

Comparative Analysis of Flat Plate Multistoried Frames with and Without Shear Walls under Wind Loads

Fayazuddin Ahmed Syed, B. Dean Kumar, Y. Chandrasekhar, B.L.P. Swami

Abstract—Flat plate is the term used for a slab system without any column flares or drop panels. Although column patterns are usually on a rectangular grid, flat plates can be used with irregularly spaced column layouts. In flat plate loads directly to supporting columns, which is different from other two way systems by the lack of beams, column capitals, and drop panels. In tall multistoried structures the flat plate floor system has weak resistance to lateral loads like wind, hence special features like shear walls, structural Walls are to be provided if they are to be used in High rise constructions. In the present investigation numerical studies for 20,40,60,80 storied for frames with normal conventional beam supported slab system, flat plate floor system, flat plate floor system with Shear walls has been conducted.

A Comparison the Critical Column Axial Forces, Column moments, Lateral Drift (in mm) due to static and wind loads on the structures located at Hyderabad at a basic wind speed of 44 m/s has been observed during analysis.

Keywords- Flat Plates; Shear walls; Wind

I. INTRODUCTION

In general slabs are classified as one-way or two-way. Slabs that primarily deflect in one direction are referred to as one-way slabs. Flat Plates present a possible problem in transferring the shear at the perimeter of the columns. In other words, there is a danger that the columns may punch through the slabs. As a result, it is frequently necessary to increase column sizes or slab thicknesses or to use shear heads. Shear heads consist of I or channel shapes placed in the slab over the columns. Although such procedures may seem expensive, it is noted that the simple formwork required for flat plates will usually result in such economical construction that extra costs required for shear heads are more than cancelled. For heavy industrial loads or long spans, however, some other type of floor system may be required.

Concrete slabs are often used to carry vertical loads directly to walls and columns without the use of beams and girders. Such a system called a flat plate is used where spans are not large and loads are not heavy as in apartment and hotel buildings.

Flat Plates are solid concrete slabs of uniform depths that transfer loads directly to the supporting columns without the

aid of beams or capitals or drop panels. Flat plates are probably the most commonly used slab system today for multi-storey reinforced concrete hotels, motels, apartment houses, hospitals, and dormitories. Flat plates can be constructed for a thickness of 125-250 mm for spans of 4.5-6 m. Flat Plate system have an advantage of introducing an edge beam at the periphery of the panel to reduce the deflection of the exterior panel of the plate. The main disadvantage in Flat slabs and Flat plates is their lack of resistance to lateral loads, hence special features like shear walls, structural Walls are to be provided if they are to be used in High rise constructions.

Husam Omar, Glenn Morris^[1]; they studied a review about a procedure which is described for performing a linear structural analysis of laterally loaded three-dimensional flat plate structures, with or without shear walls. H.S. Kim, D.G. Lee^[2]; they studied a review about the Flat Plate system which has been adopted in many buildings constructed recently due to the advantage of reduced floor heights to meet the economical and architectural demands T.Stathopoulos, Y.S. Zhou^[9] studied the numerical evaluation of wind pressures on flat roofs by using the Reynolds averaged Navier-Stokes equations and the standard k-ε turbulence model. Yasushi Uematsu, Motohiko Yamada^[10] they proposed and studied about the review about simple formulas for estimating the design wind loads for the structural frames of flat long-span roofs considering their dynamic response to turbulent wind forces.

II. SHEAR WALLS

Frame action provided by a flat slab-beam and column interaction is generally insufficient to provide the required strength and stiffness for buildings taller than about 10 stories. A system consisting of shear walls, R.C. Infill Walls and flat Plate-frames may provide an appropriate lateral bracing system.

Walls can be designed as plain concrete walls when there is only compression with no tension in the section. Otherwise they should be designed as reinforced concrete walls. Shear walls are specially designed structural walls incorporated in building to resist lateral forces that are produced in the plane of the wall due to wind, earthquake forces. In an earthquake, heavy wind affected prone zones these masonry infill wall panels attract large lateral forces and are damaged, or the perimeter columns, beams, and their connections fails. It is always advisable to incorporate them in buildings built in regions likely to experience earthquake of large intensity or high winds. They are usually provided between columns, in stairwells left wells, toilets, utility shafts, etc. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along length and width of building.

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Shear walls are like vertically oriented wide beams that carry earthquake loads downwards to the foundation L.G. Jaeger, A.A. Mufti, J.C. Mamet^[5] has studied the structural analysis of tall buildings having irregularly positioned shear walls. An analytical theory for the analysis of tall three-dimensional multiple shear wall buildings is developed. The basis of the theory is the continuum approach in which the floors of the building are replaced by an equivalent continuous medium. The results are compared with data obtained by the finite element method and experiments conducted on a seven storey multiple shear wall model. A good correlation is achieved.

III. DETAILS OF THE PRESENT STUDY

In the present investigation 20, 40, 60 and 80 storied frames were analyzed using STAAD.PRO (V8i) software package. For each of the frame under consideration, three cases were considered. Case I: Normal conventional beam supported R.C. framed structure. Case II: Flat Plate R.C. framed structure. Case III: Flat Plate R.C. framed structure with Shear walls.

All the three cases were considered for comparison with respect to the height of the structures. Comparisons was made with the Critical Column Axial Forces, Critical Column moments due to static and wind loads, Lateral Drift (in mm) in X, Z direction due to Wind loads. And also Strip moments (in Bending) in Flat Plates in both the Gravity and Wind loads on the structures located at Hyderabad at a basic wind speed of 44 m/s has been observed.

The total height of the frames considered for the study are of 62m, 124m, 186m, 248m respectively, which represents a 20,40,60,80 storied commercial building. The Plan area of the Structure is 45 m x 30 m with columns spaced at 6 m from center to center in Z-direction, 5 m from center to center in X-direction. The height of each storey is 3.10m and all the floors are considered as Typical Floors. The location of the building is assumed to be at Hyderabad. The plan view of a typical structure for 20 storey, 40 storey, 60 storey, 80 storey is shown in fig 1.

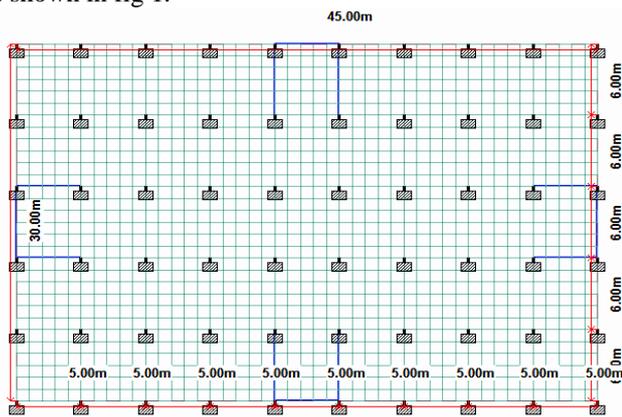


Fig 1 Plan view of a typical structure for 20 storey, 40 storey, 60 storey, 80 storey structure.

The column sizes for 20 storey, 40 storey, 60 storey, 80 storey are considered as 0.45m x 0.45m, 0.8m x 0.8m, 1.1m x 1.1m, 1.3m x 1.3m respectively. The edge beam sizes are considered as 0.25m x 0.45m, 0.35m x 0.6m, 0.45m x 0.75m, 0.55m x 0.9m respectively. The wind intensities are calculated as per IS: 875 (part 3). The wind intensities for 20 storey, 40 storey, 60 storey, 80 storey are considered as 1.789 kN/m², 1.976 kN/m², 2.092 kN/m², 2.18 kN/m² respectively.

Each and every Flat plate panel of the building for 20 storey, 40-storey, 60-storey, 80-storey was properly meshed and the size of the meshes were maintained closer to aspect ratio 1 and the properly meshed Flat Plate panels are divided into column strips and middle strips as shown in the figure 2.

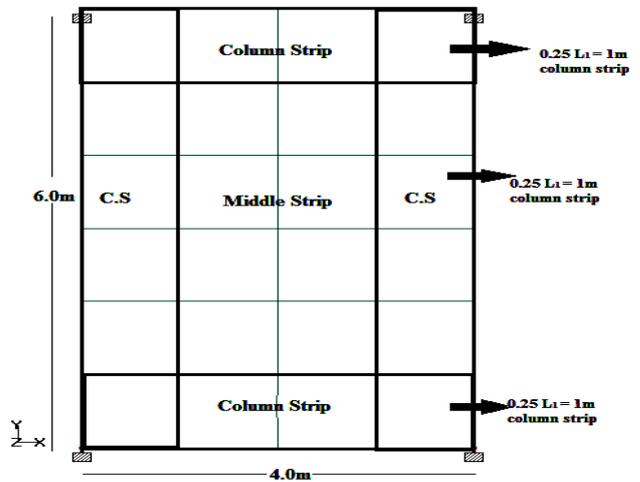


Fig 2 Division of Meshed Flat Plate Panel in to column strips and middle strips.

Similarly The buildings discussed above are designed and positioned with Shear wall to avoid total collapse of buildings under lateral forces i.e. seismic forces and wind forces. It is always advisable to incorporate them in buildings built in regions likely to experience earthquake of large intensity or high winds. Fig showing position of shear wall; the shear wall which is termed surface wall in STAAD is meshed as Equivalent frame method, gives good result and load distribution takes place in the proper manner.

The position of Shear wall in all storey is same i.e. 20 storey, 40 storey, 60 storey, 80 storey is same the thickness is same for all buildings.

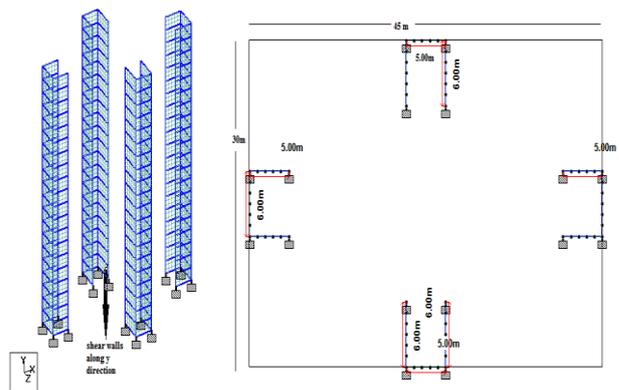


Fig 4 : (a) isometric view of shear wall (b) top view of shear walls in plan in four directions.

IV. VARIATION OF CRITICAL AXIAL FORCES WITH HEIGHT

Under factored Dead load & Live load the axial force at the base of the end column is highest in the Case I. It is true in the case of the all the four frames considered.

The axial force in the remaining two cases i.e. Case II & Case III is considerably less when compared to Case I. This is because partition walls were considered in the first case. Hence for comparison purpose only second and third cases are considered under the vertical loads.

In all the buildings considered in the case of flat plate frames the end column is getting more axial force compared to the third case where in Shear walls is provided.

This is because the Shear walls are considered as an integral element of the building and as such it contributes towards sharing of some of the axial Force.

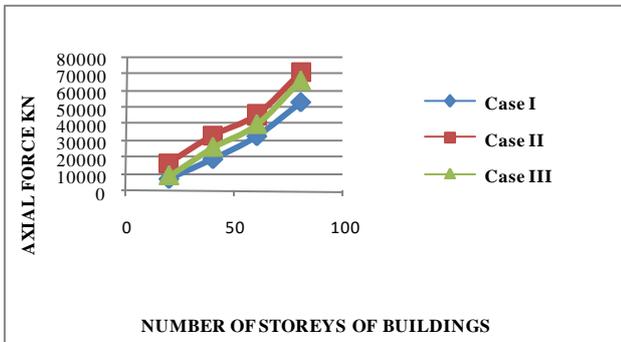


Fig 5 Graph showing the comparison of Case I, Case II, Case III for Base End Column axial forces for 20, 40, 60, 80 storied building for 1.5(D.L+L.L)

In the Case III the axial compression at base on windward column of 20 story frame is reduced by nearly 45% when wind is considered. The reduction in the axial compression force in the end column in the Case III is nearly 38%. This is because of the interaction of the peripheral walls with the frame. Similarly same can be observed in the case of 40 and 60 storied frame.

In the case of 80 storey frame when the wind is considered at the base, the reduction in axial compression of the end column is nearly 19.81 %. Again this is because of the interaction between the peripheral walls with the frame. Hence it is clear that in the case of Case III the column axial forces are very much reduced; hence the design of column becomes economical.

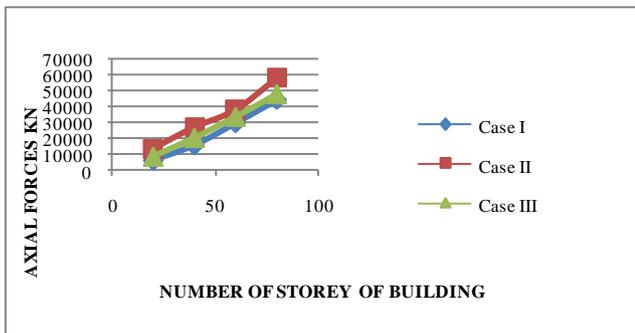


Fig 6 Graph showing the comparison of Case I, Case II, Case III for Base End Column axial forces for 20, 40, 60, 80 storied building for 1.2(D.L+L.L+W.L_Z)

V. VARIATION OF CRITICAL MOMENTS WITH HEIGHT

A. The Critical column base axial forces nearer to the R.C. In filled wall (Column 53) under gravity loads have been Studied.

For end column of 40 storied building under gravity loading the column moments for Case I are less compared to

Case II , Case III where as the column moments for Case III are much lesser than in comparison with Case I.

It is observed that the column moments for Case II are increased by 90% compared to Case I, where as the column moments for Case III has decreased by 21.75 %.

For end column of 60 storied building under gravity loading the column moments for Case I are more compared to Case II, where as the column moments for Case III are much lesser than in comparison with Case I and Case II.

It is observed that the column moments for Case II are increased by 89 % compared to Case I, where as the column moments for Case III has decreased by 79.9 % when compared with Case II.

For end column of 80 storied building under gravity loading the column moments for Case I are less compared to Case II, where as the column moments for Case III are much lesser than in comparison with Case II .

It is observed that the column moments for Case II are increased by 90% compared to Case II, where as the column moments for Case III decreased by 74.82 % when compared with Case II.

Hence it is clear the third case consisting of flat plate system with Shear wall (F.P.F.S+S.W) is more efficient against the gravity as well as wind loadings. And the column moments in the first case i.e. Flat plate floor system are more because of absence of beams.

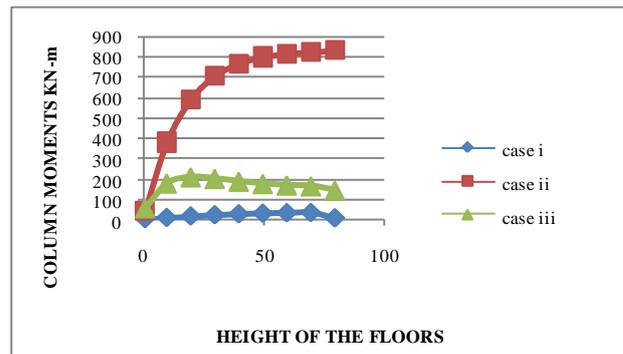


Fig 7 Graph showing the comparison of Case I, Case II, Case III for Base End Column Moments for 20, 40, 60, 80 storied building for 1.5(D.L+L.L)

B. The Critical column base axial forces nearer to the R.C. In filled wall (Column 53) under wind loads have been Studied.

For end column of 40 storied building under wind loading the column moments for Case I are more compared to Case II, where as the column moments for Case III are much lesser than in comparison with conventional, flat plate floor system building. It is observed that the column moments for Case II are decreased by 34.69 % compared to Case I, where as the column moments for Case III has decreased by 60.61% & 40 % when compared with Case II, Case I.

For end column of 60 storied building under wind loading the column moments for Case I are less compared to Case II, where as the column moments for Case III are much lesser than in comparison with Case I, Case II.

It is observed that the column moments for Case II are decreased by 55 % compared to Case I, where as the column moments for Case III has decreased by 69.17 % & 58.28 % when compared with Case II, Case I.



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For end column of 80 storied building under wind loading the column moments for Case I are less compared to Case II, where as the column moments for Case III are much lesser than in comparison with Case I, Case II.

It is observed that the column moments for Case II are decreased by 47 % compared to Case I, where as the column moments for Case III has decreased by 42.8 % & 69.72 % when compared with Case II, Case I.

Hence it is clear the Case III consisting of flat plate system with R.C. In filled external peripheral wall (F.P.F.S+R.C.I) is more efficient against the gravity as well as wind loadings. And the column moments in the Case II are more because of absence of beams, R.C. In filled walls compared to 2nd case and 3rd case.

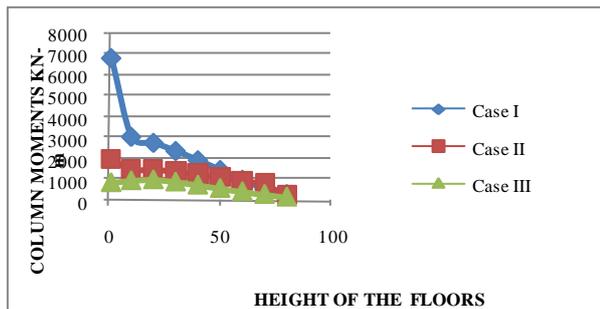


Fig 8 Graph showing the comparison of Case I, Case II, Case III for Base End Column Moments for 20, 40, 60, 80 storied building for 1.2(D.L+L.L+W.Lz)

VI. VARIATION OF LATERAL DRIFT WITH HEIGHT

The most significant basic parameter monitored throughout the whole analysis process was drift at the top of the building for 20,40,60,80 storied buildings.

It can be seen that the value of drift in the direction of wind loading is more in the case of Case I. In case of Case II because of the additional lateral stiffness provided by flat plates the drift values are reduced.

In the case of a typical 60 storied building the drift value is decreased by 34.34% from Case I to Case II. Whereas the reduction in drift value is nearly 62.2 % from Case I to Case III. Similarly in the case of typical 80 storied building the drift value is reduced by 38.81% from Case I to Case II. Whereas the reduction in drift value is nearly 65.77 % from Case I to Case III. The other buildings also follow the same trend.

In the case of tall multi storied buildings drift is a critical parameter to be considered in the design. Hence it is clear that Case II helps in reducing the drift in the case of multi storied building compared to Case I. The building can be further strengthened against the lateral loads by providing Shear walls also, hence drift becomes minimum in this case.

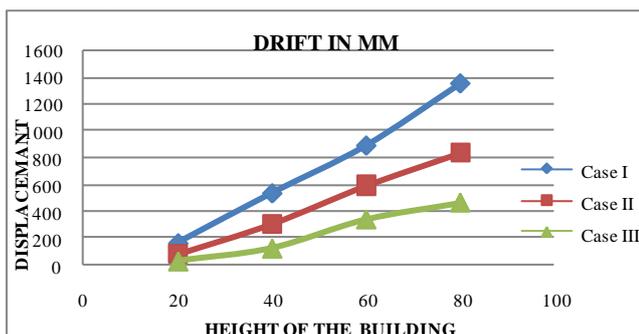


Fig 9 Graph showing the comparison of lateral drift for 20, 40, 60, 80 storied building for 1.2(D.L+L.L+W.Lz)

VII. CONCLUSIONS

- In the case of flat plate floor system (F.P.F.S) though there are no partition walls, peripheral masonry walls are available and it doesn't take part in the interaction. As such the wall loads are directly transferred to the beams and are carried by the columns to foundation and earth mass.
- As such the axial forces are more in flat plate floor system (F.P.F.S) compared to system with flat plate floor system with Shear walls (F.P.F.S+SW), this says that Axial forces in columns were reduced from ground floor to top floor because of the presence of shear wall in buildings.
- It is observed that due to wind loading the column moments for flat plate floor system building are increased by 55% compared to conventional building, where as the column moments for flat plate floor system building with Shear walls has decreased by 69.17 % & 58.2 % when compared with flat floor system, conventional beam supported slab system.
- The Shear walls with flat plates contribute towards reducing the column axial force even in the middle frame region also. In the case of other building frames there is similar reduction in column axial force when wind is acting.
- The flat plate floor system helps in reducing the drift in the case of multi storied building compared to conventional beam slab column system. There is 38.81% reduction in the drift in the case of flat plate floor system when compared to conventional beam supported slab system.
- The flat plate floor system can be further strengthened against the lateral loads by providing Shear walls also. The drift becomes minimum, so that there is 65.77% reduction in the drift in this case.
- Hence it is clear that flat plate floor system helps in reducing the drift in the case of multi storied building compared to conventional beam slab column system and among these two cases the best choice is flat plate floor system with shear wall
- It is recommended that provision of flat plate system with Shear walls (or) infilled walls is the best choice to safeguard the building against the lateral loads.

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