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Effect of Different Types of Staircase in a Structure Subjected to Seismic Forces

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ABSTRACT: Generally, the staircase is the part of secondary system of the structures and it is one of the essential parts of a building because of its functional importance. Staircase when compared to the modern escalators serves not only better in emergency conditions (such as fire escapes, natural disaster, etc.) but also provides considerable stiffness to the building. Due to the complex modelling of the staircase, it is designed separately for non-seismic and seismic forces. It can be concluded that the effect of a staircase in the analysis and design of RC frame buildings cannot be ignored. The Linear Response Spectrum analysis of the models has been carried out as per IS: 1893 (Part 1) - 2002 and IS: 456 – 2000 with the help of Etab 18 software.

KEYWORDS: Story drift, Story displacement, Response spectrum analysis, Short column effect, Time period.

I. INTRODUCTION

An earthquake is a spontaneous event and behaves quite differently. The force generated by the seismic action of an earthquake is different than other types of loads, such as gravity and wind loads. It strikes the weakest spot in the whole three dimensional building.

Ignorance in design and poor quality of construction result, many weaknesses in the structure, thus cause serious damage to life and property.The staircase is the part of secondary system of the structures and it is one of the essential parts of a building because of its functional importance. Due to the complex modeling of the staircase, it is designed separately for non-seismic and seismic forces.

From a geometrical point of view, a stair is composed of inclined element (beam and slabs) and by short column. These elements contribute to increase stiffness of the building. Hence it can be suggested that the effect of a staircase in the analysis and design of RC frame buildings cannot be ignored.

In addition, masonry infills are frequently used to fill voids between the vertical and horizontal resisting elements (as partition wall) of the building frames with the assumption that these infills will not take part in resisting any kind of load either axial or lateral. Hence, its significance in the analysis of frame is generally neglected. As recent studies have shown that a properly designed infilled frames can be superior to a bare frame in terms of stiffness, strength and energy dissipation. From structural point of view, the composite action between infill panels and frames give more lateral resistance and in-plane stiffness, resulting in reduction of total and inter storey drift.

The short columns are subjected to high shear force that can lead to a premature brittle failure .The inclined beams are subjected by high variation in axial force that can modify the resistance and deformability of all these elements. Due to complex modelling of staircase, it is designed separately for non-seismic and seismic forces.

The effect of staircase on the RC frame structure includes discontinuity in the modelling, variation in failure of allied structural elements, contribution in non-linear performance of buildings, modification in various seismic parameters such as reduction in time period and storey drift of the building. Hence it can be concluded that the effect

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of staircase in analysis and design of RC frame buildings cannot be ignored.

The relative displacement of the stair's ends which are on different floors, causes a considerable distress and must be taken into account in the design stage of the structure. Furthermore, the interaction between the staircases and the other parts of the three dimensional structure (space structure), i.e., the interaction with the beams, columns and shear walls, result to patterns of deformation should be studied during the design process.

The effect of changing position of staircase in the building should also be taken into consideration. In addition to these, short column effect, variation in moments of beams and columns that are attached to staircase slab, failure and deformation in staircase models and comparison of effects of infill panels should be taken into consideration. In general the presence of a stair creates a discontinuity in a reinforced concrete frame made of beams and columns.

To make sure that staircases work as safe passage in strong earthquake, the study for seismic design of buildings claims special requirements on the design of staircase.

II. AIM, OBJECTIVE AND SCOPE OF WORK

2.1 Aim of study

The aim of my research work is "Effect of Different Types of Staircase in a Structure Subjected to Seismic Forces".

2.2 Objective of study

Objectives of the present study are as follows:

- To study the effects of different types of staircase in a structure subjected to sesmic forces.
- To study the distributions of loads and its effects on staircase.
- To study the seismic behaviour of structural member near the staircase when seismic load is applied to the structure.

2.3 Scope of work

- The focus is on understanding Effects of Different Types of Staircase when it is subjected to sesmic forces and how it behaves.
- Also demonste the structural concepts by Analytical, numerical and experimental methods in this research.

III. ANALYSIS FOR EFFECT OF DIFFERENT TYPES OF STAIRCASE IN A STRUCTURE SUBJECTED TO SEISMIC FORCES

3.1 General:

The ETABS software is used here to model building structure for same heights of building models and all structures are square in geometry. The buildings are multi-storied and for analysis, response spectrum method is taken out. In all structures, seismic zone Ⅲ is taken and the type of is medium taken for analysis.

3.2 Response Spectrum Analysis of Structures in ETABS :

The analysis was carried out by considering different types of staircase for structure. A multi-storied buildings are taken of G+7, G+14 storey. The analysis is carried out on total numbers of 6 models using response spectrum analysis in ETABS 2018. IS 1893:2016, IS 875:2015 codal provisions are considered for the analysis. The plan dimensions considered for analysis are rectangle shape building has 16.5mX 31.27m.

Models taken for analysis are as follow:

Table 1 Model List

Model Number	Number Of Storey's	Type of staircase
1	G+7	Half Turn
2	G+7	Open Well
3	G+7	Open Well With Quarter Turn Landing
4	G+14	Half Turn
5	G+14	Open Well
6	G+14	Open Well With Quarter Turn Landing

Considering the data for the **Model – 1, 2, 3** shown in table :

Table 2 Model Data – 1, 2, 3

Number of Storey	G+7
Distance in grid (X – dir.)	16.5 m
Distance in grid (Y – dir.)	31.27 m
No. of grid (X – dir.)	11
No. of grid (Y – dir.)	12
Concrete grade	M 30
Steel grade	Fe-415
Seismic zone	III
Height of floor	3 m
Columns size	230 x 450mm, 300 x 450mm
Beams size	230 x 450 mm
Depth of slab	125 mm
Thickness of wall	125 mm
Parapet wall height	1.5 m
Density of concrete	24 kN/m²
Density of masonry	22.5 kN/m²
Floor Finish	1.5 kN/m²
Live load	3 kN/m²
Importance factor	1.2
Response reduction factor	5
Type of soil	Medium
Type of support	Fix

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Considering the data for the **Model – 4, 5, 6** shown in table :

Table 3 Model Data – 4, 5, 6

Number of Storey	G+14
Distance in grid (X – dir.)	16.5 m
Distance in grid (Y – dir.)	31.27 m
No. of grid (X – dir.)	11
No. of grid (Y – dir.)	12
Concrete grade	M 30
Steel grade	Fe-415
Seismic zone	III
Height of floor	3 m
Columns size	230 x 450mm, 300 x 450mm, 500 x 500mm
Beams size	230 x 450 mm, 300 x 450 mm
Depth of slab	125 mm
Thickness of wall	125 mm
Parapet wall height	1.5 m
Density of concrete	24 kN/m²
Density of masonry	22.5 kN/m²
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Live load	3 kN/m²
Importance factor	1.2
Response reduction factor	5
Type of soil	Medium
Type of support	Fix

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3.3 Modelling of the Structure Using ETABS :

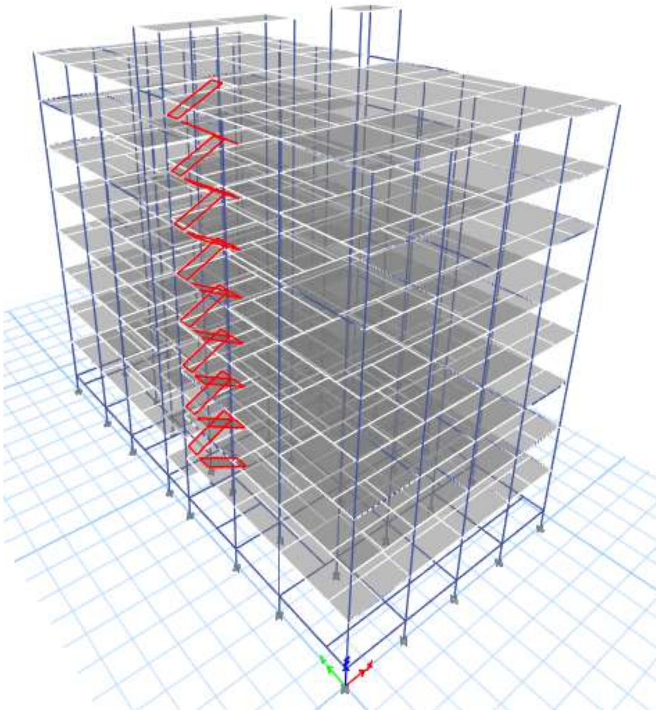

Fig 1 Model – 1

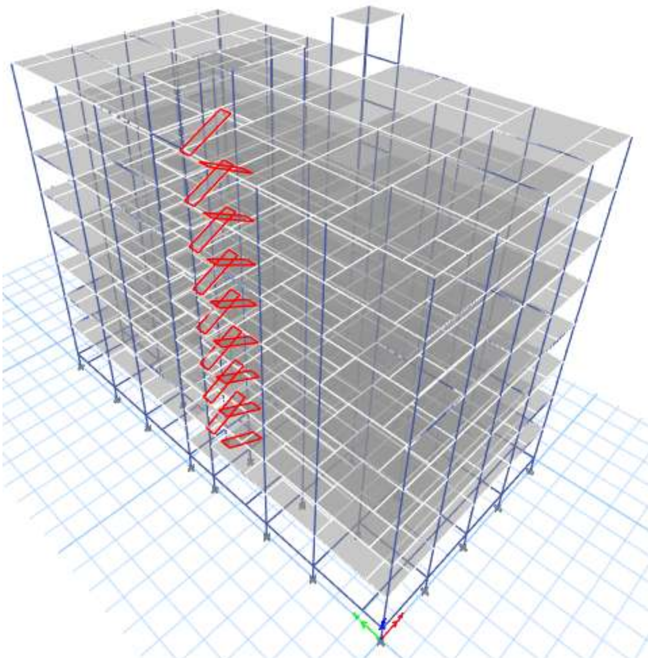

Fig 2 Model – 2

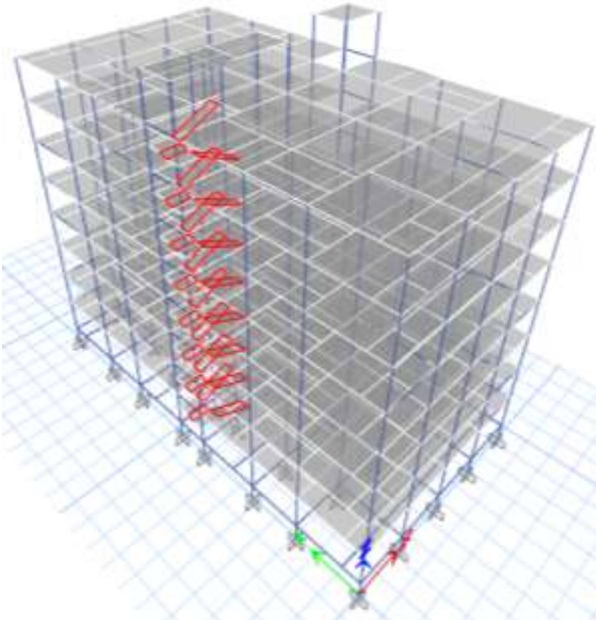

Fig 2 Model – 3

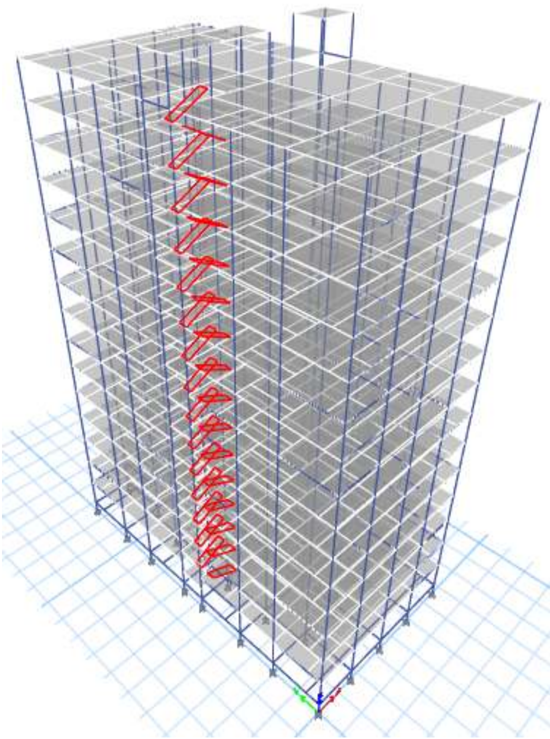

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Fig 4 Model - 5

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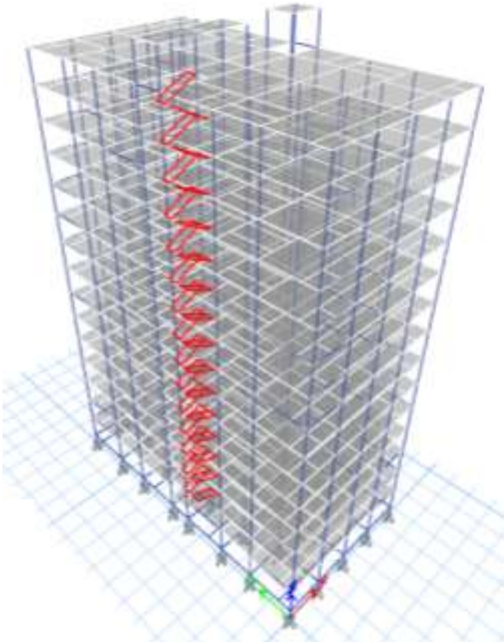

Fig 3 Model - 4

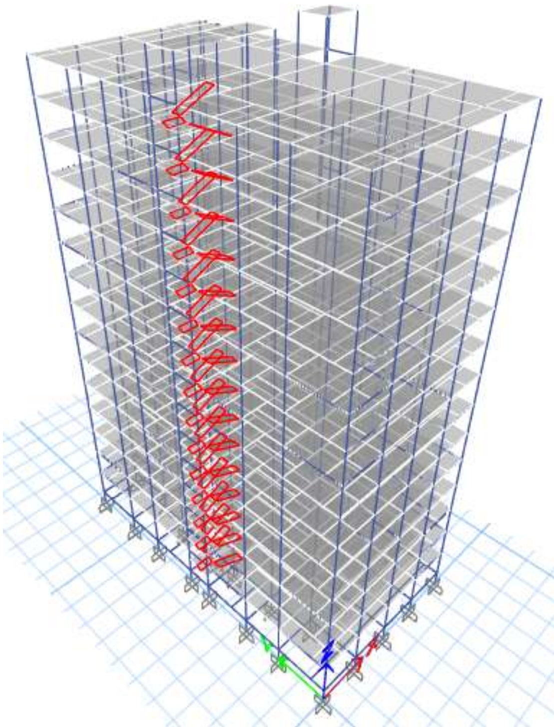

Fig 5 Model - 6

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IV. ANALYSIS AND RESULTS

4.1 Results of Model – 1,2,3 :

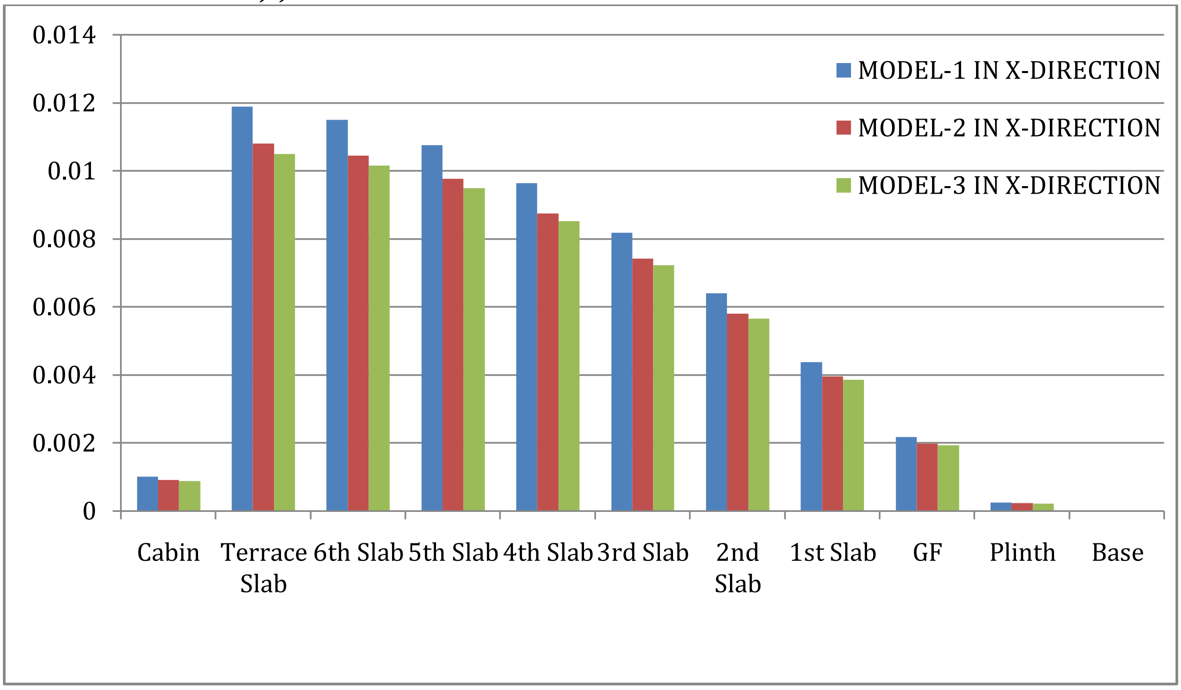

Fig 7 Graph of Maximum Story Displacement in X-Direction of Model-1,2,3

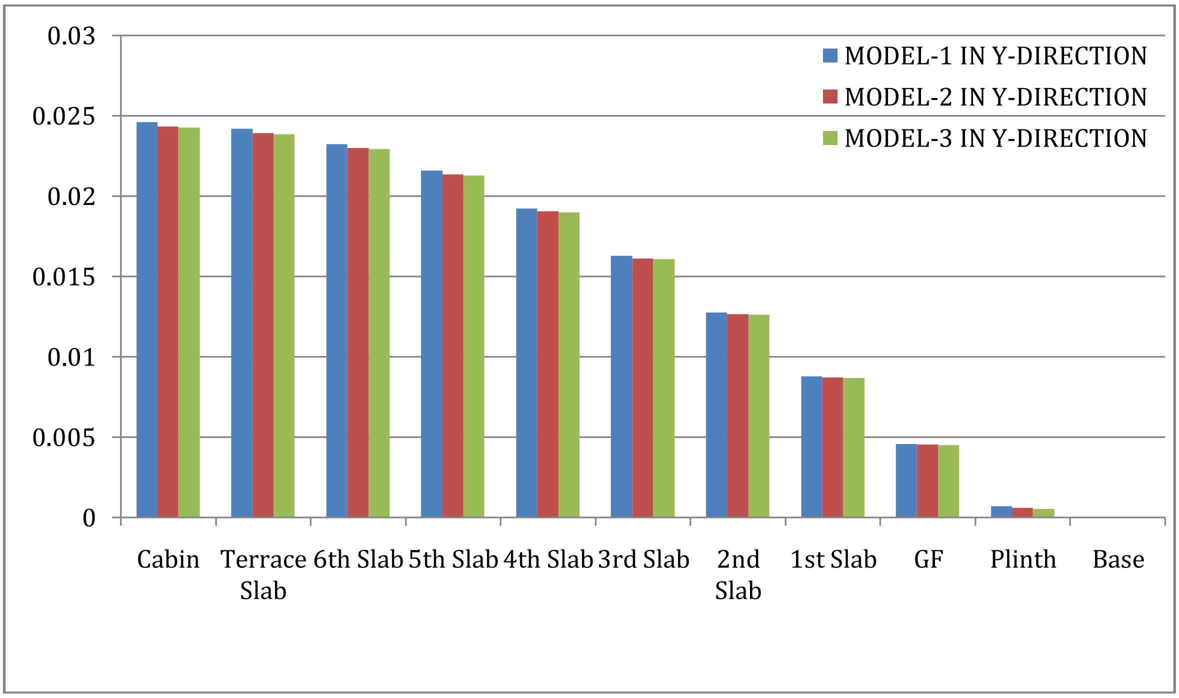

Fig 8 Graph of Maximum Story Displacement in Y-Direction of Model-1,2,3

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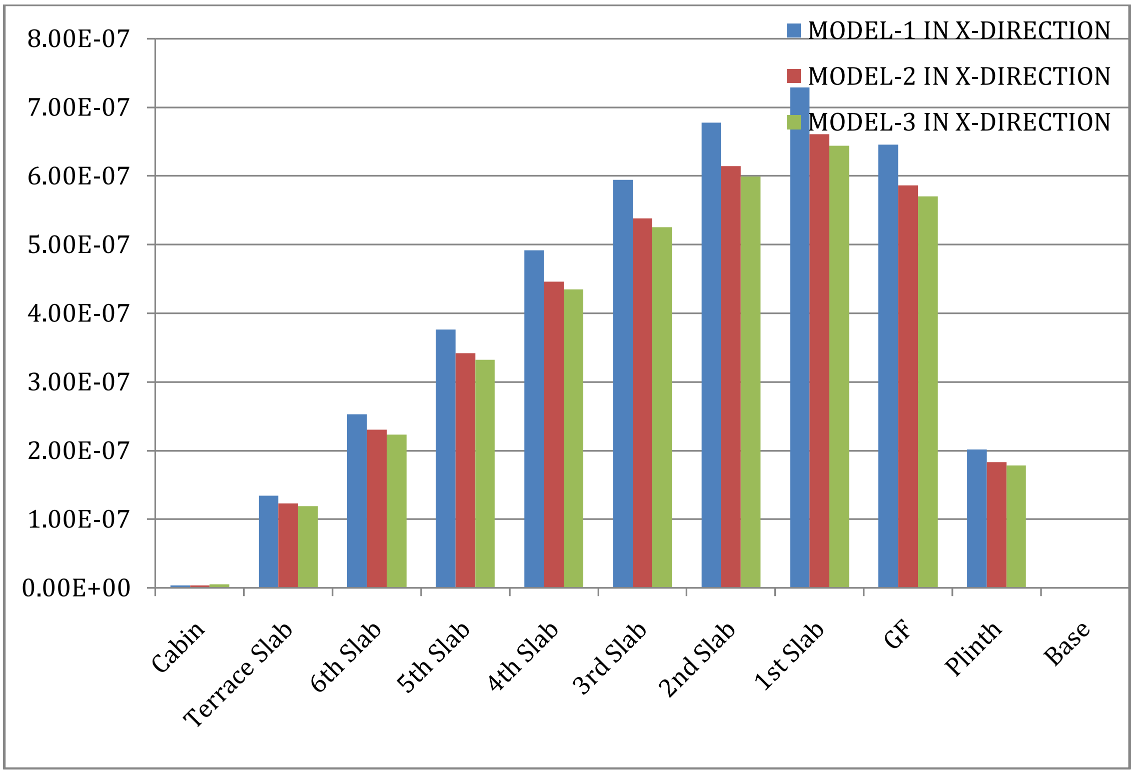

Fig 9 Graph of Maximum Story Drifts in X-Direction of Model-1,2,3

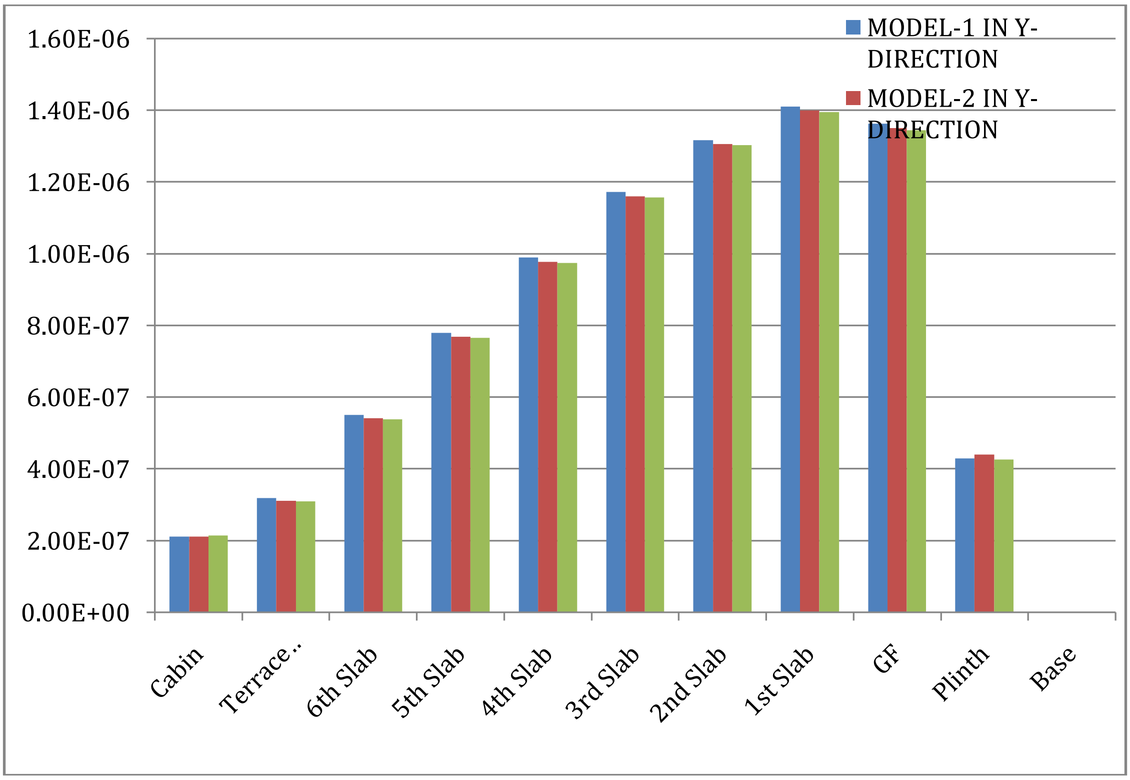

Fig 10 Graph of Maximum Story Drifts in Y-Direction of Model-1,2,3

4.2 Results of Model – 4,5,6 :

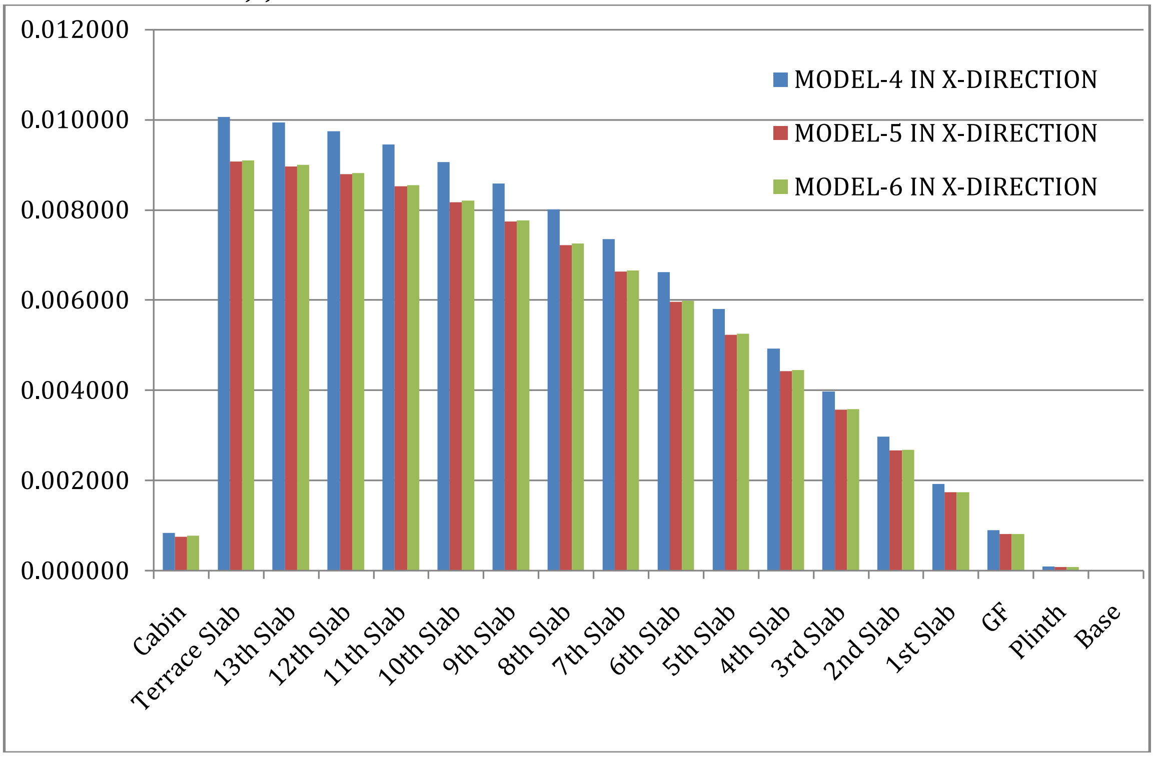

Fig 11 Graph of Maximum Story Displacement in X-Direction of Model-4,5,6

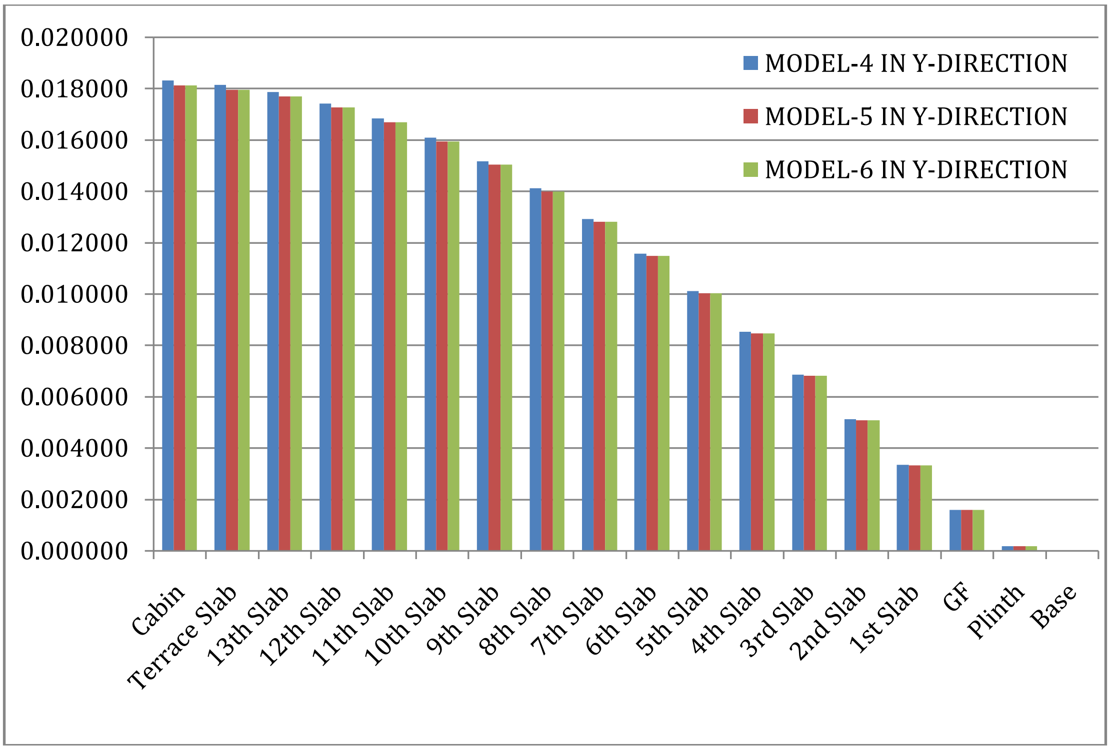

Fig 12 Graph of Maximum Story Displacement in Y-Direction of Model-4,5,6

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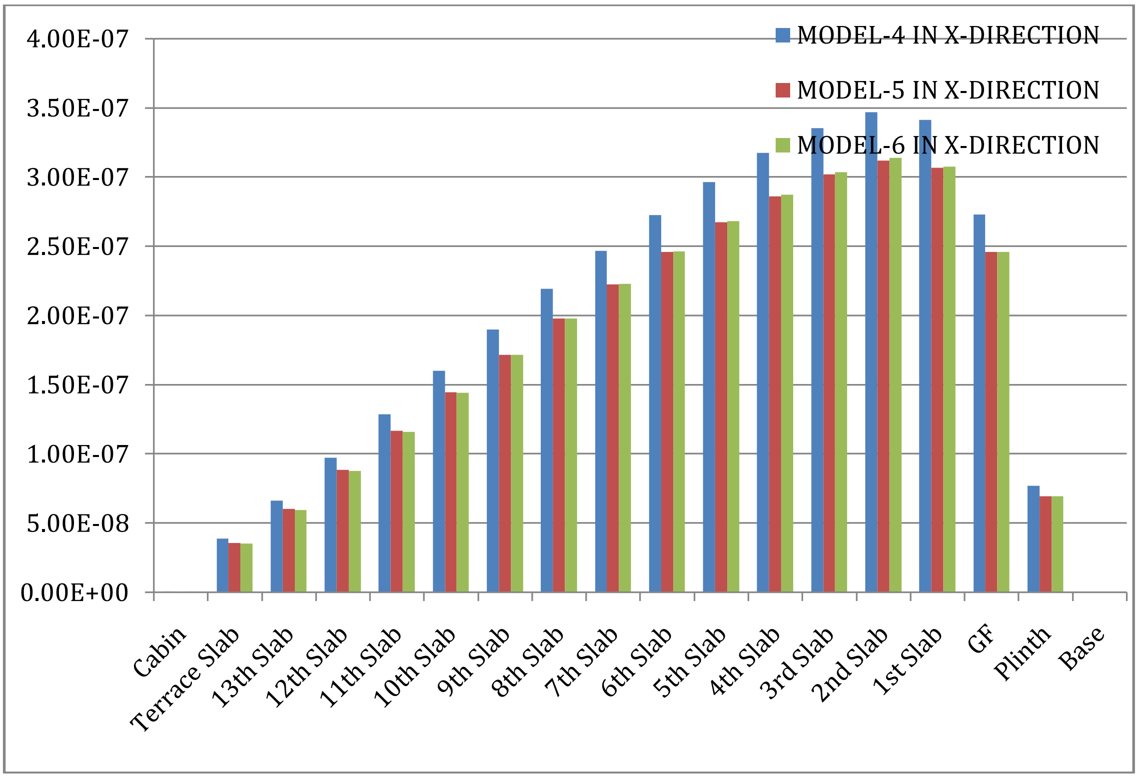

Fig 13 Graph of Maximum Story Drifts in X-Direction of Model-4,5,6

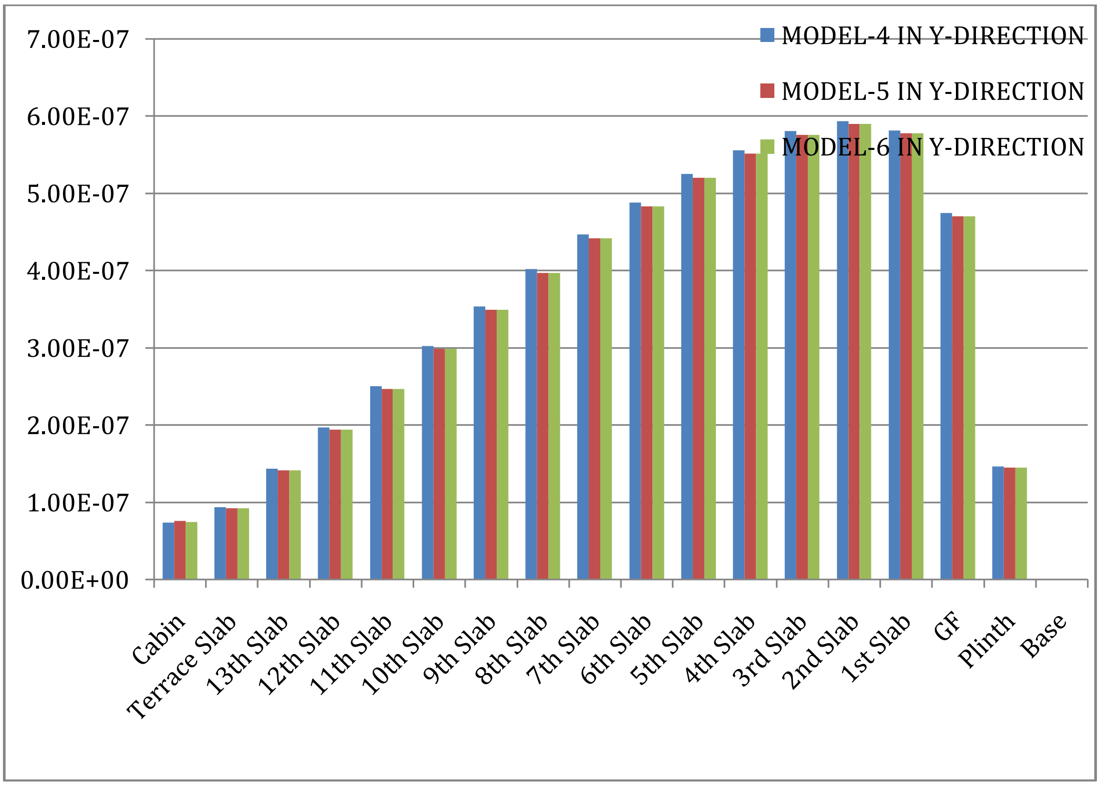

Fig 14 Graph of Maximum Story Drifts in Y-Direction of Model-4,5,6

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V. CONCLUSION

- From the study, it is observed that the percentage of rebar reinforcement changes with change in type of staircase.
- From the study, it is observed that the Maximum Story Displacement value of Model-1 is greater than Model -2 and Model -3 , Model -2 value is greater than Model-3, Model -3 Value is less than Model-1 and Model -2 .
- From the study, it is observed that the Maximum Story Displacement value of Model-4 is greater than Model -5 and Model -6 , Model -5 value is greater than Model-6, Model -6 Value is less than Model-4 and Model -5 .
- From the study, it is observed that the Maximum Story Displacement (D+L) value of Model-1 is greater than Model -2 and Model -3 , Model -2 value is greater than Model-3, Model -3 Value is less than Model-1 and Model -2 .
- From the study, it is observed that the Maximum Story Displacement (D+L) value of Model-4 is greater than Model -5 and Model -6 , Model -5 value is greater than Model-6, Model -6 Value is less than Model-4 and Model -5 .

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