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# Performance Analysis of Outriggers System in Triple Towers Coupled with Cantilever Meeting at Point

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## Abstract:

Tall building development has been rapidly increasing worldwide introducing new challenges. As the height of the building increases, the stiffness of the building reduces. The Outrigger and Belt trussed system is the one of the lateral load resisting systems that can provide significant drift control for tall buildings. Thus, to improve the performance of the building under seismic loading, this system can prove to be very effective. The outrigger and belt truss system is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure. The objective of this paper is to study, the performance of outrigger structural system in triple towers coupled with cantilever meeting at center and to compare the vertical and horizontal displacement of nodes at extreme ends with the rigid jointed structure of same plan and elevation. The structure is analyzed and designed using staad.pro v8i software.an (G+9) Irregular structure is assumed for analysis and the material used for the purpose of analysis is steel.

*Keywords* **—out rigger and belt trussed bracing, rigid joint, triple towers etc.**

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## I. INTRODUCTION

In the past years, structural members were assumed to carry primarily the gravity loads. Today, however, by the advances in structural design/systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake. Specifically for the tall buildings, as the slenderness, and flexibility increases, buildings are severely affected from the lateral loads resulting from wind and earthquake. Hence, it becomes more necessary to identify the proper structural system for resisting the lateral loads depending upon the height of the building. There are many structural systems that can be used for the lateral resistance of tall buildings.in this study

Structural systems for tall buildings are a. Rigid frame systems, b. Braced frame and shear-walled frame systems, c. Braced frame systems, d. Shear-walled frame systems, e. Outrigger systems, f. Framed-tube systems, g. Braced-tube systems, h. Bundled-tube systems. For the purpose of this study

1.rigid frame system and

2. Outrigger systems are considered

### 1.Rigid frame system

The use of portal frames, which consist of an assemblage of beams and columns, is one of the very popular types of bracing systems used in building design because of minimal obstruction to architectural layout created by this system. Rigid frames are most efficient for low rise to mid-rise buildings that are not excessively slender. To attain maximum frame action, the connections of beam to columns are required to be rigid. Rigid connections, are those with sufficient stiffness to hold the angles between members virtually unchanged under load. It gets strength and stiffness from the no deformability of joints at the intersections of beams and columns, allowing the beam, in reality, to develop end moments which are about 90 to 95 percent of the fully fixed condition. Rigid frames generally consist of a rectangular grid of horizontal beams and vertical columns connected in the same plane by means of rigid connections. Because of the continuity of members at the connections, the rigid frame resists lateral loads primarily through flexure of beams and columns.

The rigid frame can prove to be quite expensive. Resisting the lateral loads through bending of the columns exhibits inefficiency in the system and requires more material than would another structural system. Rigid frames also require labour-intensive moment resisting connections. Limited field welding is desirable by using bolted connections where possible; however, achieving full rigidity of a connection with bolts only is nearly impossible

## 2. Outrigger system

The outrigger and belt truss system is used in high rise structures to resist the lateral loads like wind and earthquake loads in which the external columns in the structure are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the external columns of building while the outriggers engage them with main or central shear wall. The outrigger and belt truss system is mostly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure.

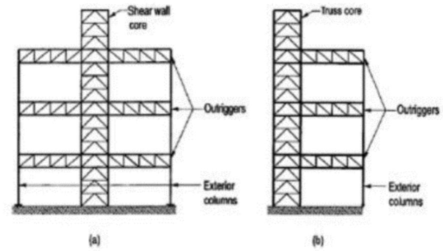


Fig: outrigger bracing

### 2.1 Load transfer

In a high rise structure, an outrigger system connects a central core lateral system to external columns through horizontal trusses or girders. These horizontal elements leads windward external columns in tension and leeward columns in compression (Figure 1).

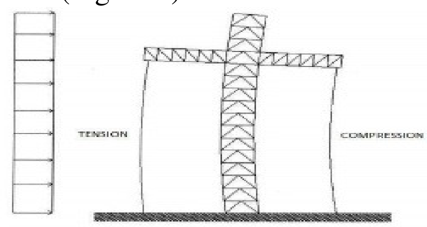


**Figure 1.2***:* Tension compression couple

Due to this coupling action bending moment is reduced in the core, leading to reduced story drift while gravity columns can typically handle this increased compressive loading, tension capacity should always be verified

## II. BUILDING DESCRIPTION

For the analytical purpose a ten storied (G+9) high-rise irregular steel towers coupled with cantilever meeting at center. The storey height of each floor was taken as 5.5 while at 7$^{th}$ floor 15 m cantilever portion is extended in each towers to carry the central hexagonal portion. The structure was assumed to be located in Bengaluru with Basic wind speed 33m/s.

**Table 4.2** Building General details

| | |
|---|---|
| ***A.*** Cantilever Dimension | 15m*15m |
| ***B.*** Tower Dimension | 15m*55m |
| ***C.*** Storey Height | 5.5m |
| ***D.*** Seismic Zone | 2 |
| ***E.*** Soil Type | Medium |
| ***F.*** Response Reduction Factor | 4 |
| ***G.*** Structure Type | Steel Building |
| ***H.*** Damping Ratio | 2% |

| | |
|---|---|
| ***I.*** Importance Factor | 1 |
| ***J.*** Steel Grade | Fe 250 |
| ***K.*** Steel's Elastic Modulus | $2.1 * 10^6$kN/m² |
| ***L.*** Steel's Poisson's Ratio | 0.3 |
| ***M.*** Steel Density | 76.819kN/m³ |
| ***N.*** Concrete Density | 25kN/m³ |
| ***O.*** Concrete's Elastic Modulus | 27386*10³kN/m² |
| ***P.*** Concrete's Poisson's Ratio | 0.2 |

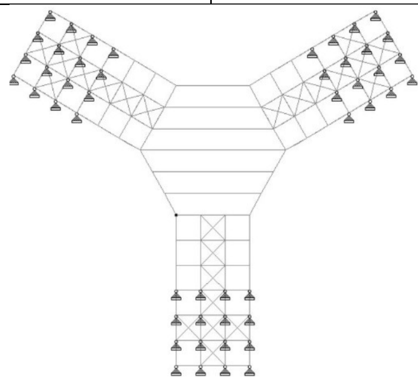

FIG.3 PLAN OF THE STRUCTURE

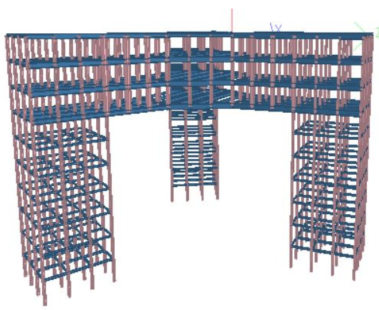

FIG.4 RIGID JOINT FRAME

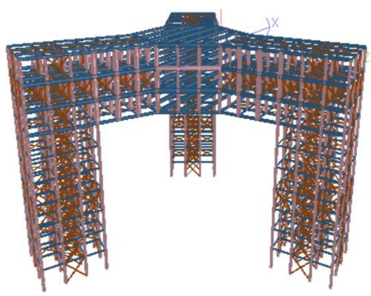

Fig 5 outrigger bracing system frame

## III. RESULTS AND DISCISSIONS

### 3.1 Comparison in horizontal displacement

Displacements at extreme nodes of the tower are considered for the comparison of horizontal displacement in both towers. The corresponding horizontal displacements at extreme nodes of structure at top are given in below table7.1 and 7.2 in x and z direction. We can observe from the tables given below that the horizontal displacement in model without any bracing is approximately 76% more than the structure with outrigger bracing system. Form the observed results we can say that

Bracings have significant role in reducing the effects of horizontal loads like earthquake load and seismic load.

**Table .2**Horizontal Displacements in x direction

| NODE | Displacements in Model 1 (in mm) | Displacements in Model 2 (in mm) |
|---|---|---|
| 19 | 122.052 | 21 |
| 20 | 91.813 | 18.994 |
| 43 | 122.150 | 17.470 |
| 44 | 91.882 | 14.690 |
| 83 | 56.180 | 12.339 |
| 86 | 56.180 | 12.305 |

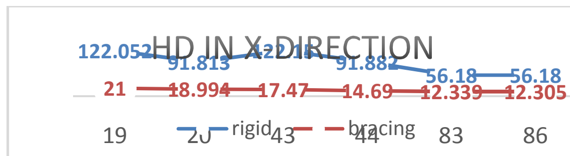


Fig:6Horizontal Displacements in x direction

**Table.3** Horizontal Displacements in z direction

| NODE | Displacements in Model 1 (in mm) | Displacements in Model 2 (in mm) |
|---|---|---|
| 19 | 144.832 | 24.335 |
| 20 | 145.039 | 24.503 |
| 43 | 145.558 | 26.979 |
| 44 | 145.601 | 28.127 |
| 83 | 121.420 | 24.510 |
| 86 | 120.209 | 23.952 |

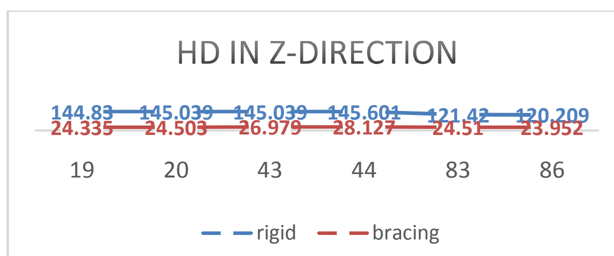


Fig:7 Horizontal Displacements in z direction

### 3.2 Comparison in vertical displacement

Extreme nodes, with the maximum displacement, in the central hexagonal portion are considered for the comparison of vertical displacement in model one without bracing system and one with outrigger bracing system. Results obtained from the analysis of both models are given in table 7.5.

Vertical displacement in the model without bracing system is 12% less than the model without rigger bracing system due to rigid joints provided in the model 1

**Table 7.5** Vertical Displacements

| node | Displacements in Model 1 (in mm) | Displacements in Model 2 (in mm) |
|---|---|---|
| 319 | 55.750 | 63.341 |
| 322 | 55.627 | 63.302 |
| 325 | 72.690 | 68.836 |
| 328 | 62.763 | 55.556 |
| 331 | 63.336 | 55.515 |
| 334 | 73.049 | 68.885 |

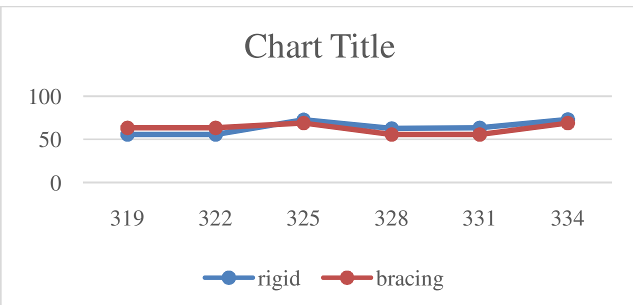


Fig: Vertical Displacements

### 3.3 Comparison in Steel take-off

Steel take-off is the quantity of steel required for the building, drawn by the means of material properties assigned in the model

Steel used in model one without any bracing =4049078.418 kg

Steel used in model two with outrigger bracing system =2573274.749kg

From the above observation we can observe that steel used in model without any bracing system is more 36% more than the steel used in the model with outrigger bracing system. Steel used in model one can be reduced.

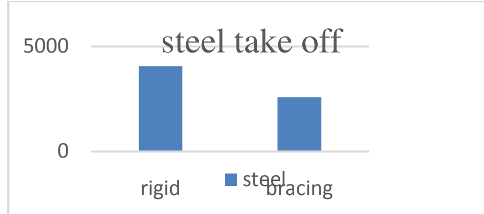


**Fig:** steel take off

## IV. CONCLUSIONS

Points concluded by the study as follows

1. Model, provided with the outriggers was found to be effective in all aspects: Steel take-off, vertical displacement and horizontal displacement.
2. In terms of Steel take-off, model 1 requires 36% more steel than the model with outrigger system in terms of economy using outrigger system is beneficial
3. The percentage increase in steel usage of Model 2, when compared with Model 1, would have been still more, if there was no suppression of the forces by the adjacent tower.
4. In terms of horizontal displacement, Model 1 showed upto70% more displacement, when compared with Model 2 in both z and x direction

In terms of vertical displacement, Model 1 showed and up to 12% less displacement, when compared with Model 2 due to rigid jointed nature

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