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Behavior of Outrigger Structural System for High-rise Building

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Abstract— As the height of the building increases, the core alone is not adequate to keep the drift within permissible limit, some other structural element need to be added in that building to take care of drift. Outriggers are the structural system, which helps in reducing the lateral drift. It increases the stiffness of the structure by huge amount. Optimum location of the outrigger is an important thing while adopting the outrigger system, in order to meet the economy criteria.

In this paper, the optimum location of the outrigger is found by considering few constraint conditions. The parameters on which the conclusions made are the lateral drift and formation of soft storey. It also takes into account the change in results due to changes in sizes of cross sections of columns and shear walls. From the analysis of the results obtained, it is found that the effect of reduction of cross section of columns and shear walls is less for considered models. Considering the assumed constraint conditions, two outriggers are provided at their respective optimum location. To meet the lateral top sway requirement, when an additional outrigger is provided at top of the building to existing outriggers, it offers the best results for the permissible top sway and also there was no soft storey formation.

Keywords - Drift; Outrigger; Soft storey; Stiffness; Shear wall.

I. INTRODUCTION

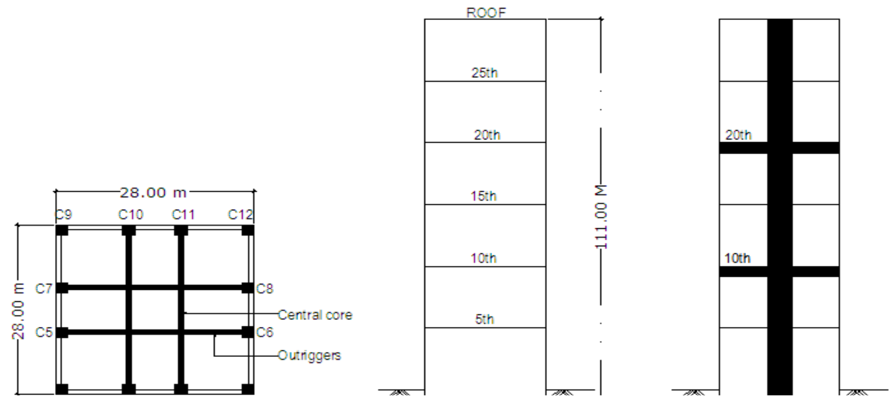
Drift is the major criteria for all tall buildings. IS 456:2000, has put a limit of H/500 for the permissible top sway. If any building is unable to fulfill these criteria, we need to add or change structural units in that building in such a way that drift is in permissible limit.

Outriggers are single or double storey deep beams which connects the central core to the peripheral columns. When horizontal load is applied to the structure the core wall will interact with the exterior columns by introducing tension in the windward exterior columns and compression in the leeward exterior columns, these forces form restraining moments at the outrigger and foundation level which act in opposite direction as that of applied load, as a result of this horizontal deflection is reduced.

II. PROBLEM FORMULATION

A 3-D building with simple geometry is considered, which has mixed occupancy. The building is square with plan dimensions of 28 X 28 m. Total height of the building is 111 m, floor to floor height is 3.50 m and it is 3 m for basements. Along height the building is divided in three zones as parking, office and residential. The architectural detail of each zone is done in accordance with NBC 2005. The details of the assumed building are shown in ***Figure1.***

After preparation of all architectural drawing structural layout is made considering the changes in the architectural plans. The load details are calculated as per IS 875 Part I, Part II and Part III. According to the loading the slab and wall load is calculated for all typical floors.



(a) Plan *(b) Elevation* *(c) Section through core*

Figure1. Building details.

III. MODELS TO BE CONSIDERED FOR THE OPTIMUM LOCATION ANALYSIS

It is really difficult to find the optimum location and number of outriggers to be provided in any structural system. In order to work in specific direction constraint is put in this study for locating the optimum location. The considered constraint conditions are

i. System with single outrigger.
ii. System with two outriggers.
   a. One outrigger fixed at 28^{th} floor and other at various assumed locations.
   b. Two outriggers spaced at 0.333H away from each other.

For locating the optimum location of the outriggers 6 different arrangements are considered. The details of these model's structural arrangements are given below.

Model 1 – With shear walls and frames; without change in cross sections of columns and shear walls.

Model 2 – With shear walls, frames and one outrigger; without change in cross section of columns and shear walls.

Model 3 – With shear walls, frames and two outriggers; without change in cross section of columns and shear walls.

Model 4 – With shear walls and frames; with change in cross section of columns and shear walls.

Model 5 – With shear walls, frames and one outrigger; with change in cross section of columns and shear walls.

Model 6 – With shear walls, frames and two outriggers; with change in cross section of columns and shear walls.

IV. ANALYSIS OF THE BUILDING

For analysis lateral wind load is taken from IS 875: Part III-1987 and response spectrum analysis is carried out in accordance with IS 1893–2002. The analysis is done in E-TABS.

When the results of all models are compared for drift, it is observed that no model satisfies the criteria for Y direction. The results of Model 6 are comparatively close to permissible drift limit, so changes are made in Model 6. To do this nine more trials are taken, the details of structural layout of these trials are shown below.

Trial 1 – Change in column sizes for C2, C3, C10 and C11.

Trial 2 – Additional shear wall near car-lift at all parking levels.

Trial 3 – Combination of Trial 1 and Trial 2.
Trial 4 – An outrigger at top, in addition to two previously existing outriggers.
Trial 5 – Change in column sizes for C2, C3, C5, C6, C7, C8, C10 and C11.
Trial 6 – Change in sizes of all columns.
Trial 7 – Change in thickness of core shear wall.
Trial 8 – Combination of Trial 6 and Trial 7.
Trial 9 – Increasing thickness of existing outriggers.

V. RESULTS AND DISCUSSION

The drift is governed by wind for all trials of Model 6. The results of all trials of Model 6 are shown in ***Figure 2*** and ***Figure 3*** for X and Y directions respectively.

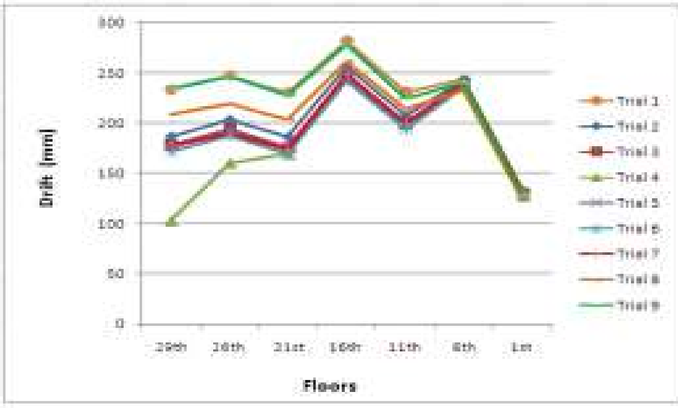


Figure 2. Drift in X direction for all trials of Model 6.

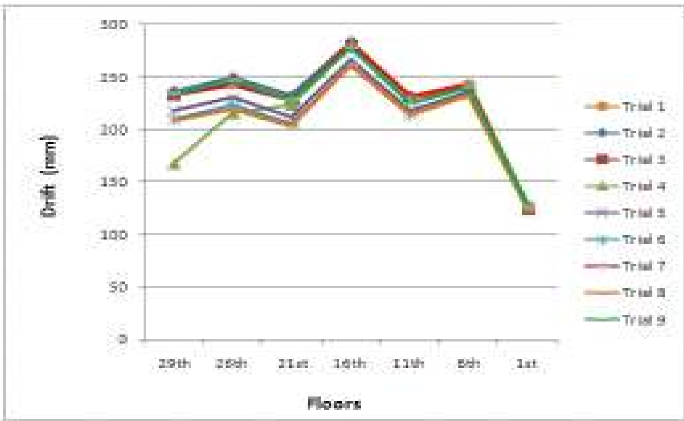


Figure 3. Drift in Y direction for all trials of Model 6.

When the results of all trials made in Model 6 are studied, it is noticed that only two trials fulfill the permissible drift criteria. From both the figures we can see that when an additional outrigger is provided at top (i.e. Trial 4) top sway is reduced by huge amount and it is in permissible limit. In order to meet the economy criteria concrete quantity consumption of all models is checked. It is noticed that Trial 4 gives the best outcome not only for drift but also for concrete consumption.

VI. CONCLUSION

On the basis of problem formulation done for this work, following conclusions are made

i. For single outrigger, the optimum location of the outrigger is at 0.47H from bottom of the building.

ii. When the system is provided with two outriggers, out of which one is fixed at top floor, the optimum location of the second outrigger is at 0.30H from bottom of the building.

iii. When two outriggers are placed at 0.333H away from each other, for this condition the optimum locations of the outriggers are at 0.333H and 0.667H from bottom of the building.

iv. When system has only one outrigger at the top floor, it is not much effective as far as drift is concerned.

v. Change in the drift profiles is noticed when outriggers are provided; the change is remarkable when two outriggers are provided.

vi. The effect of reduction of cross sections of columns and shear walls is less for drift.

vii. No storey was found as soft storey for all trials made in Model 6.

viii. To fulfill the sway criteria when different trials are made in Model 6, the trial in which one additional outrigger is provided at the top, in addition to previously existing outriggers, offers the best results.

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