

A STUDY ON OUTRIGGER & BELT STRUCTURAL SYSTEM AND ITS EFFECTS ON STRUCTURAL RESPONSE OF TALL BUILDINGS

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Abstract— Ever since the evolution of humankind, they were fond to build structures such as monuments, sculptures, buildings, palaces that are bigger than ever. It was a matter of pride to build such structures to their community or tribe.

Even today, we are continuing to build taller and bigger structures to meet the human needs. However, as everything has certain limitations, building such structures, especially taller structures also has certain limitations such as Elevator technology, Construction difficulties, Natural conditions, etc.

From Structural Engineering point of view, the challenges to build such taller and taller structures are Wind and Seismic forces. On taller structures, the Lateral forces (Wind and Seismic) become predominant when compared to Gravity loads, because of which the building will be subjected to sway/lateral displacement, the result of which could be catastrophic.

Many Structural systems were invented to cater sufficient stiffness to the building such that the sway/lateral displacement can be minimized. One such system is “Outrigger & Belt Structural system”.

Keywords— Outrigger & Belt Structural system, Tall buildings, Lateral load resisting system, Structural systems.

I. INTRODUCTION

By name itself Outrigger means to rig something out side. In buildings, the core is connected to the outer periphery columns by means of extremely stiff wall or truss which is named as “Outrigger”.

The structural arrangement of this system consists of main core of the building which is connected to outer columns by relatively stiff horizontal members as a one or two storey deep walls which are referred as “Outriggers”.

The core may be centrally located in the building and the outriggers will extend on both the sides of the core. The core may also be located at the corner of the building and the outriggers extending to the other end of the building.

The outriggers and the core function together to reduce the lateral displacement of the building.

II. OUTRIGGER & BELT STRUCTURAL SYSTEMS

As shown in figure, the core is connected to the exterior columns by Outriggers then a deep wall again connects these peripheral columns as stiff as an outrigger wall called “Belt”. This belt wall behaves as though the peripheral columns are tied together.

This system with outrigger wall and belt wall function together to give the response of the building. This system is referred as “Outrigger and Belt Structural System”.

Figure below shows the general arrangement of Outrigger and Belt system.

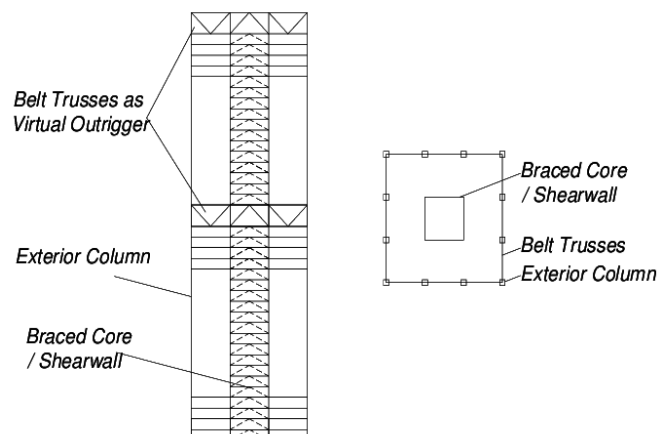


Fig. 1 Arrangement of Outrigger & Belt Structural system

The basic structural response of this system is quite simple. When the building is subjected to lateral loads, the column-restrained outriggers resist the rotation of the core, thereby causing the lateral deflections and moment in the core to be smaller than that of the system having the freestanding core alone resisting the lateral loads.

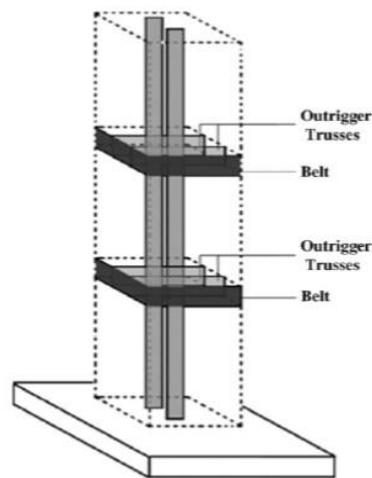


Fig. 2 Figure showing Outrigger & Belt Structural system

A lot of research has been done on this structural system such as finding an optimum location of the outrigger in the building, finding no of outriggers required, what should be the size of the outrigger, etc.

In this paper, the effect of structural response of tall building due to location and no of outriggers is studied. It is also studied how the outrigger will affect the structural designs of the building components.

III. EXPERIMENT

The experiment to study the effects of an Outrigger & Belt structural system is as follows:

A. AIM:

To Study the effects of an Outrigger & Belt Structural System on the response of the Tall building.

B. METHODOLOGY:

Models of tall buildings will be built in “ETabs” to conduct and interpret the results of the experiment.

C. PROCEDURE:

1. Firstly a 2D frame of building will be modelled having different structural systems such as
 - a) Moment resisting frame system.
 - b) Moment resisting frame with shear walls.
 - c) Moment resisting frame with shear walls and outrigger at different floors of the building.
2. By studying the response of the above models, we can derive
An optimum location in a building where the outrigger is most efficient.
Response in the forces and moments in the building frame.
3. After studying the 2D frame, the responses of the building frame is listed in the conclusion.

D. Models:

The models studied are as shown below:

1. Moment resisting frame system:

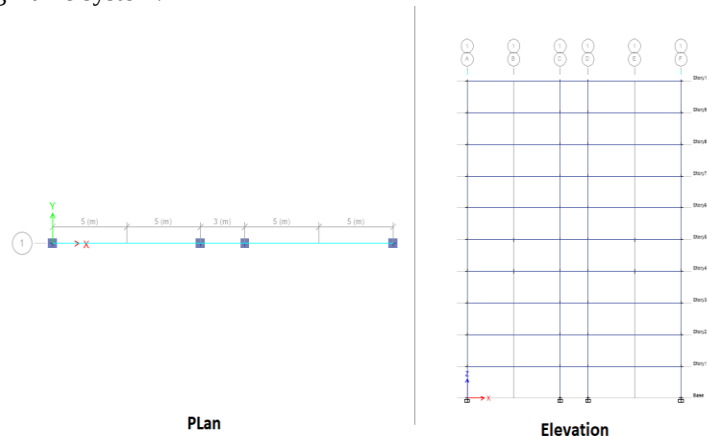


Fig. 3 Model of Frame system

2. Moment resisting frame with shear walls:

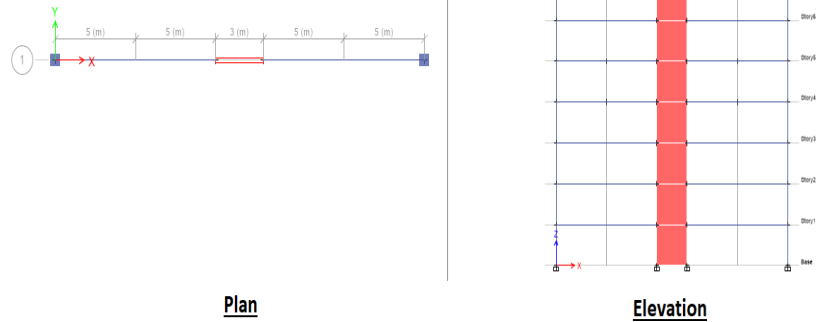


Fig. 4 Model of Frame with Shear wall

3. Moment resisting frame with shear walls and outrigger at different floors of the building.
For Ex: on 10th & 5th Storey is shown:

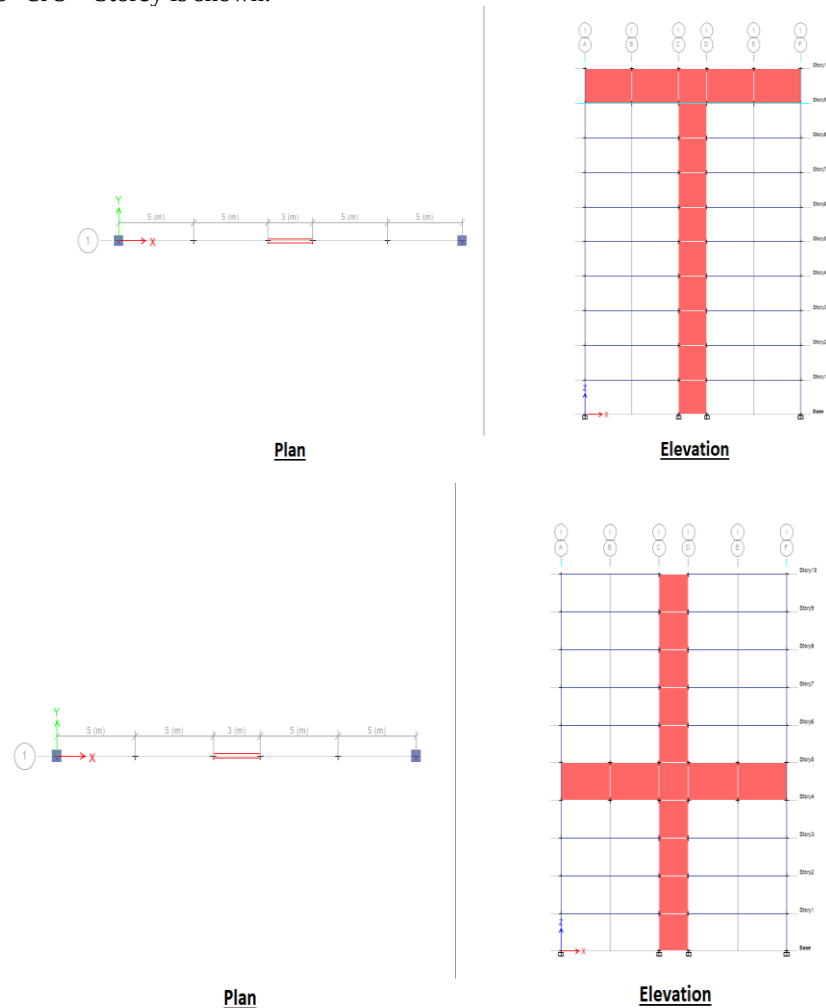


Fig. 5 Model of Frame with Shear wall and Outrigger on 10th & 5th storey

E. Loading:

The models are subjected to arbitrary loads to study the behaviour of the models. The loading considered is as shown below:

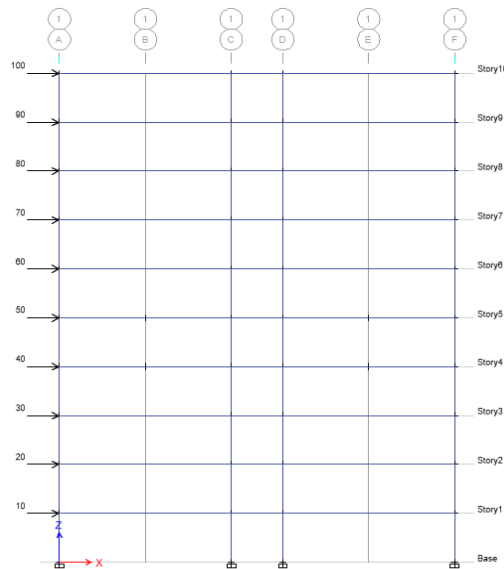


Fig. 6 Loading diagram

IV. RESULTS

The analysis is carried out on the models and the results are studied. The Lateral displacement, Axial forces, Bending moments, Shear forces, Shell stresses are studied as a result of this study.

1. Lateral Displacement:

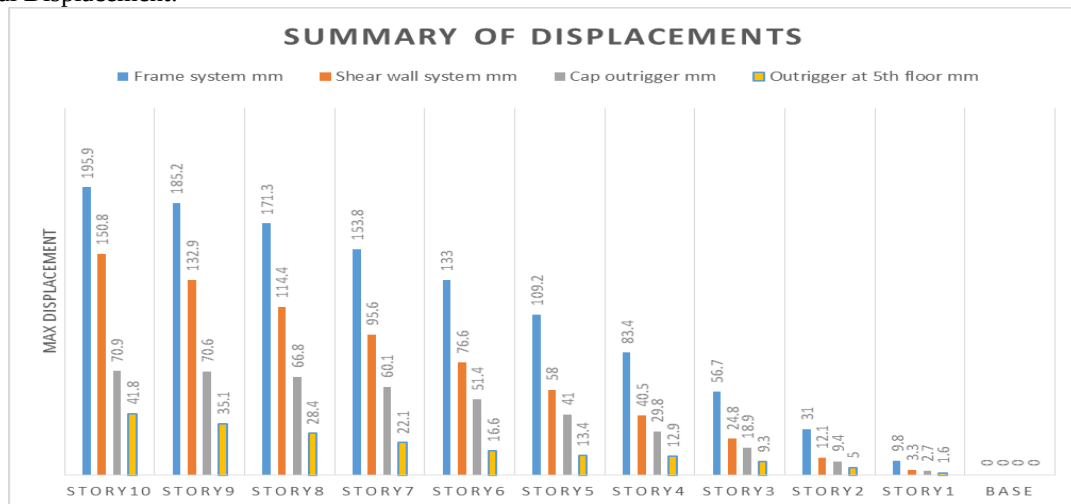


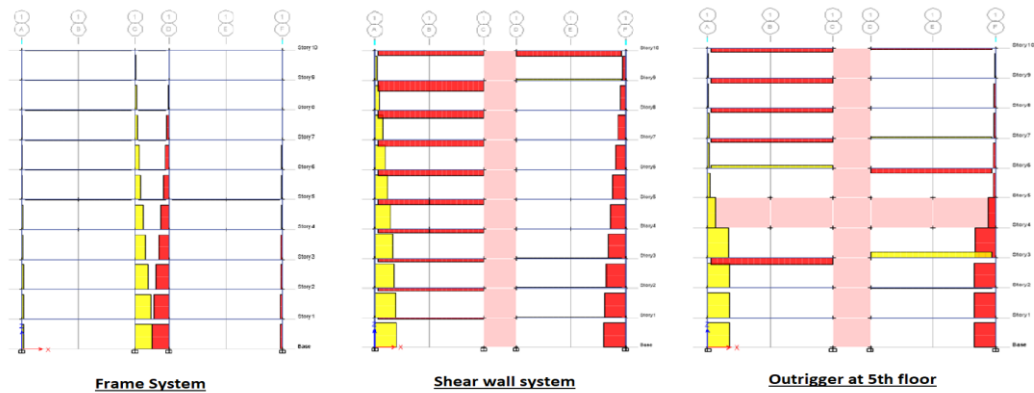
TABLE I
LATERAL DISPLACEMENT AT DIFFERENT FLOORS (IN MM)

				Outrigger at various floors									
Story	Elevation	Frame	Shear wall	10	9	8	7	6	5	4	3	2	1
		X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir	X-Dir
		m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Story10	30	195.9	150.8	70.9	57.3	46.5	39.2	37.3	41.8	53.4	72	96	121.8
Story9	27	185.2	132.9	70.6	55.9	44.2	36.2	32.6	35.1	44.4	60.5	82.1	105.9
Story8	24	171.3	114.4	66.8	55.6	42.6	33	28	28.4	35.2	48.8	67.9	89.4
Story7	21	153.8	95.6	60.1	51.8	42.2	30.8	23.7	22.1	26.4	37.2	53.6	72.8
Story6	18	133	76.6	51.4	45.2	38.3	30.4	21	16.6	18.4	26.1	39.6	56.2
Story5	15	109.2	58	41	36.8	31.9	26.5	20.6	13.4	11.7	16.4	26.6	40.3
Story4	12	83.4	40.5	29.8	27.2	24.1	20.5	16.7	12.9	7.9	8.6	15.3	25.8
Story3	9	56.7	24.8	18.9	17.5	15.8	13.8	11.5	9.3	7.5	4.4	6.7	13.5
Story2	6	31	12.1	9.4	8.8	8.1	7.2	6.2	5	4.3	4	2.2	4.6
Story1	3	9.8	3.3	2.7	2.5	2.3	2.1	1.9	1.6	1.3	1.4	1.8	0.5
Base	0	0	0	0	0	0	0	0	0	0	0	0	0.4

It can be seen that when an outrigger is placed at 5th, 6th, & 7th floor, the lateral displacement of the building is reduced significantly.

From overall results at every storey of the building, it can be seen that when an outrigger is placed at 5th floor, the building is having significantly less lateral displacement and the forces within the beams and columns are reduced significantly.

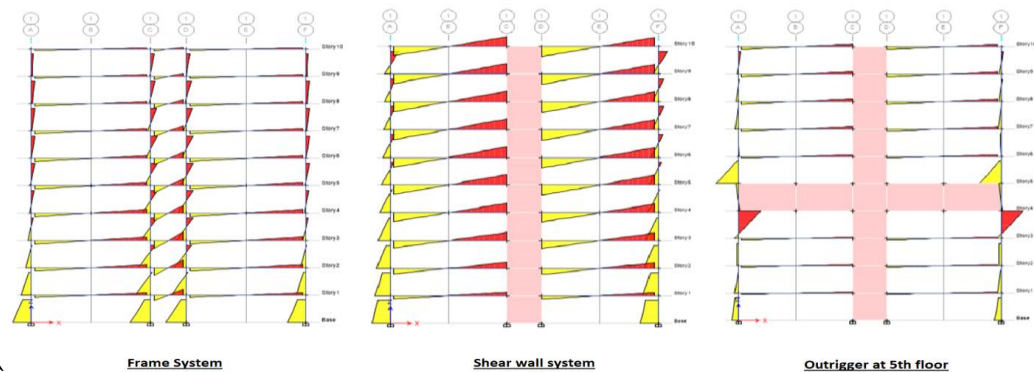
2. Axial Forces:



From the comparison above, it can be clearly seen that when an Outrigger is used, the axial forces within the columns above the outrigger are reduced significantly. Whereas the Frame system and Shear wall system gives moderate axial forces, the lateral displacements are very high in them.

Therefore, the outrigger system is giving less Axial forces thereby reducing the construction cost by reducing the column sizes.

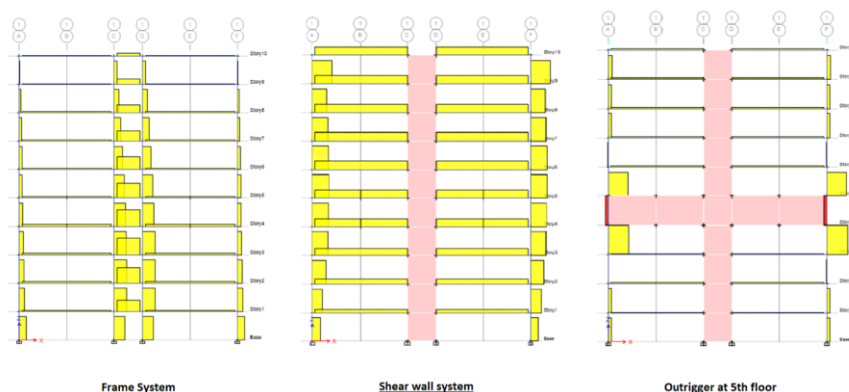
3. Bending Moments:



From the comparison above, it can be clearly seen that when an Outrigger is used, the bending moments within the beams are reduced significantly. Whereas the Frame system gives moderate bending moments, and Shear wall system is giving high bending moments when compared to other two systems.

Therefore, the outrigger system is giving less bending moments thereby reducing the construction cost by reducing the beam sizes.

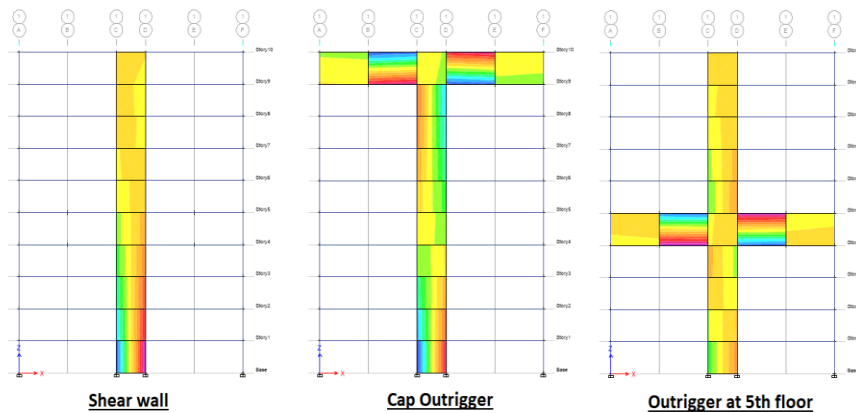
4. Shear Forces:



From the comparison above, it can be clearly seen that when an Outrigger is used, the shear forces within the beams are reduced significantly. Whereas the Frame system gives moderate shear forces, and Shear wall system is giving high shear forces when compared to other two systems.

Therefore, the outrigger system is giving less shear forces thereby reducing the construction cost by reducing the beam sizes.

5. Shear Stresses:



From the comparison above, it can be clearly seen that when an Outrigger is placed in the building, the shell stresses in the shear walls show complicated stress pattern, which has to be taken care while designing them.

In the frame with shear wall, we can see tension (blue) at the windward side and compression (red) on the leeward side at the base, whereas in the model with an outrigger the stresses reverse the stress pattern near the junction of outrigger and shear wall. This reversal of stresses creates an anti-clockwise moment within the shear wall thereby reducing the displacements, forces and moments within the building.

V. ADVANTAGES & DISADVANTAGES

A. ADVANTAGES:

The advantages of having an Outrigger being placed in the building structural systems are:

1. Due to the reduction of **“Max displacement”** of the building, we can be able to build **“Taller structures”** as there will not be any constraints due to the lateral sway of the building.
2. Due to the reduction of the **“Axial forces in the columns”**,
 - a. We can **reduce the Column sizes** thereby reducing the construction cost.
 - b. The reduction in column sizes can lead to **more sellable carpet area** for the commercial purpose, thereby we can have more area to be given for lease.
3. Due to the huge reduction of **“Bending moments & Shear forces in the Beams & Columns”**, we can save the construction materials thereby reducing the construction cost.

B. DISADVANTAGES:

The disadvantages of having an Outrigger being placed in the building structural systems are:

1. The **“Mid height of the building is an optimum location”** for an outrigger to be placed in a building, but the Architect may not allow a Structural Engineer to place the outrigger as per the structural requirement because of the functional uses and aesthetics.
Solution: The solution to this problem is to provide opening in the outrigger just like an Vierendeel girder or truss.
2. The **“Stresses within the Shear wall and Outrigger shows unusual pattern”** which creates a chaos during the design process. Special considerations to be taken while designing the Shear wall and Outriggers.

VI. CONCLUSION

From the results obtained, it can be concluded that when an Outriggers is adopted as buildings structural system,

1. The **“Max displacement”** of the building can be reduced by placing an Outrigger system into the building.
2. The **“Axial forces in the columns”** above the floors where an outrigger is placed is reduced.
3. There is a huge reduction of **“Bending moments & Shear forces in the Beams & Columns”**.
4. The **“Stresses within the Shear wall and Outrigger shows unusual pattern”** which has to be taken care in during the design process.
5. The **“Mid height of the building is an optimum location”** for an outrigger to be placed in a building.

Hence, the Outrigger and Belt structural system can be efficiently used to reduce the displacement and forces in structural elements of the building due to lateral loads.

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