Ideal Location Of Outrigger System And Its Efficiency For Unsymmetrical Tall Buildings Under Lateral Loadings

V. Swamy Nadh, B. Hema Sumanth, K. Vasugi, and Manish.R. Shirwadkar

Abstract: Nowadays many techniques have been developed to make buildings taller and more efficient. Moreover, if unsymmetrical tall buildings are considered, the stability of structure plays a vital role and these are majorly effected by the lateral loads like wind and earthquake. In order to resist from lateral loads, different structural systems have been followed practically like bracing system, outrigger system, dia grid, hexa grid systems. This paper deals with the use of outrigger system for unsymmetrical tall building of 30 storey and its Comparision with the same building without outrigger system. This paper also emphases on determining the exact position of outrigger in tall buildings. Also, in the second case, keeping the height of the building same as that of the conventional building the floor areas are increased by reducing the number of interior columns with and without outrigger system and the stability is checked. The results reveal the ideal position of outrigger at top position and other at 0.5 times the height of the building. and with the use of outrigger system the displacement is reduced to 26.69% which improves the stiffness and efficiency of unsymmetrical building.

Index Terms: Lateral displacement, Outrigger system, Tall building, Ideal location, Lateral loads

1. INTRODUCTION

Mankind is always fascinated by evolution. If the height of the building is considered, it is going on increasing year after year. Moreover, in metro cities like Mumbai where there is a lack of places for development and also increasing demand for houses leads to one solution i.e. tall buildings [1]. From moment frame structures to modern ultra-efficient braced frame structures, the engineering profession has come a very long way. The structural analysis and design of the structure have become quite easy and more accurate due to development in software's and also advancement in finite element analysis cannot be ignored [2]. This advancement has helped us in designing innovative forms of modern architectural structures. As the height of the building goes on increasing, wind and seismic loads try to play their part. Due to the lateral loads produce by wind and seismic loads, the deflection of the building is increased and thus affecting the stability of the structure. In order to nullify this effect, the stiffness of the building must be increased. Thus, outriggers play a vital role in providing so. Due to the outrigger system stiffness of the building is increased and thus eventually reducing the lateral displacement. Hence outriggers can also be called as lateral load resisting systems.

1.1 Concept and Benefits of Outrigger System

Outriggers are mainly rigid horizontal structures which are designed to improve the efficiency of the building by providing stiffness for overturning and also a strength which is provided by connecting the building core to the exterior columns [3].Outrigger is frequently used in tall and narrow buildings.

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The main use of it is that they act as lateral load resisting system for tall buildings [4]. The behavior of the outrigger is simple as outriggers act as stiffeners which leads exterior columns to participate to resist tilt of the central core [5]. Due to outriggers restoration moment is created which prevents rotation of the building and thus reduces the displacement. Also, due to an increase in stiffness which outrigger systems provide, they are cost effective and very efficient solutions to reduce buildings acceleration [1]. Analyzing and designing outrigger system is not simple. It depends on the relative stiffness of each element and also the distribution of the forces between the outrigger system and the core [6]. It is very important to bring the structural elements together as a shear force in the core elements can also increase and change its actual direction at the story where outriggers are located due to horizontal force couple acting on the outriggers. This effect can be effectively reduced by the proper assembly of structural elements of the outrigger system and its proper position in the tall building [7]. The main benefits of providing outrigger systems are deformation reduction, increase in stiffness, efficiency and force reduction at foundation level.

2. EXPERIMENTAL INVESTIGATION

The building considered in the investigation is an unsymmetrical tall building of 30 storey. In the current study, a real time ongoing construction of residential building in Mumbai, India was compared with and without outrigger system. Also, the same building will be analyzed and designed with a reduction in interior column with the use of outrigger system and the results will be compared. As the consideration is made of a residential building the live load taken into account is of 2 kN/m. The floor load considered is of 1.5 kN/m which is applied on all slab panels of all floors. For all beams, a uniform distributive load of 5 kN/m is considered. This 5 kN/m consists of loads of the wall which are assumed to be made of lightweight bricks. As the design is done by IS standards, wind load in the present study is calculated by using IS 875 (Part 3-Wind loads). The location selected for the present study in Mumbai, therefore basic wind speed (V_b) in accordance with the code provision is V_b=44 m/s. The coefficients K_1 & K_2 are taken as 1. The terrain category and the class of the structure are 'Category 4' and 'Class C' respectively. Internal pressure coefficient is considered to be ±2 and the net pressure coefficient in windward direction are calculated as C_p = +0.8 and in the leeward direction as 0.5. It is calculated on l/w and h/w ratio. The above values are uploaded in ETABS software and K3 coefficient is directly evaluated by ETABS software and thus lateral wind loads are calculated at each storey. The worst condition is determined by applying the loads evaluated above in negative and positive X & Y axis. In accordance with IS1893 (part 1)-2002, the earthquake loads are established. As the city considered as the location is Mumbai, it falls in zone 3. Therefore, Z=0.16 the important factor of the building considered is 1.0. Hard and rocky site of Type 1 is assumed. 'R' representing the response reduction factor is taken as 3.0. Thus, the fundamental time period is calculated as

$$T_a = 0.075 \times h^{0.75}$$

The horizontal seismic coefficient (A_h) is calculated by ETABS software using the above data. The Ah value calculated by an appropriate response spectrum is thus used future to calculate the designed seismic base shear (V_b),

$$V_b = A_h \times W$$

The following expression is used to distribute the design seismic shear throughout the height of the structure,

$$Q_i = V_b \times (W_i \times h_i^2) \times (\sum W_i \times h_i^2)\text{-}1$$

The loading combinations considered to analysis the structure is according to IS: 456-2000 clause 36.4.1.

The load combinations for the present study are as follows: -

1.5D
1.5D + 1.5L
1.5D ± 1.5W
0.9D ± 1.5W
1.2D ± 1.2L ± 1.2W
1.5D ± 1.5E
0.9D ± 1.5E
1.2D + 1.2L ± 1.2E

The maximum lateral deflection of the building will be determined using the above combinations and the comparison will be evaluated.

2.1 Position of Outrigger System

Position of outriggers plays a vital role in reducing the lateral displacement of the building. Thus, in order to determine the probable best position of the outrigger, different positions of outriggers have been analyzed with different models and results have been evaluated. In the present study the different arrangements of outriggers analyzed using ETABS software are: -

Model S1: -Unsymmetrical tall building without outrigger system

Model S2: - Unsymmetrical tall building with one outrigger system on the top floor.

Model S3: - Unsymmetrical tall building with one outrigger system at the top floor and another at 0.75 times height of the building.

Model S4: - Unsymmetrical tall building with one outrigger system at the top floor and another at 0.50 times height of the building.

Model S5: - Unsymmetrical tall building with one outrigger system at the top floor and another at 0.25 times height of the building.

Model S6: - Unsymmetrical tall building with interior columns reduced with one outrigger system at the top floor and another at 0.50 times height of the building.

2.2 Model Details

The floor plan of the unsymmetrical building is as shown in the Fig.1. The plan view of outrigger system located at 0.5 times of the height, 0.75 times of the height, 0.25 times of the height of the building and at the top of the building for different position of outriggers is as shown in Fig. 2. The member properties use in outrigger system are I sections of 2-ISMB 500, 2-ISMB 350, angle section of 90 x 90 x 12 mm and channel section of ISMC 350 at a different location according to structural need. The section was selected by trial and error method.

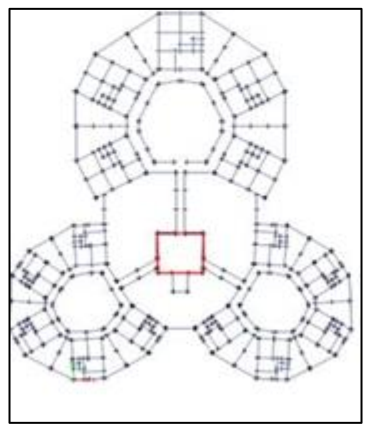

***Fig. 1**. Floor plan of Unsymmetrical Building without outrigger system*

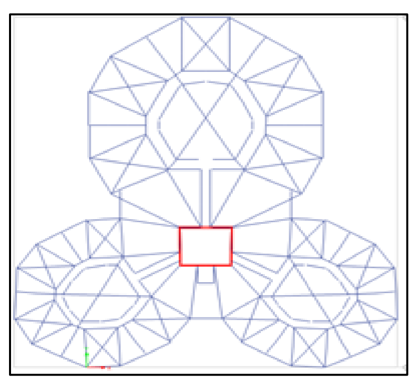

***Fig. 2.** Floor plan of unsymmetrical building with outrigger system*

3. RESULTS AND DISCUSSIONS

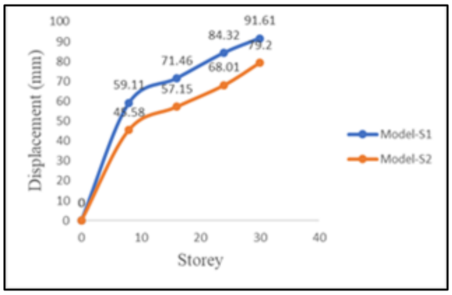

Fig. 3. *Comparision between model S1 and Model S2*

Fig.3 represents the comparison between unsymmetrical tall building without an outrigger system (S1) and unsymmetrical tall building with one outrigger system at the top floor (S2). The building with outrigger having 79.2 mm displacement at the 30th storey about 13.55% reduction in lateral displacement is observed. And Fig.4 indicates the comparison between unsymmetrical tall building without outrigger system (S1) and unsymmetrical tall building with one outrigger system at the top floor and another at 0.75 times height of the building (S3). The building having the maximum displacement at the 30th storey which is less than building with outrigger at the top floor about 17.49% reduction in lateral displacement.

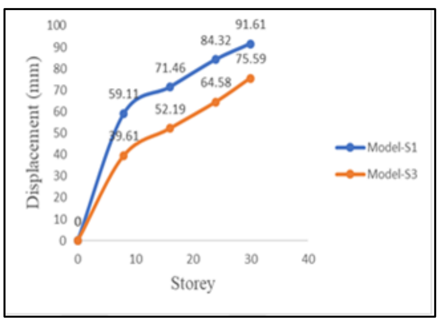

Fig. 4. *Comparision between model S1 and Model S3*

Fig.5 represents the Comparison between Unsymmetrical tall building without outrigger system (S1) and Unsymmetrical tall building with one outrigger system at the top floor and another at 0.50 times height of the building (S4). We can observe the gradual decrease in the displacement and it is about 26.69% reduction in lateral displacement and compare with outrigger at 0.75 times the height of the building (S3) it reduces the displacement about 8.43 %

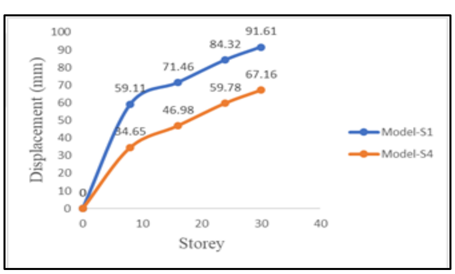

Fig. 5. *Comparision between model S1 and Model S4*

Figure-6 indicates the comparison between unsymmetrical tall building without outrigger system (S1) and unsymmetrical tall building with one outrigger system at the top floor and another at 0.25 times height of the building (S5). Again, we can observe the increase in the lateral displacement in the system with outrigger but when compared with the system without outrigger there is a reduction in the displacement of about 21.87%.

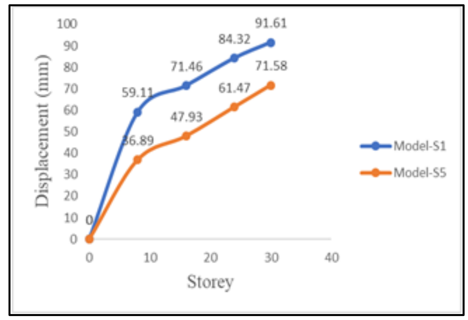

Fig. 6. *Comparision between model S1 and Model S5*

Figre-7 represents the comparison between the unsymmetrical building with an outrigger(S1) and Unsymmetrical tall building with interior columns reduced with one outrigger system(S6) at the top floor and another at 0.50 times height of the building and about 26.69% reduction in lateral displacement is observed.

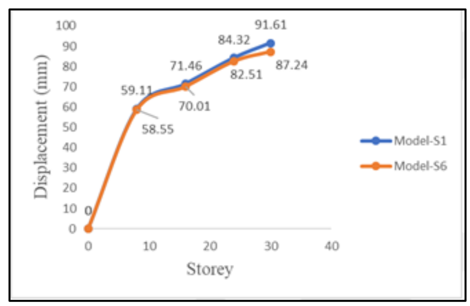

Fig. 7. *Comparision between Model S1 and Model S6*

4. CONCLUSIONS

Optimum location of outrigger places a vital role to resist the building against the lateral forces, so in the present study for real time structure constructing in Mumbai, India was taken into consideration for the wind and seismic analysis. From all the comparison made we can conclude that the best position of outrigger systems is one at the top and another at 0.50 times the height of the building and also, the results in graph 6 indicate that reduction in the interior columns can be made to some extent with the use of outrigger system. Lateral displacement can be reduced to about 26.69% with the use of outrigger system. Thus, the efficiency and stiffness of the building are improved with the use of outrigger system in an unsymmetrical tall building.

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