STATIC ANALYSIS AND OPTIMIZATION OF OUTRIGGERS IN A TALL BUILDING

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Abstract - As the building goes taller stiffness and stability becomes important factor in the design. Outriggers are often used to give lateral stiffness to tall and slender buildings. But the floor space occupied by these flexurally stiff and deeper beams is large. In this paper, an attempt has been made to optimize outriggers provided in a building and to increase its lateral stability by including other structural elements. Different types of floor systems and belt truss are added to the structure and their effects towards lateral responses are found out. A 40-storey tall building has been modeled in Etabs-2015 and analyzed under static wind and earthquake loads. The key parameters discussed in this paper include lateral displacement at the top and inter-storey drift ratio.

Key Words: outriggers, flexural rigidity, slab stiffness, belt truss

1. INTRODUCTION

Due to increase in urbanization and scarcity of available land, buildings have started moving skywards. The tall buildings are the solution where more people can be accommodated on less land space. But as the building becomes taller, additional lateral forces starts acting on them and serviceability requirements governs the design. For a tall building, lateral drift and building acceleration at the top should be analyzed and kept within the limits specified on codes.

1.1 Outrigger

Outriggers are the horizontal members which resists lateral loads by mobilizing axial stiffness of perimeter column by connecting them to the core of the structure. When lateral loads acts on the structure, column restrained outriggers resists the rotation by inducing tension force on windward columns and compression force on leeward columns thereby generating a restoring tension-compression couple to resist core overturning moment and lateral deflection. This system can work efficiently for buildings upto 150 stories [1].

1.2 Challenges Associated with Outriggers

- Outriggers occupying large vertical space upto 2-3 stories deep interferes with floor area in a building and restricts space utilization on these floors.
- Outriggers connecting core and distant columns undergo additional stress due to differential vertical shortening between them.
- The connections between core and outriggers needs to be properly studied and designed especially when the two are made up of different materials.

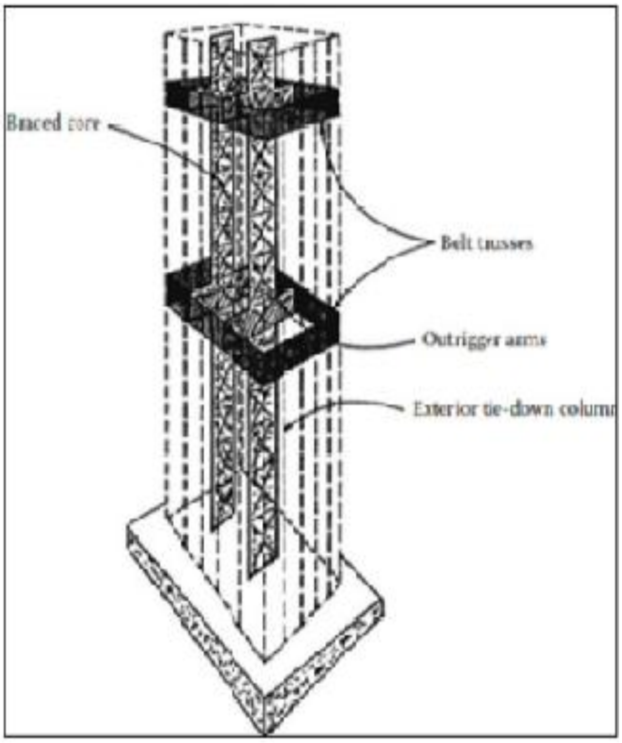

Fig -1: “Outrigger system”

2. METHODOLOGY

A structure with two outriggers is analyzed and then a single outrigger system with slabs and belt truss is found out which will be equivalent to two-outrigger system in its lateral stiffness. In this manner, multiple outrigger system can be reduced to single outrigger and its disadvantage of occupying large space can be avoided

3. MODEL DETAILS

- Plan dimension : 27X24 m
- Typical storey height : 3.5m
- No. of storey : 40
- Beam Details
  Breadth – 230mm
  Depth – 500mm
- Column Details
  Breadth – 750mm
  Depth -750mm
- Concrete Grade : M-40
- Steel Grade : Fe-250
- Wind load (IS 875(Part-3)-1987)
  Design speed – 44m/s
  Terrain Category – 2
  Structural Class – B
- Seismic load (IS 1893(Part-1):2002)
  Zone 3 – 0.16
  Importance factor – 1.5
  Soil type – Medium
  Reduction factor – 3

Following Different Models Have Been Prepared

Case1: Two-Outrigger system with

- Core and Outriggers -300mm thick
- Outriggers placed at ⅓rd and ⅔rd height of the building i.e at 13th and 26th floor according to Taranath thumb rule[2] (Fig. 1&2)

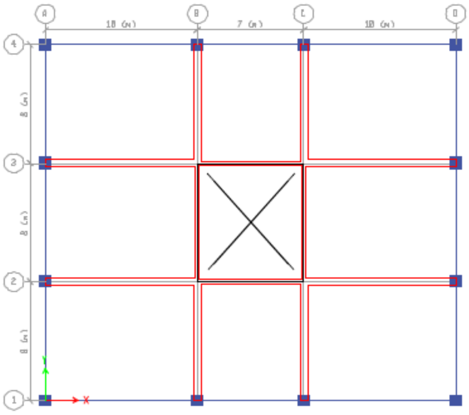

Fig -1: Plan

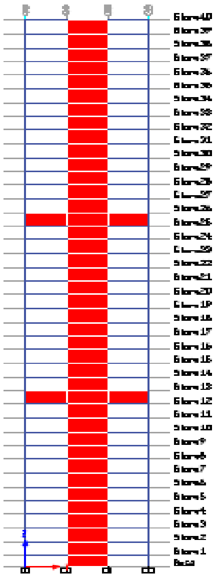

Fig -2: Elevation

Case2: Single outrigger system with

- Core -300mm thick
- Variation of relative flexural rigidity between outrigger and core (γ) = (EI)o/(EI)core and location of the outrigger in the above same plan and elevation (Fig -1&2).

(γ)	
0.25	The location of outrigger (H_s/H) is varied as 0.25,0.5,0.75,1 for each value of (γ).
0.5	
0.75	
1	
1.25	

Case 3 : Following Floor systems are added

1) Single-outrigger system with composite deck slab (Fig -3).

   - Light-weight concrete of 70mm thickness over 80mm metal deck on all typical floors and 250mm regular weight concrete of M-25 grade on outrigger level

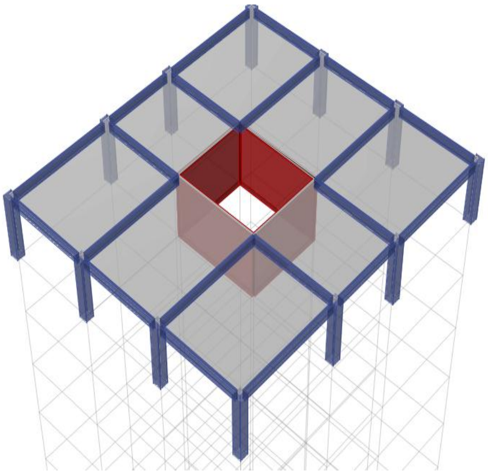

Fig -3 : Composite deck slab

2) Single–outrigger system with horizontal steel bracing (Fig -4).

- X-shaped horizontal steel bracing made up of hollow pipe sections of diameter 500mm and 30mm thickness is modeled on all typical floors

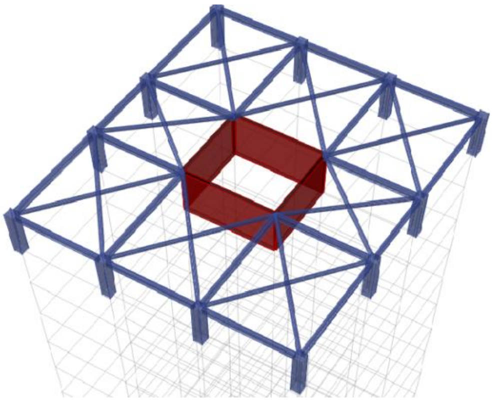

Fig -4: Horizontal steel bracing

Case4: Following belts truss are added (Fig 5&6)

- Single outrigger system with composite deck slab and X-shape belt truss
- Single outrigger system with composite deck slab and inverted V-shape belt truss

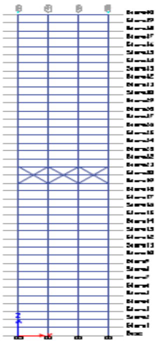

Fig -5 :Elevation showing X-shape belt truss

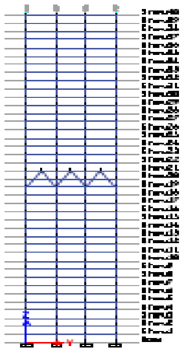

Fig -6: Elevation showing inverted V-shape belt truss

4. RESULTS AND DISCUSSION

For case 3, the effect on lateral deflection due to variation in flexural rigidity and location of the outrigger is obtained and shown in (Fig 7 &8).

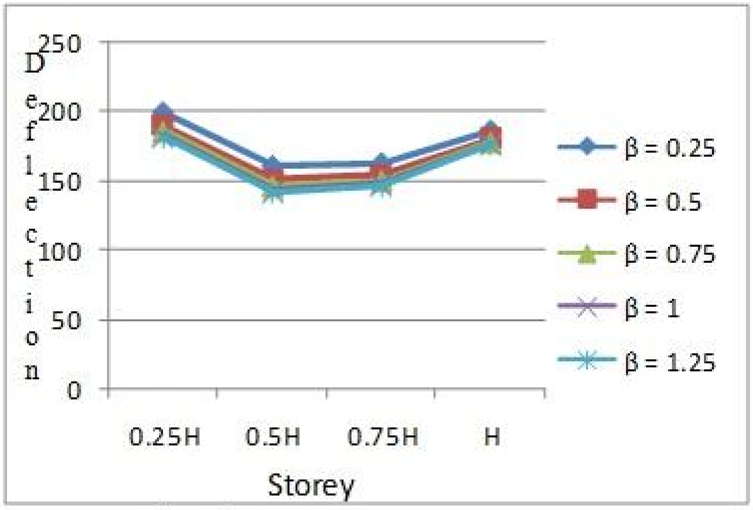

Fig -7: Variation of lateral deflection for wind load

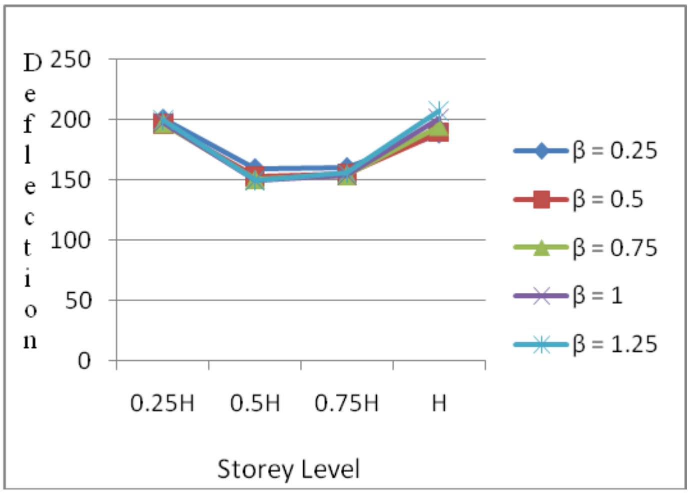

Fig -8: Variation of lateral deflection for seismic load

Fig-7 & Fig-8 indicates that deflection decreases by increasing outrigger rigidity. It is observed that the maximum reduction of 29% and 25% is obtained when outrigger is placed at mid-height of the building for wind and seismic case respectively. Top displacement gets reduced to 6.2% and 3.31% by varying 'γ' from 0.25 to 0.5 and 0.5 to 0.75 respectively. It is observed that any further increase in flexural rigidity has relatively less effect in reducing deflection. Hence an increase in relative flexural rigidity to 0.75 and locating single outrigger at 0.5H is taken as the most optimum condition.

For Case 3, effects of adding composite deck slabs and horizontal steel bracing to the lateral deflection is shown in Chart -1 and Chart -2

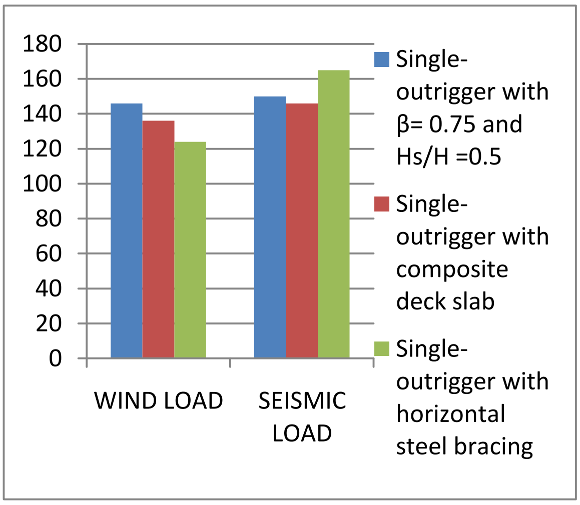

Chart -1: Lateral deflection due to wind and seismic load

It is noticed that including floor diaphragms reduces lateral deflection and makes the structure stiffer. A reduction upto 6.85% and 2.67% is gained by adding composite slabs for wind and seismic load respectively. Horizontal steel bracing reduces deflection due to winds to 15% but it increases to 10% for seismic case due to an increase in buildings overall weight.

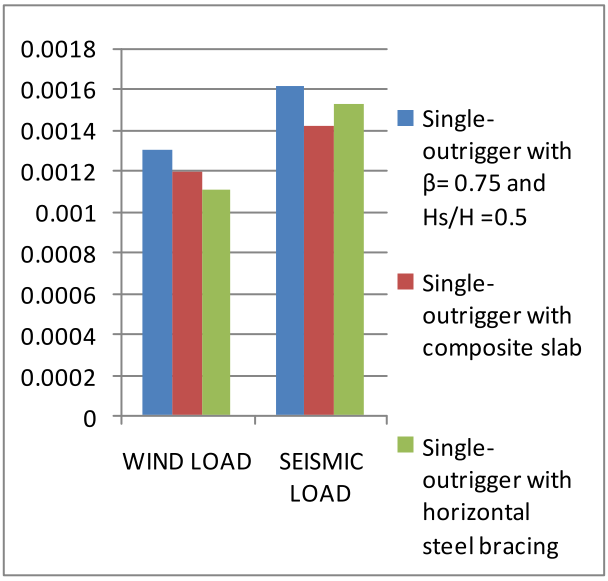

Chart -2 Storey drift due to wind and seismic load

A similar trend in the reduction of storey drift is also observed. A maximum reduction of 22.26% storey drift due to wind load and 12.15% due to seismic load is obtained.

For Case 4, results are found by adding belt truss and its effect on different parameters is shown in Chart -3 and Chart-4

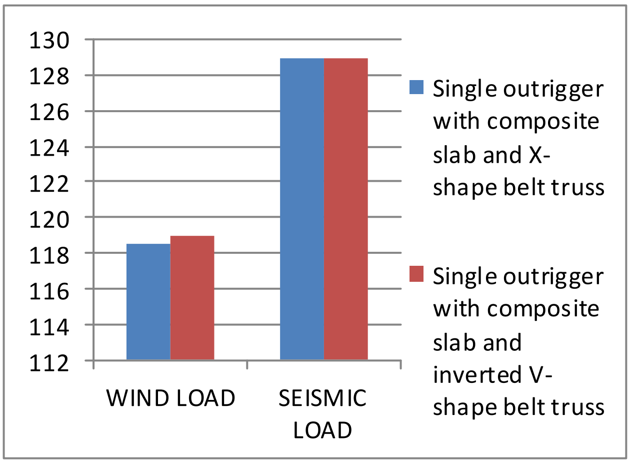

Chart -3: Lateral deflection due to wind and seismic load

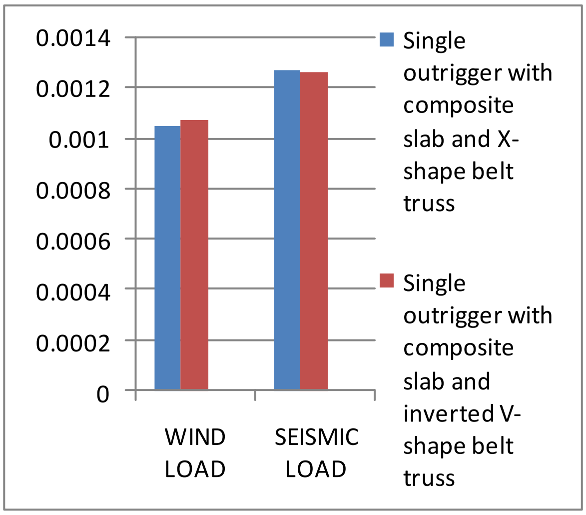

Chart -4: Storey drift due to wind and seismic load

A minor difference of 0.45% between performance of X and inverted V-shape towards lateral stiffness is observed . But it is clearly seen that X shape gives more stability to the structure compared to inverted V-shape.

Type of structure	Lateral Deflection (mm) due to wind load	Lateral Deflection (mm) due to seismic load
Two-outrigger system	126	131
Single-outrigger system	146	150
Single-outrigger system with composite deck slab	136	146
Single-outrigger system with composite deck slab and X-shape belt truss	118.47	128.9

Table-1: Comparison of lateral deflection for different structures

Type of structure	Storey Drift due to wind load	Storey Drift due to seismic load
Multi-outrigger system	0.001248	0.001321
Single-outrigger system	0.001298	0.001613
Single-outrigger system with composite deck slab	0.001194	0.001417
Single-outrigger system with composite deck slab and X-shape belt truss	0.001057	0.001273

Table -2: Comparison of storey drift for different structures

From Table-1 and Table 2, it can be seen that single outrigger system with slabs and belt truss is found to have equal lateral stiffness compared to the two outriggers system. Hence the optimization process adopted is found to be feasible and effective.

5. CONCLUSIONS

1) When lateral deflection is considered providing a single outrigger at mid height of a building is found to be the optimum location for both wind and seismic loads.

2) Floor diaphragms provided in the form of composite deck slab and horizontal steel bracing enhances building lateral behaviour.

3) The maximum reduction of 15% due to wind loads by horizontal steel bracing and 2.67% due to seismic loads by composite slabs is achieved.

4) Further increase in lateral stiffness is obtained by adding belt truss on outrigger floors . X-shaped is found to have performed better than inverted V-shape.

5) It is concluded that a two-outrigger structure can be replaced by single outrigger structure by adding slabs and belt truss and is found to be equivalent stiffer in resisting lateral loads. Hence this proves to be a good alternative solution to mitigate outrigger disadvantage of occupying more space in a building.

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