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Comparative Analysis of Flat-Slab Considering Seismic Effect

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Abstract:

Flat-slabs with mixed boundary conditions are common in practice, and occur in commercial as well as residential buildings. Several mixed boundary conditions are possible, common combinations being one edge free, two adjacent edges free and interior panel. In structures, these boundary conditions correspond in several places. One of the factors which influence the behavior of a slab is its boundary conditions. The common tendency is to simplify the boundary conditions by providing peripheral beams so that slab panels supported on beams along all the edges are obtained.

But substantial savings in roof space and construction time can be realized by avoiding beams in such cases. Usually slabs with mixed boundary conditions are designed by the approximate methods. Such slabs are likely to be over safe and un-economical. Since the behavior of the slab change with the changes in the boundary conditions. A few typical cases of square, rectangle flat-slabs with mixed boundary conditions are considered in the dissertation. These slabs wear analyzed by the finite element package using E-TABS. The behavior of these slabs was investigated for various aspect ratios.

The following boundary conditions were considered in the analysis.

1. Two Edges Discontinuous
2. One Edge Discontinuous
3. Internal Panel.

Finally comparing the member forces for different aspect ratios with different live load conditions at various zones III, IV and V.

Introduction:

Support conditions of flat-slabs in buildings are not always the same for all the four edges. Several mixed boundary conditions are possible, common being those with one edge discontinuous, two adjacent edges discontinuous and interior panel. Rectangular, square flat-slabs with mixed boundary conditions occur frequently in commercial structures. However, data to assess the deformation and bending moment values of such flat-slabs are very scant.

Earthquakes:

Earthquakes are occasional forces on structures that may occur rarely during the lifetime of buildings. It is also likely that a structure may not be subjected to severe earthquake forces during its design lifetime. Reinforced concrete multi storied buildings are supposed to be of engineered construction in the sense that they might have been analysed and designed to meet the provisions of the relevant codes of practice and building byelaws. The construction might have been supervised by trained persons. In such cases, even if earthquake forces have not been considered precisely, the structures should have adequate in built strength and ductility to withstand earthquake intensity.

Effect of earthquakes on high rise buildings:

When a building experiences earthquake vibrations its foundations will move back and forth with the ground. These vibrations can be quite intense, creating stresses and deformation throughout the structure making the upper edges of the building swing from a few millimetres to many centimetres depending on their height, size and mass.

This is uniformly applicable for buildings of all heights, whether single storied or multi-storied in high risk earthquake zones. A building needs to be slightly flexible and also have components, which can withstand or counter the stresses caused in various parts of the building due to horizontal movements caused by earthquakes. It was observed that buildings of different sizes and heights vibrated with different frequencies. Where these were made next to each other they created stresses in both the structures and thus weakened each other and in many cases caused the failure of both the structures. Bureau of Indian Standards clearly gives in its code IS 4326 that a Separation Section is to be provided between buildings.

Thus it is advised to provide adequate gap between two buildings greater than the sum of the expected bending of both the buildings at their top, so that they have enough space to vibrate. This situation is further compounded when the slab level of one building is near the mid-level of the walls and columns of the neighbouring building, the walls and columns are normally not designed for taking this additional shear force caused by the horizontal force coming from the neighbouring slab. This causes buckling of the columns and walls at times of excessive stresses at the mid points and thus the collapse of the buildings onto each other starting a chain reaction.In the case of high rise multi storied residential and commercial complexes expansion joints are provided when the length of the building exceeds a length specified by code. This expansion joint is provided for relieving stresses caused due to expansion or contraction of construction material owing to temperature changes. At this point the buildings are totally separated and a gap of 1 to 2 inches is provided which is filled with a flexible material.

However, this is causing a major problem i.e., the deflection of these independent buildings during earthquake is much more in high rise buildings than the expansion joint and since at this point these buildings are separate and of varying size they would swing and hammer with each other and weaken the buildings. Structural components around the expansion joint would be severely damaged and there shall be a chain reaction of forces in the total structure for which the structure has not been designed.

System Identification:

Structural engineering of high rise buildings requires the use of different systems for different building heights. Each system, therefore, has an economical height range, beyond which a different system is required. The requirements of these systems and their ranges are somewhat imprecise because the demands imposed on the structure significantly influence these systems. However, knowledge of different structural systems, their approximate ranges of application, and the premium that would result in extending their range is indispensable for a successful solution of high rise building project.

The primary motivation is the desire to have a more accurate description of the dynamic characteristics of a structure to predict its response to different kinds of excitations such as earthquake and wind loading. System identification is often used to apply the methodology of system controls which is to reduce the unwanted response to the excitation. Therefore it is important to have an accurate model of the real structure. The general problem of the modelling and identification can be divided into three parts:

i.Determination of the class of models from the available data.
ii.Estimation of the unknown parameters of the modal from the data.
iii.Verification of the quality of fit of the model to the given data.

The class of models is always obtained from the classical dynamic properties, i.e. from Newton's second law, and assuming classical damping. Therefore, the class of models is usually well defined although in some cases, it must be determined for the nonlinear case and for the soil interaction case. The merits and demerits of each scheme should be evaluated not only from structural cost but also the overall sense of the project. During the preliminary design, the engineer should not be overly concerned with the details, but should allow for sufficient load paths in the structure to obey the inescapable laws of nature.

Analysis is the easy part because today we can analyse almost any structure with computers.The selection of the optimal model from the class of models is achieved by either time domain or frequency domain techniques. The time domain techniques are concerned with the parameter estimation based upon the least squares, maximum likelihood and recursive techniques. The frequency domain techniques are concerned with the estimation and identification of the frequency response characteristics.

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Modelling:

Three different models are considered for live load 3 and 5 Mpa, the location of the structure is considered to be located in seismic zone III, IV and V as per Indian standard code. Where maintaining same column properties for a particular zone, the structures are modelled in three dimensional in the commercial structural analysis and design software ETABS 2009. X and Y axis are the global horizontal axis and Z is the global vertical axis. The buildings are analysed as space frames. The modelled space frame is analysed for dead loads, live loads, earthquake loads and their combinations. The buildings are compared for base shear, story drifts, modal participation mass ratios, and member forces for all the models mentioned above. All the supports are considered to be fixed at the base. The Effective lengths of columns are considered as per the standard codes of practice. Effect of rigid diaphragm for slabs is considered in the analysis.

Project Design Brief:

Number of Stories Considered 11
Height of the Story considered 3.2m
Building plan dimensions 30mx42m, 37.5mx42m and 45mx42m.

Beam sizes considered

Structure	Peripheral beams	Lift core and stair case
Flat slab structure	Beam 750 x 250 mm	Beam 230x230 mm

Internal columns

Storey level	Sizes (mm)
Base-11th storey	700x700
Base-11th storey	800x800
Base -11th storey	1200x1200

Details

Flat slabs	200, 220 and 250mm
Drop thickness	200mm
Size of Drop	3m x 3m
Slabs with Drop	400, 420 and 450mm
Roof slab	Same
Density of concrete	25kN/m^3
Grade of concrete	Columns and shear walls M50 Beams and slabs M35
Grade of Steel	Fe415

Live load	Typical floors 3, 5 kN/m^2 Roof level 1.5 kN/m^2
Super imposed load (SDL) (including furnishings)	Typical floors 2.5 kN/m^2 Roof level 2 kN/m^2
Live load contribution	50%.
Zone factor considered	0.16, 0.24 and 0.36
Type of soil	Type II, Medium and with 5% Damping
Importance factor	1
Response reduction factor	3

Earthquake load was considered As per IS 1893(Part-1): 2002 by Response spectrum method.

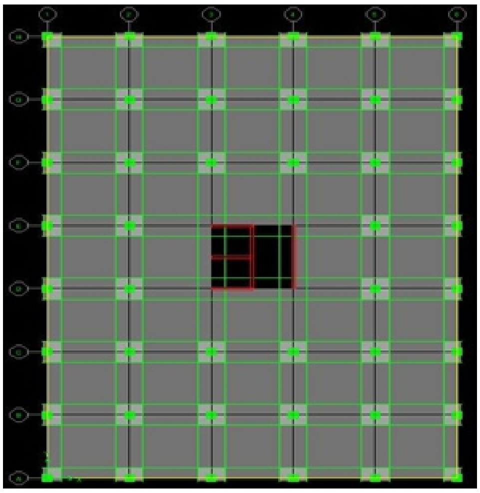

Fig.3.1: Plan of flat slab 42 x 30m building.

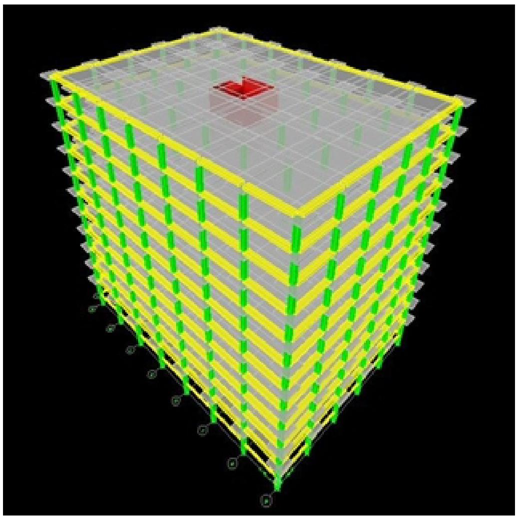

Fig.3.2: Three dimensional view of 42 x 30m building.

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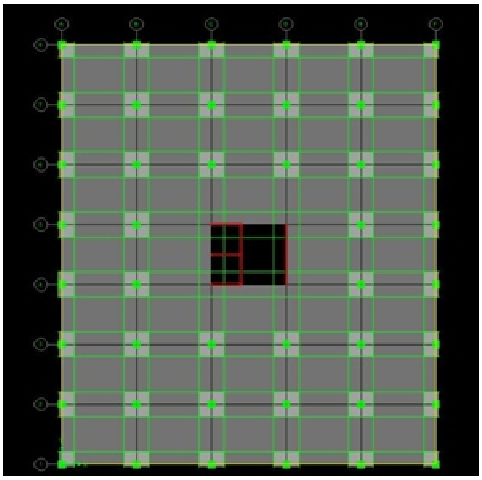

Fig.3.3: Plan of flat-slab 42 x 37.5m building

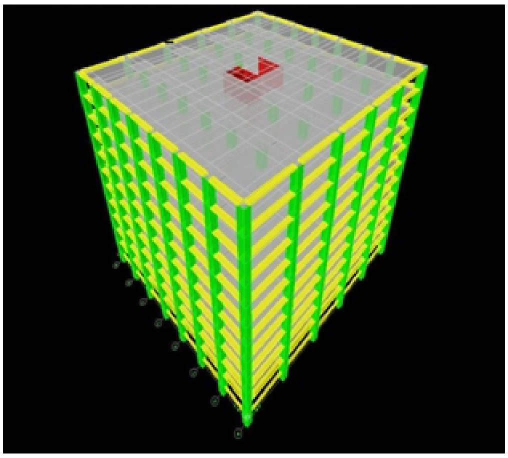

Fig.3.4: Three dimensional view of 42 x 37.5m building

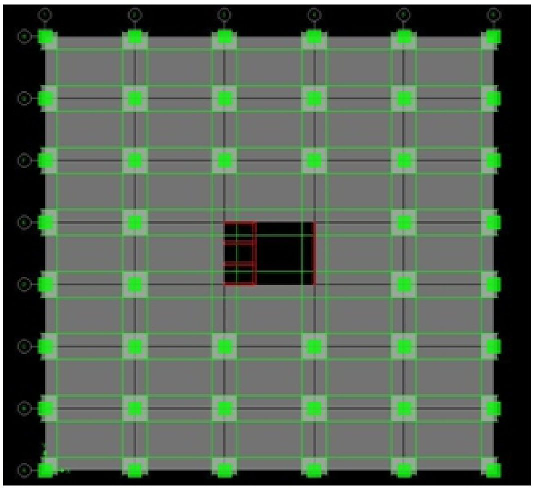

Fig.3.5: Plan of flat slab 42 x 45m building.

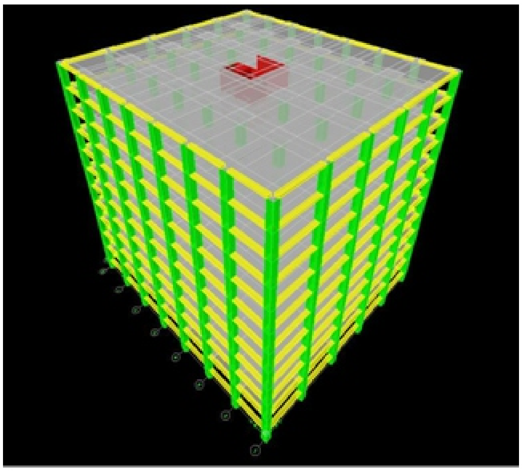

Fig.3.6: Three dimensional view of 42 x 45m building.

4. Results and Discussion:

The study examines the seismic performance of eighteen with 11 storey buildings having, flat slabs as shown in the pictures 3.1 to 3.6. As use of flat slabs makes the structure flexible under seismic loading and behaviour of these three buildings are studied. To study the effectiveness of all these models, the base shear, the storey shears and member forces of the structure are drawn from the analysis. These results obtained from the analysis have been discussed in detail in this chapter. Further these results have been used for the understanding of the behaviour of these structures under the effects of lateral loads.

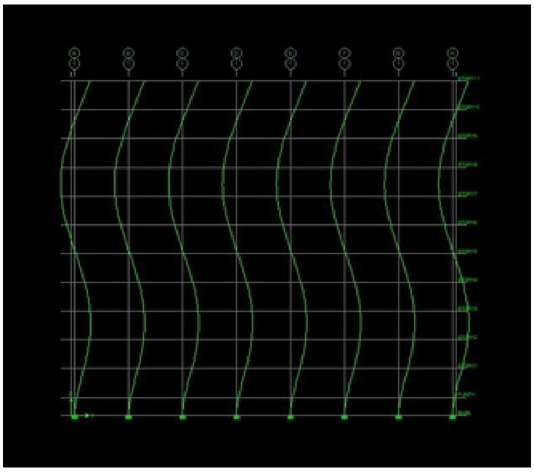

Fig. 4.1.1: Mode shape of slab structure at 90% mass participation in zone III with live load 3 Mpa.

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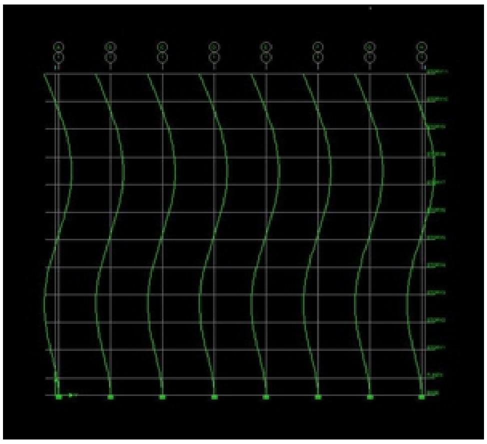

Fig 4.1.2: Mode shape of slab structure at 90% mass participation in zone IV with live load 3 Mpa.

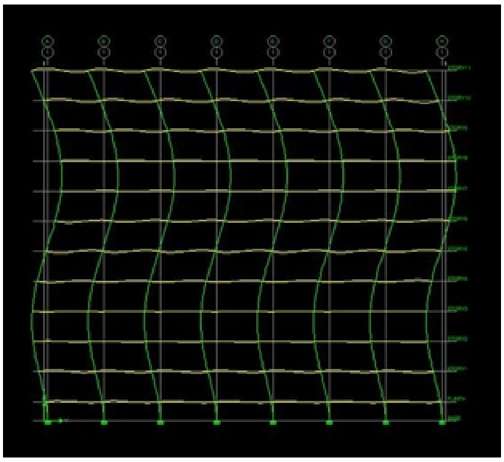

Fig 4.1.3: Mode shape of slab structure at 90% mass participation in zone V with live load 3 Mpa.

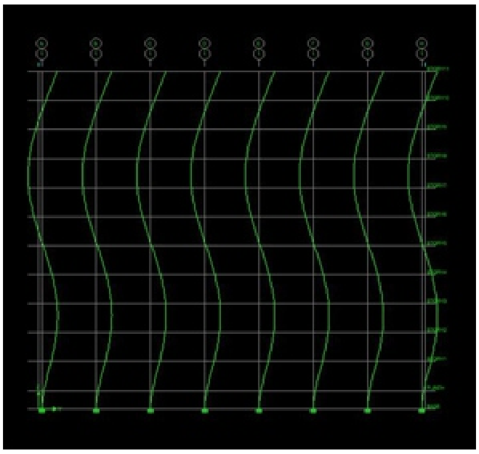

Fig 4.1.4: Mode shape of slab structure at 90% mass participation in zone III with live load 5 Mpa.

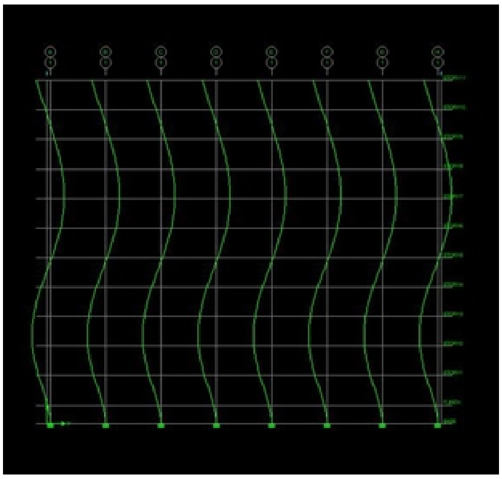

Fig 4.1.5: Mode shape of slab structure at 90% mass participation in zone IV with live load 5 Mpa.

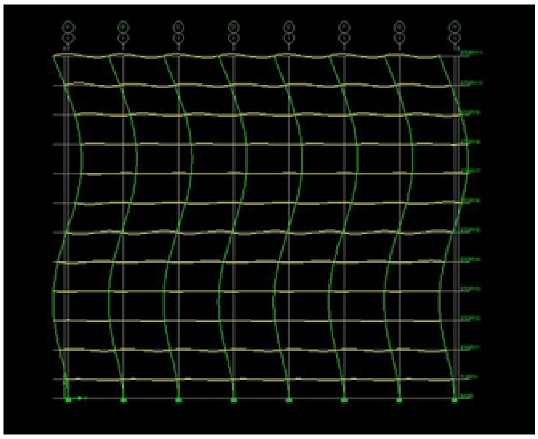

Fig 4.1.6: Mode shape of slab structure at 90% mass participation in zone V with live load 5 Mpa.% in zone V.

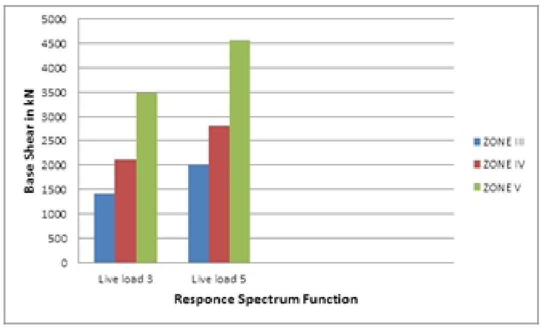

Fig 4.2.1 Comparison of base shear in SPEC X for panel with aspect ratio of 1

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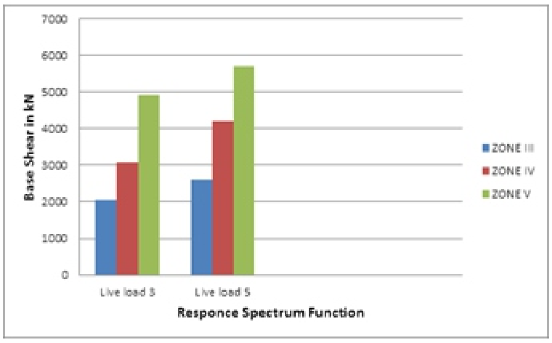

Fig: 4.2.2 Comparison of base shear in SPEC Y for panel with aspect ratio of 1

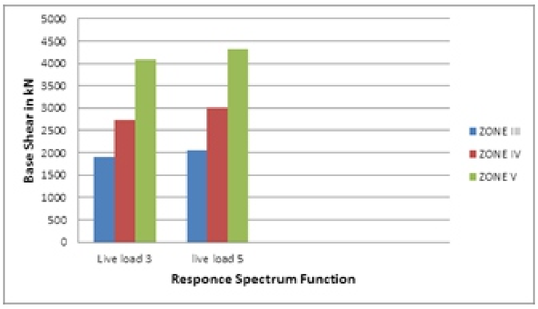

Fig 4.2.3 Comparison of base shear SPEC X for panel with aspect ratio of 1.25

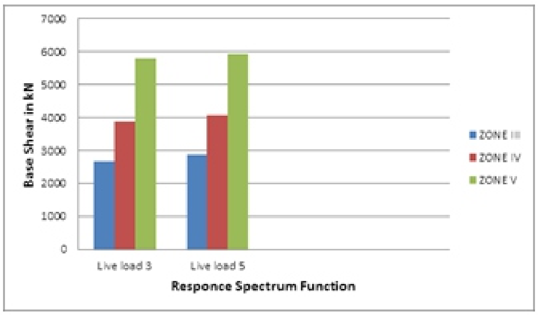

Fig 4.2.4 Comparison of base shear SPEC Y for panel with aspect ratio of 1.25

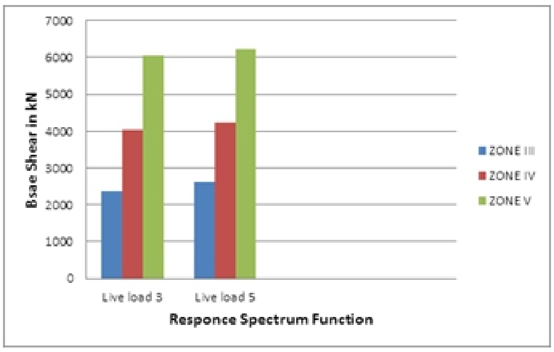

Fig 4.2.5 Comparison of base shear in SPEC X for panel with aspect ratio of 1.5

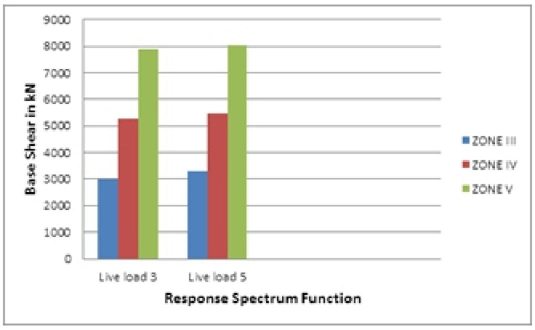

Fig 4.2.6 Comparison of base shear in SPEC Y for panel with aspect ratio of 1.5

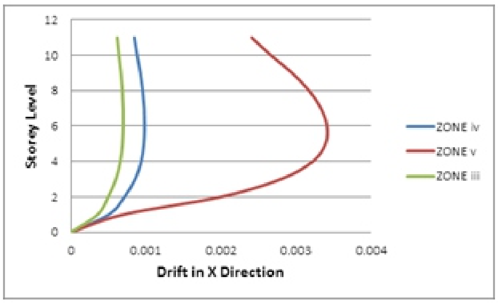

Fig 4.3.1: Comparison of Storey drifts for SPEC X with Live load 3 Mpa for aspect ratio 1.

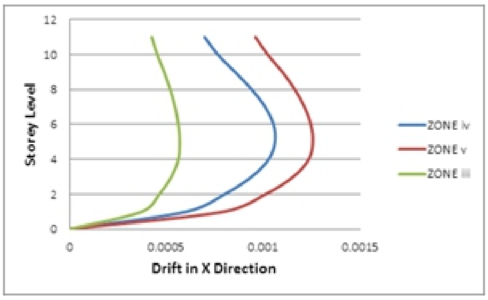

Fig 4.3.2: Comparison of Storey drifts for SPEC X with Live load 5 Mpa for aspect ratio 1.

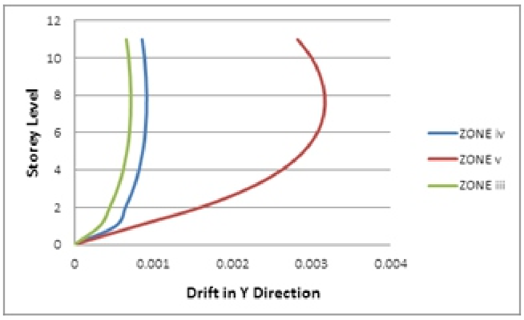

Fig 4.3.3: Comparison of Storey drifts for SPEC Y with Live load 3 Mpa for aspect ratio 1.

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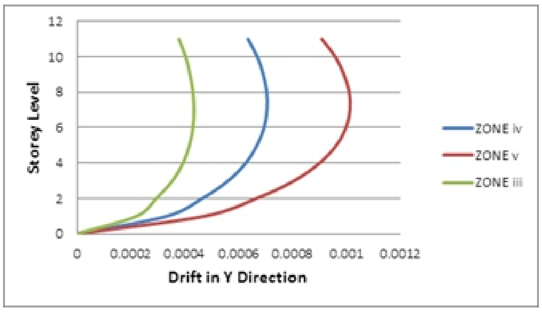

Fig 4.3.4: Comparison of Storey drifts for SPEC Y with Live load 5 Mpa for aspect ratio 1.

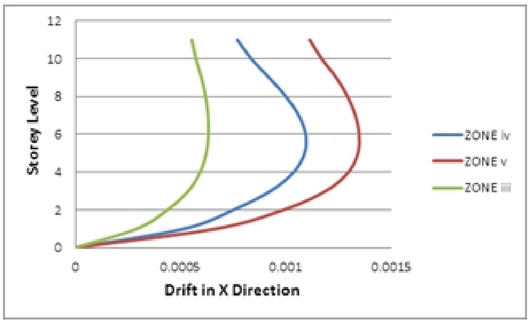

Fig 4.3.5: Comparison of Storey drifts for SPEC X with Live load 3 Mpa aspect ratio 1.25.

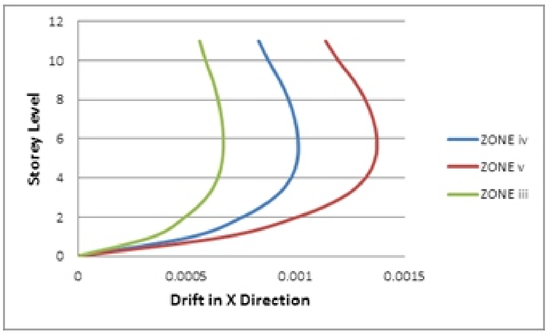

Fig 4.3.6: Comparison of Storey drifts for SPEC X with Live load 5 Mpa aspect ratio 1.25.

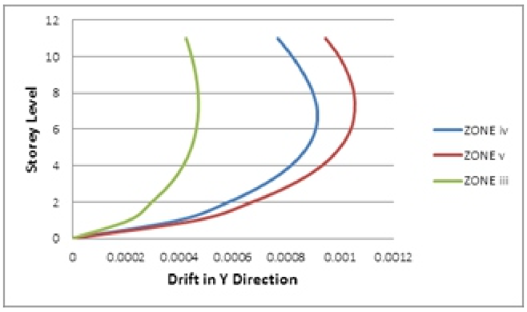

Fig 4.3.7: Comparison of Storey drifts for SPEC Y with Live load 3 Mpa for aspect ratio 1.25.

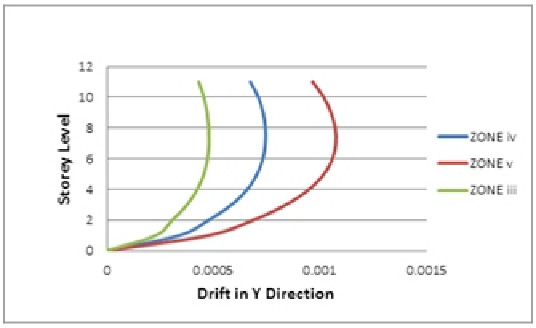

Fig 4.3.8: Comparison of Storey drifts for and SPEC Y with Live load 5 Mpa for aspect ratio 1.25.

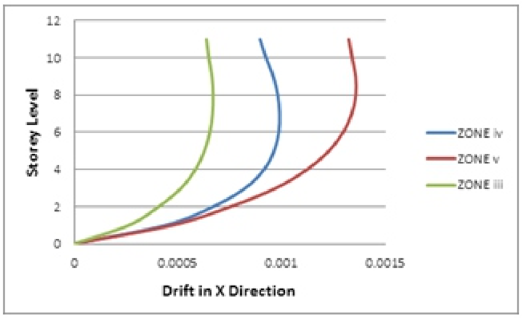

Fig 4.3.9: Comparison of Storey drifts for SPEC X with Live load 3 Mpa for aspect ratio 1.5.

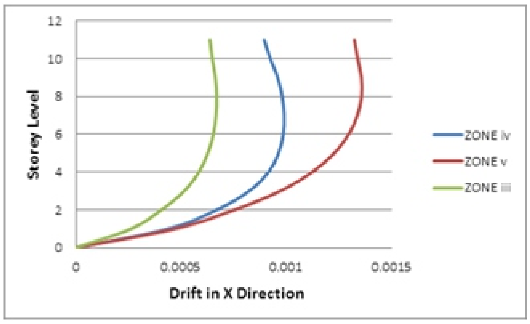

Fig 4.3.10: Comparison of Storey drifts for SPEC X in Live load 5 Mpa for aspect ratio 1.5.

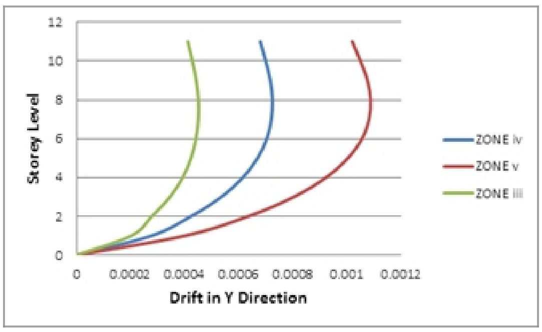

Fig 4.3.11: Comparison of Storey drifts for SPEC Y with Live load 3 Mpa for aspect ratio 1.5.

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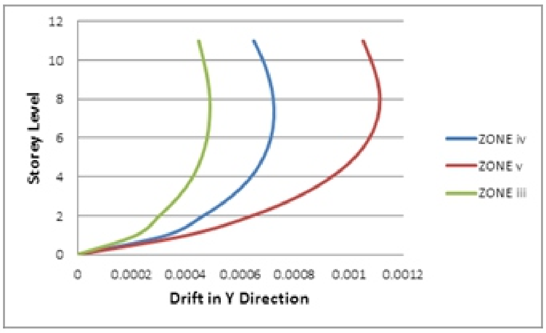

Fig 4.3.12: Comparison of Storey drifts for SPEC Y in Live load 5 Mpa for aspect ratio 1.5.

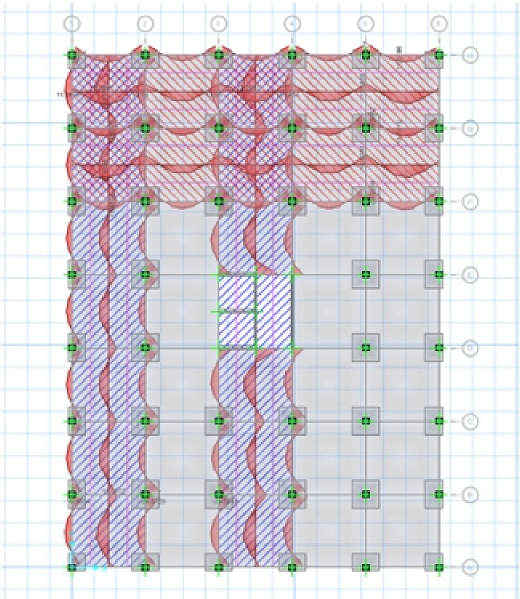

Fig 4.4.1 Bending Moment in strips X and Y directions for 1.5(DL+LL) case

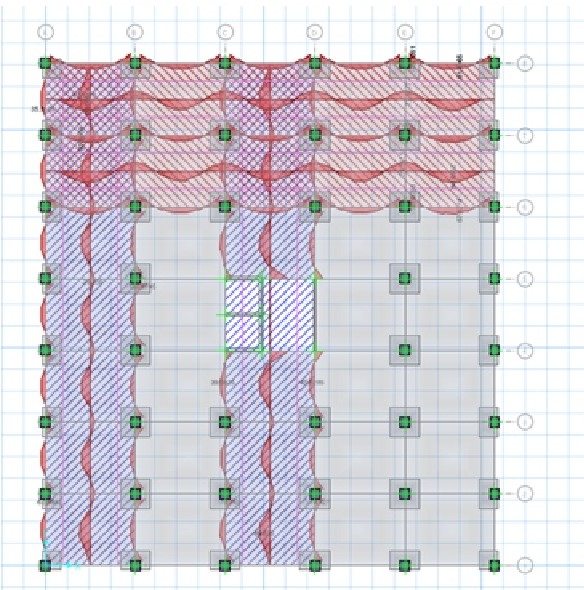

Fig 4.4.2 Bending Moments in the strips X and Y directions for 1.5(DL+LL) case

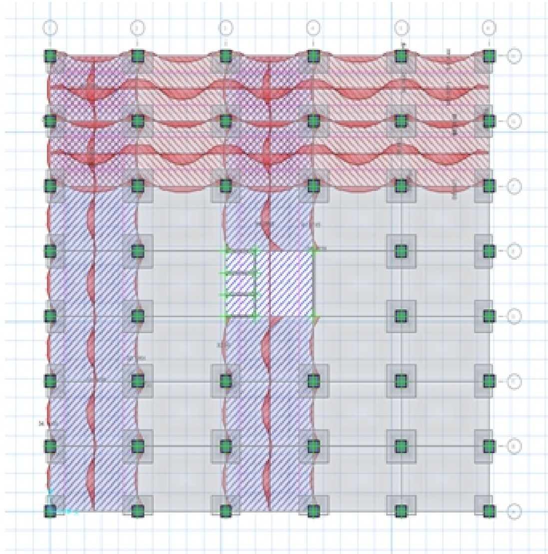

Fig 4.4.3 Member forces in strip both X and Y direction for 1.5(DL+LL) case

CONCLUSIONS:

The thesis is a study of bending moments of the flats-slabs with different aspect ratios at various zones. Based on the observations and the results obtained during the course of this study, the following conclusions can be stated:

1.The 90% mass participation is achieved at 9th mode in all the structures.
2.For all the cases considered drift values follow a parabolic path along storey height with maximum value lying near the 7th and 8th storey.
3.In the case of storey drifts live load increases storey drift value also increases in all the zones.
4.The member forces are increasing in accordance to their increase in aspect ratios, live load and zone level, but varies in the following cases

i.Flat slabs with two edges discontinuous panel (corner panel) with aspect ratio 1, 1.25 and 1.5 DL+LL combination is governing compared to DL+EQX combination for both the live loads 3 and 5 Mpa in all the zones.
ii. Flat slabs with interior panel for aspect ratio 1, 1.25 and 1.5 DL+LL combination is governing compared to DL+EQX combination for a live load of 3 Mpa in all the zones.

iii.Flat slabs with aspect ratio 1 and 1.25 DL+LL combination is governing compared to DL+EQX combination for both live load cases in all the zones considered.
iv.Flat slab with aspect ratio 1.5 DL+EQX combination is governing compared to DL+LL combination for a live load of 5 Mpa in all the zones.

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