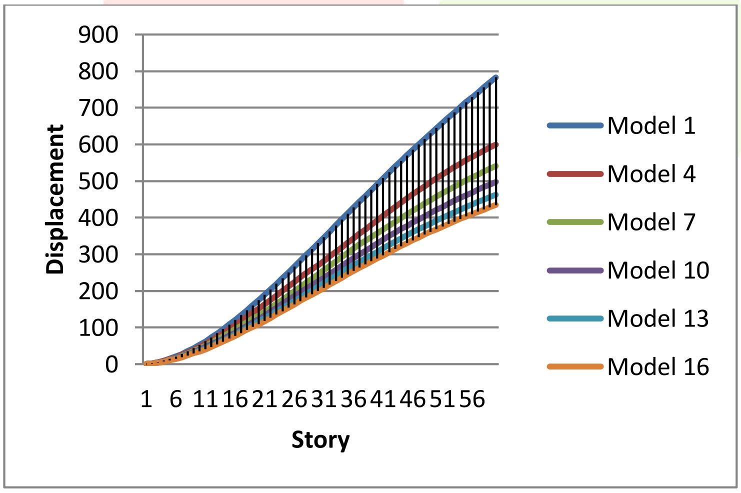
Model No.	X type Maximum displacement at top storey (mm)	Percentage reduction (%)
Model 1	782.9	
Model 3	598.6	23.54%
Model 6	539.7	31.06%
Model 9	496.3	36.66%
Model 12	461.8	41.01%
Model 15	433.6	44.61 %

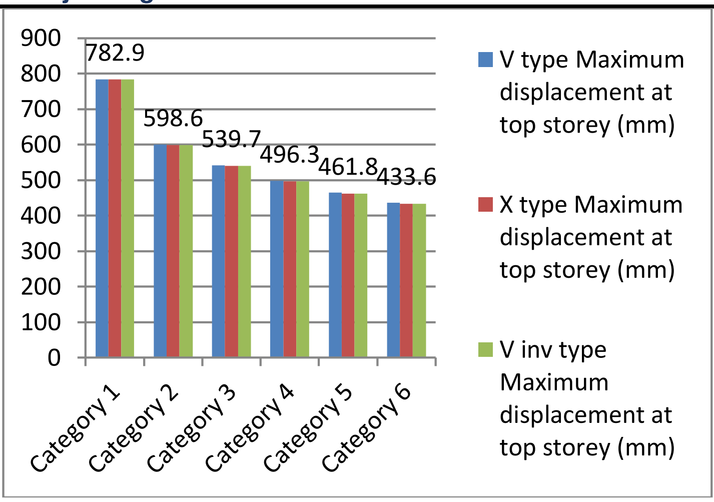


Lateral displacement for X type outrigger and belt truss system



Lateral displacement for V inv type outrigger and belt truss system





Displacement results

4.2 Storey drift results:

Table 4.4: Maximum storey drift

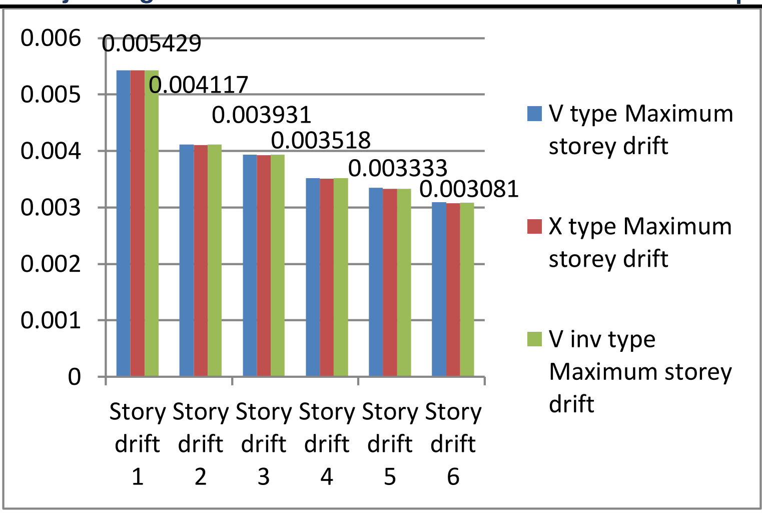
Model No.	V type storey drift at 30th Story	Percentage reduction (%)
Model 1	0.00538	-
Model 2	0.003602	24.16%
Model 5	0.00393	27.44%
Model 8	0.00316	35.23%
Model 11	0.003345	38.38%
Model 14	0.00281	43.04%

Table 4.5: Maximum storey drift

Model No.	X type storey drift at 30th Story	Percentage reduction (%)
Model 1	0.00538	-
Model 2	0.003585	24.40%
Model 5	0.00396	27.68%
Model 8	0.00313	35.32%
Model 11	0.003329	38.68%
Model 14	0.00275	43.34%

Table 4.6: Maximum storey drift

Model No.	V inv storey drift at 30th Story	Percentage reduction (%)
Model 1	0.00538	-
Model 2	0.003594	24.40%
Model 5	0.00391	27.59%
Model 8	0.00315	35.19%
Model 11	0.003333	38.86%
Model 14	0.0028	43.32%



Storey drift results

4.3 Base shear:

Base shear is the maximum expected lateral force that will occur due to earthquake ground motion at the base of a building structure almost same on every building.

5.0 CONCLUSION

1. The seismic behavior of G+60 storey building with outrigger and belt truss system shows reduction in responses such as lateral displacement, storey drift, base shear and is in good agreement with the literature study.
2. From analysis of the G+60 storey building provided with the outrigger and belt truss systems using X, V, and V inv type bracing, it is observed that X type bracings are more effective than V and V inv type bracings as are giving minimum displacement and drift values.
3. In the analysis of the G+60 storey building, provided with outrigger and belt truss system with X type bracings, the lateral displacement and maximum storey drift gets reduced by 44.61 % and 43.34% respectively compared to the values obtained from the analysis of conventional frame type building.
4. But as we compare the result of all type of bracing and belt truss, V inv is convenient than the X bracing and belt truss, because the value of lateral displacement, story drift obtained by V inv bracing and belt truss is 44.55 % and 43.32% which is similar to the X bracing and belt truss
5. As X bracing has more connection between them as compared to V inv bracing, even the X bracing is only connected to the column but V inv bracing is connected to column and beam so that beam get's the supported.

6. The effective numbers of outriggers and belt truss in the structure for safety were observed as 4, 5, 6.

6.0 ACKNOWLEDGEMENT

It gives us great pleasure that we completed our project work in the stipulated time frame. The project, which is the part of our bachelor of civil engineering, syllabus, gives us some anxious as well as very exhilarator experience throughout its period. The project we selected is “Seismic Analysis of Outrigger Braced Systems in High Rise Building”.

The success of any project is never limited to the individual undertaking the projects. It is collective efforts of the people around, that spell success. This acknowledgement is a humble attempt of earnestly thanking all those who were directly or indirectly involved in our project. The desired to have best and get closer to perfection has made us to try to achieve the perfection.

Ability and ambition is not for success. Success of any project depends solely on support, guidance, encouragement received from the guides and parent's well wishes. We would like to express our sincere gratitude to our honorable Principal, Dr. Ashok S. Kasnale for his constant support and encouragement.

We would like extend our sincere, heartfelt gratitude to our Head of Department, Dr. Nagesh L. Shelke and our internal project guide Prof. Manoj U. Deosarkar. Under Whose Guidance we had the privileged of doing this work and whose constant inspiration at all faces of the project, lead to our successful completion of work.

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