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SEISMIC ANALYSIS OF MULTISTOREY BUILDING ON FLAT AND SLOPING GROUND WITH DIFFERENT SLABS TYPE

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Abstract: In this research paper traditional construction methods like conventional slab, waffle slab, and flat slab structures with drop panels are being employed on inclined land with varying degrees of slope. Specifically, the study focuses on three models of 15-story structures: one positioned on a 0° slope, another on a 5° slope, and a third on a 10° slope. These models are meticulously generated using the ETABS 20 structural analysis software. The subsequent analysis encompasses critical parameters such as displacement, storey drifts, and base shear. The seismic assessment adheres to the guidelines outlined in IS-1893 2016.

The results of the analysis, which include irregularities, are methodically tabulated and subsequently subjected to detailed scrutiny. Additionally, a graphical comparison of the outcomes is provided for visual clarity.

Index Terms - sloped terrain, hilly areas, conventional slab, flat slab, waffle slab, ETABS software.

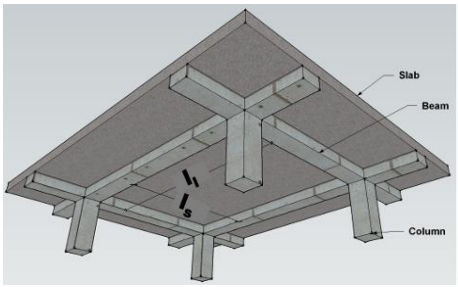
I. INTRODUCTION

1.1 GENERAL:

The term "earthquake" encompasses various types of seismic disturbances, which can either occur naturally or be induced by human activities, resulting in seismic waves. Earthquakes are primarily triggered by the rupture of geological faults. Seismicity is a term used to describe the overall pattern and behaviour of earthquakes in a particular region. It helps seismologists and geologists understand the geological processes occurring beneath the Earth's surface and assess the potential seismic hazards in that area. Seismicity can vary greatly from one region to another, and monitoring and studying seismicity is crucial for earthquake prediction, preparedness, and mitigation efforts.

1.2 CONVENTIONAL SLAB:

A traditional slab is one that is held up by shafts and columns. As a result, the cargo is transferred to the ray and the column since the slab consistence is low and the ray's depth is high. In contrast to flat crossbeams, this need additional formwork. Traditional crossbeams do not require a column cap. When concrete will be subjected to heavy loads on a frequent basis, such as motorhomes or scrap exchanges, 5 to 6 elevations are advised rather than the usual 4 elevation or 10 cm. Underpinning is provided by strips that are put both

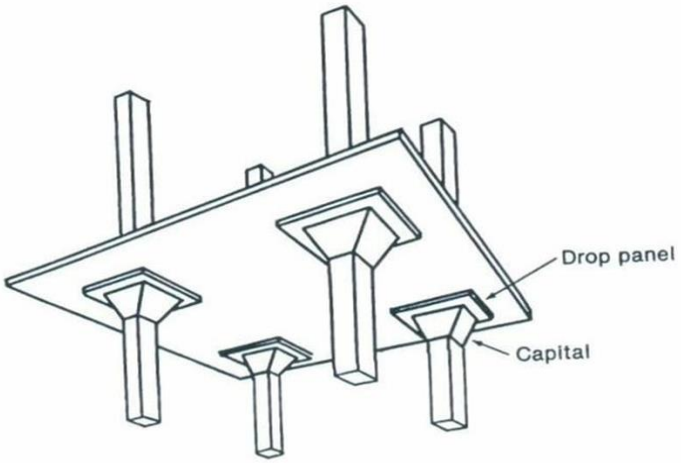


horizontally and vertically in the typical form of crossbeams. The horizontally mounted strips are referred to as primary underpinning bars. while the strips that are installed vertically are known as distribution bars.

Fig-1 Conventional Slab

1.3 FLAT SLAB:

The construction method known as "slab-beam construction" involves the direct support of reinforced concrete slabs by beams, with these beams being supported by columns. However, the presence of beams in this construction approach can decrease the usable clear height of the floor. In some cases, particularly in buildings such as offices, warehouses, and public halls, aesthetic preferences may lead to the omission of beams. As a result, concrete slabs are directly placed onto the columns without the use of intermediate beams. This design choice aims to create open and visually pleasing spaces but should be carefully considered for

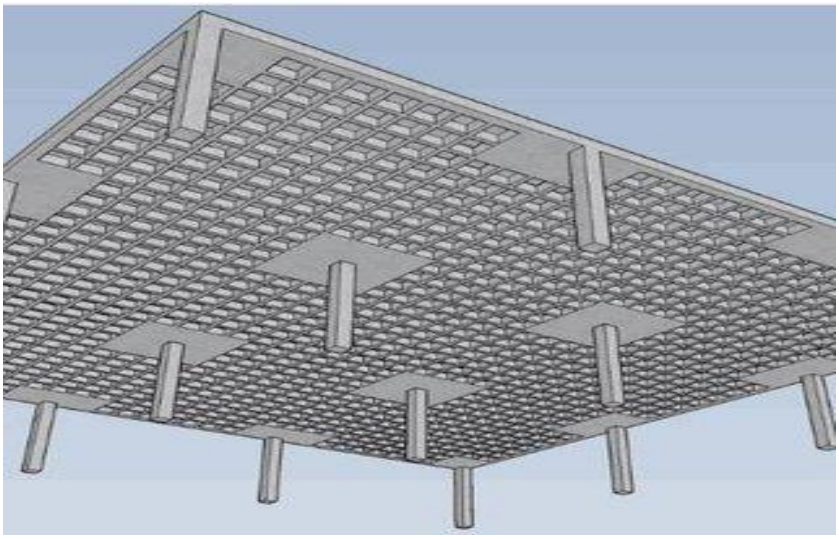


both structural and design implications. These types of slab constructions that rely on direct support from columns are commonly referred to as "flat slabs," as depicted in the illustration below.

Fig-2 Flat Slab

1.4 WAFFLE SLAB:

A waffle slab, often referred to as a two-way joist slab, is a reinforced concrete slab Waffle slabs are known for their superior structural strength when compared to other types of slabs like flat slabs with drop panels, two-way slabs, one-way slabs, and one-way joist slabs. This increased strength and load-bearing capacity



make waffle slabs a popular choice for applications where spans exceed 40 feet (approximately 12 meters).

Fig-3 waffle Slab

II. LITERATURE REVIEW

1. **Likhitharadhya Y R, Praveen J V, Sanjith J, Ranjith A "Seismic Analysis of Multi-Storey Building Resting On Flat Ground and Sloping Ground"**

   Structures are typically built on suitable ground conditions, but when those conditions are not met, construction efforts might commence on less ideal ground. There are two main approaches for constructing on less ideal ground: the "step back" method and the "step back setback" method. In this study, a G 10 narrative RCC structure with ground slopes ranging from 100 to 300 degrees is analysed.

2. **Dr. S. A. Halkude, Mr. M. G. Kalyanshetti, Mr. V. D. Ingle "Seismic Analysis of Buildings Resting on Sloping Ground with Varying Number of Bays and Hill Slopes"**

   In hilly regions where geographical constraints come into play, construction projects often require the use of architectural configurations involving step-back or both step-back and set-back elements. These configurations result in a structural design that frequently exhibits irregularities stemming from differing column heights within permissible limits. These variations can, in turn, give rise to torsional effects and heightened shear forces, especially during seismic events. In areas characterized by varying slopes and a diverse number of building bays, two specific types of building frames, namely step-back frames and step-back & set-back building frames, undergo analysis using response spectrum analysis (RSA).

3. **K Veera Babu, S Siva Rama Krishna, Venu Malagavelli "Seismic analysis of Multi storey Building on Sloping Ground and Flat Ground by using ETABS"**

   The study's objective was to explore the behaviour of structures built on sloped and inclined terrain, with a specific focus on hilly regions, primarily in emerging countries like India, where land availability is limited. The construction of multistorey buildings on mountainous terrain presents unique challenges due to the uneven and asymmetrical nature of the landscape. These structures are especially vulnerable to earthquake stresses when compared to buildings on flat ground. The primary focus of the study was to understand the behaviour of structures on sloped terrain, especially in comparison to structures on level ground, considering Earthquake Zone II.

III. OBJECTIVES OF STUDY

1. TO EVALUATE THE PERFORMANCE OF RCC FRAME WITH CONVENTIONAL SLAB, FLAT SLAB, AND WAFFLE SLAB STRUCTURE ON PLAIN GROUND AND INCLINED GROUND. ALONG THE BUILDING'S HORIZONTAL LENGTH, THE ANGLES ON SLOPING TERRAIN RANGE FROM 0° TO 10° (0°, 5° & 10°).
2. TO EXAMINE HOW STOREY DISPLACEMENT VARIES IN RELATION TO CHANGES IN HILL SLOPE ANGLE FOR VARIOUS BUILDING FRAME TYPES.
3. TO EXAMINE HOW FOUNDATION SHEAR VARIES FOR VARIOUS BUILDING FRAME TYPES IN RELATION TO CHANGES IN HILL SLOPE ANGLE.
4. TO EXAMINE HOW THE VARIANCE IN STOREY DRIFT FOR VARIOUS BUILDING FRAME LAYOUTS RELATES TO THE VARIATION IN HILL SLOPE ANGLE

IV. METHODOLOGY

1. in this study, nine (9) sets of buildings were examined, and it's important to note that each set shares the same model plan.
2. Medium soil condition is considered
3. Seismic zone 4 is considered
4. Three sets with conventional, flat & grid slab on plain ground is considered.
5. Three sets with conventional, flat & grid slab resting on a sloping ground angle of 5°, three sets with conventional, flat & grid slab resting on a sloping ground at an angle of 10°Sloping
6. Total number of models =9
7. The models used in this study were created using ETABS 2020, a structural analysis software.

V. MODELLING AND ANALYSIS

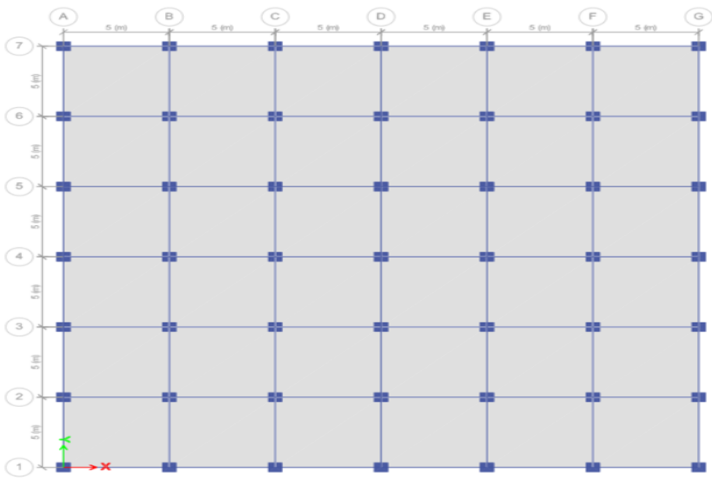


Fig-6 Plan Of Model

BUILDING INFORMATION

Number of storeys	:	16
Floor height	:	3.0 m
Soil type	:	Medium (type II)
Seismic zone	:	IV

MATERIALS

Grade of Concrete	:	M30
Grade of Steel	:	Fe-550

MEMBER DIMENSIONS

Size of Column	:	675mm X 675mm
Size of Beam	:	230mm x 450mm
Wall thickness	:	230 mm
Slab thickness	:	150 mm

For flat slab models

Slab thickness	:	150mm
Drop panel size	:	3m
Drop panel thickness	:	350mm

For waffle slab models

Overall depth	:	350mm
Slab thickness	:	150mm
Stem width at top and bottom	:	125mm
Spacing of ribs	:	800mm

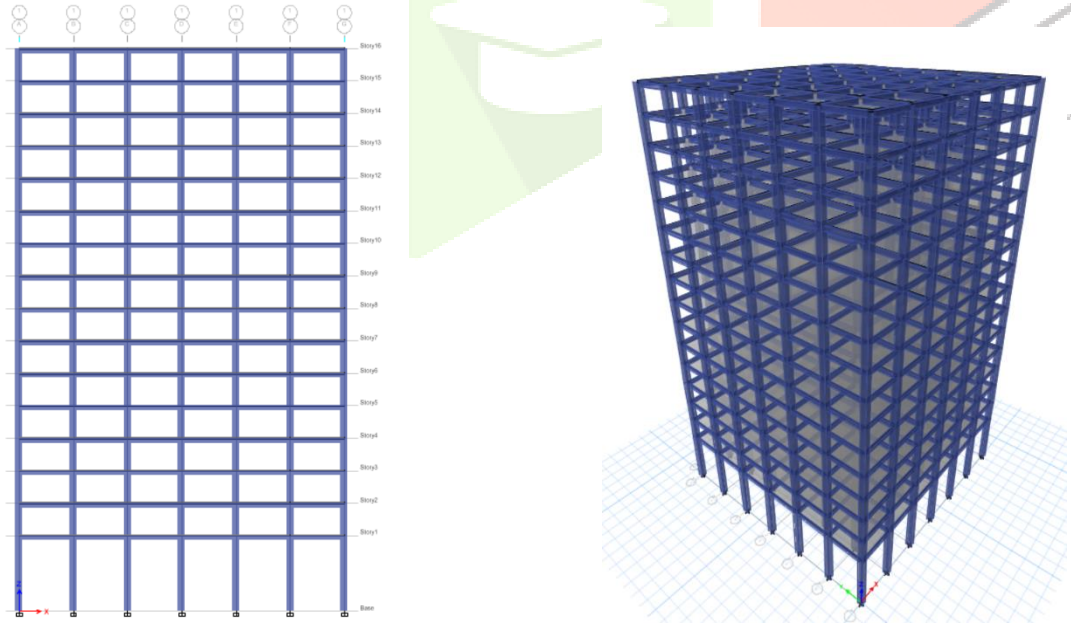
LOADS

LL	:	3.0 KN/m²
FF	:	1.0 KN/m²

DATA

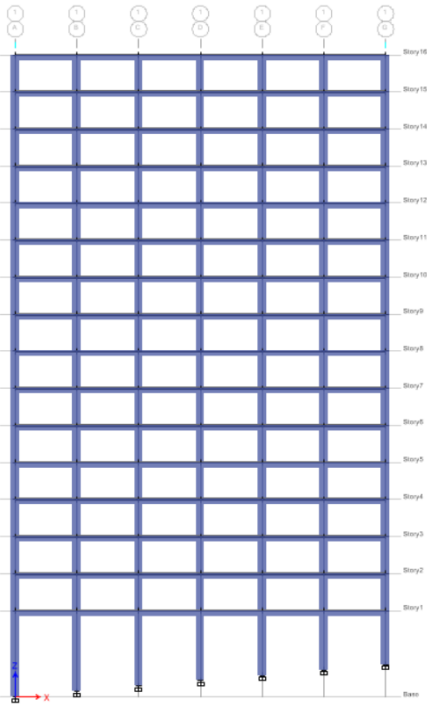
Response reduction	:	5
Zone factor (Z)	:	0.24
Site type	:	II
Importance factor	:	1.0

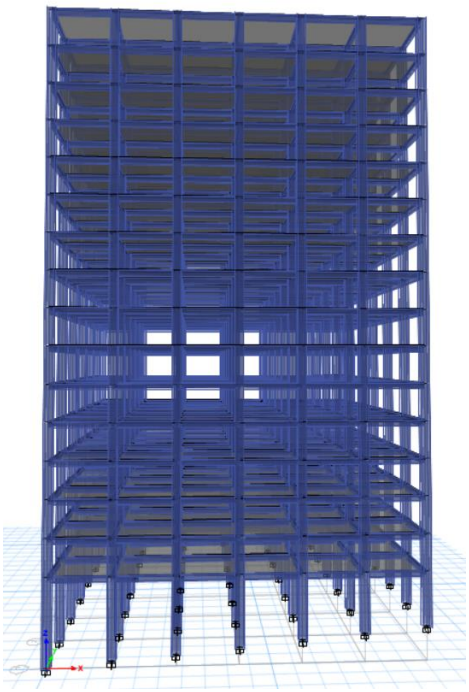
MODEL NO 1



Conventional Slab at 0 Degree Slope

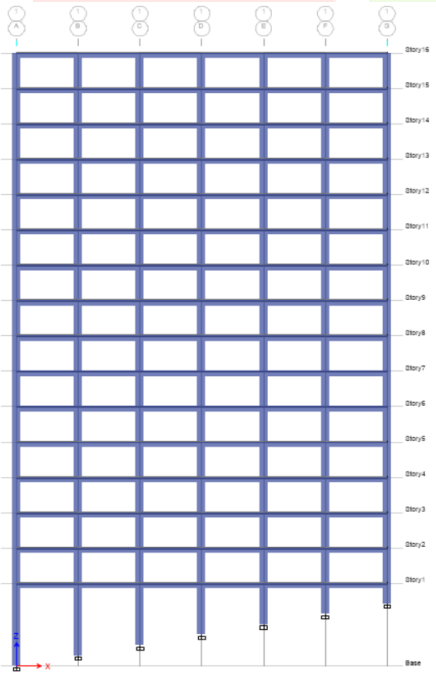
MODEL NO 2

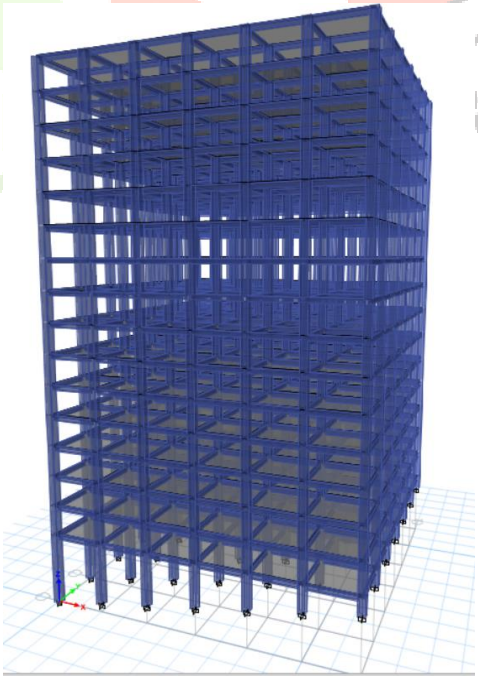




Conventional Slab at 5 Degree Slope

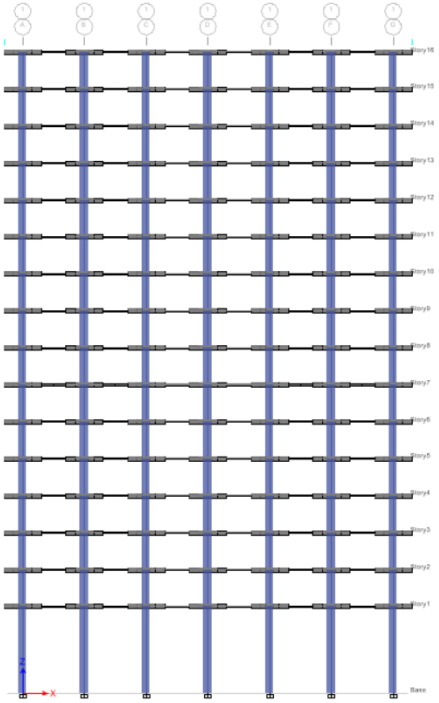
MODEL NO 3

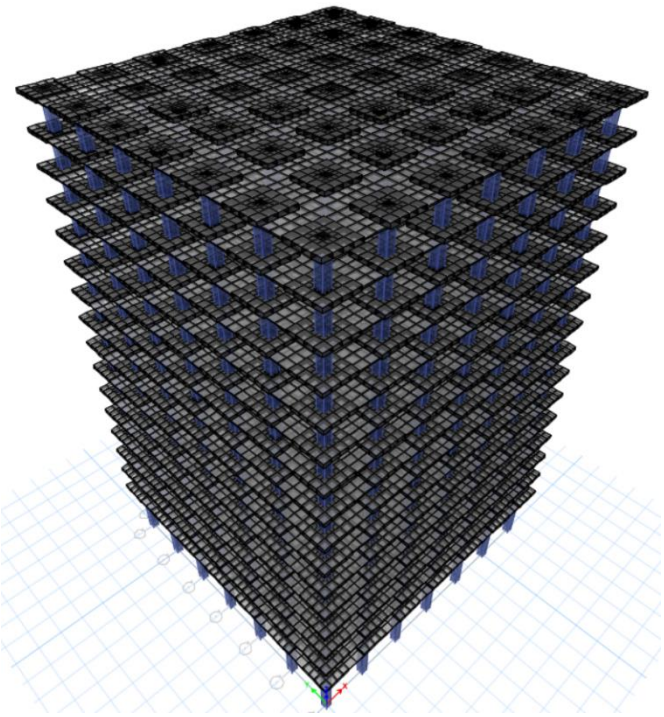




Conventional Slab at 10 Degree Slope

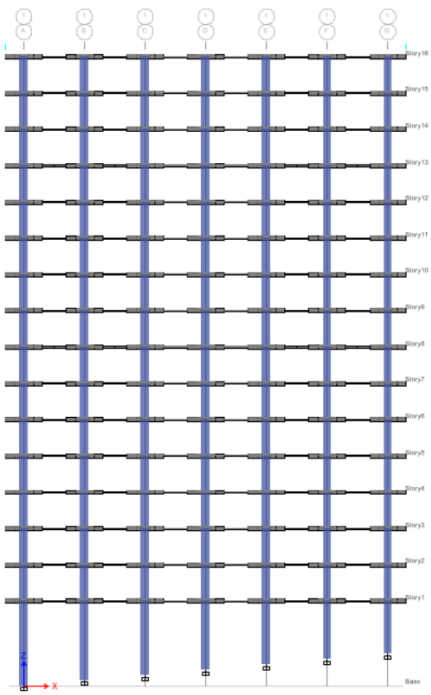
MODEL NO 4

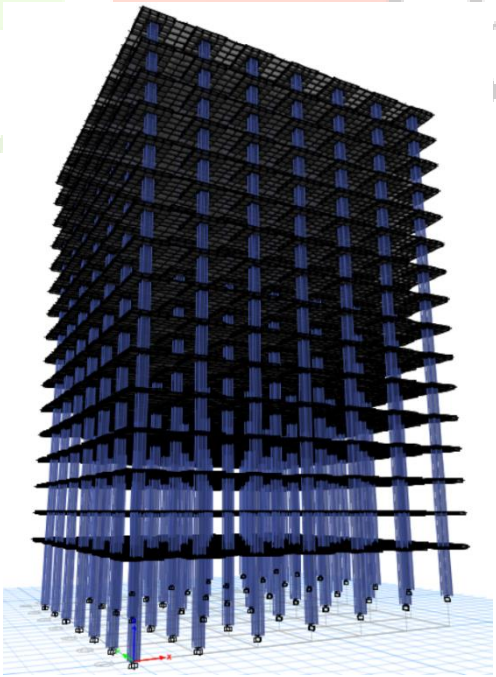




Flat Slab at 0 Degree Slope

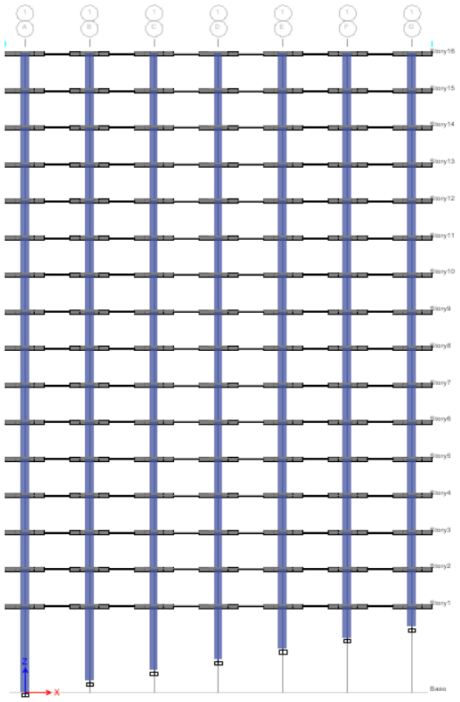
MODEL NO 5

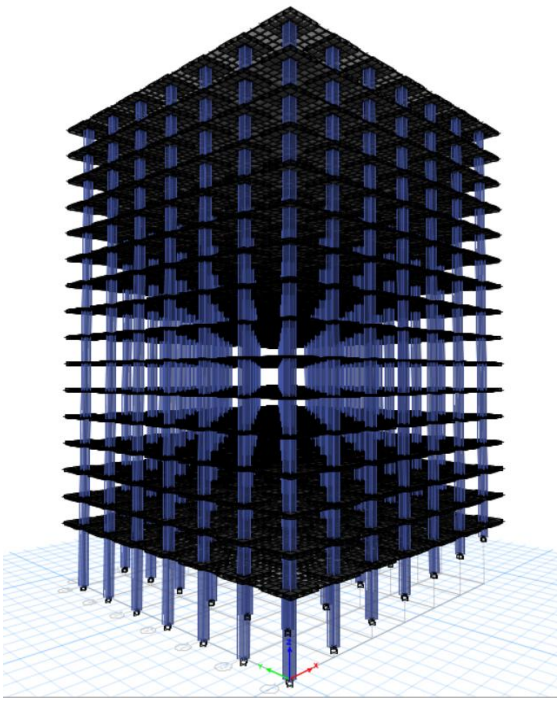




Flat Slab at 5 Degree Slope

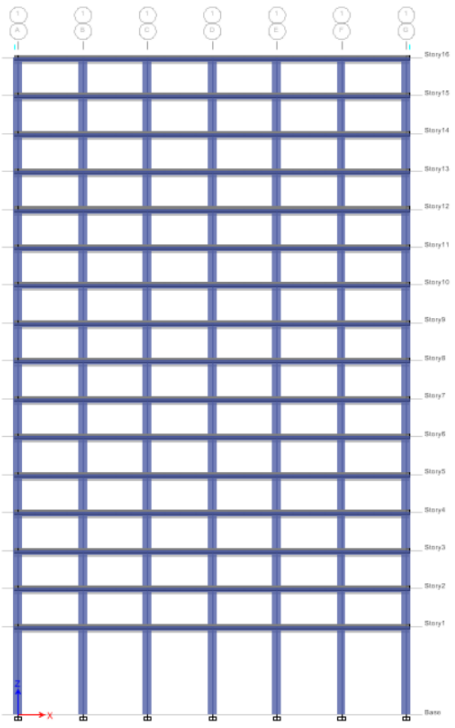
MODEL-6

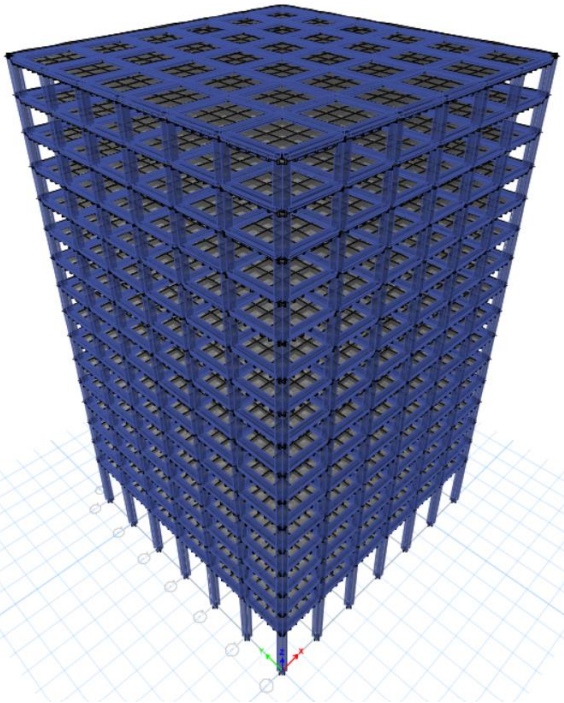




Flat Slab at 10 Degree Slope

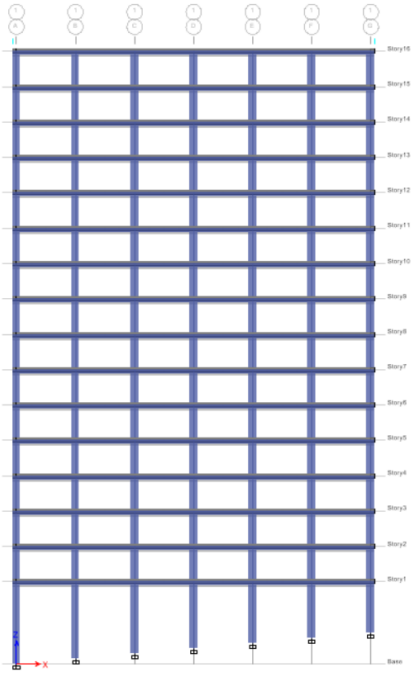
MODEL NO 7

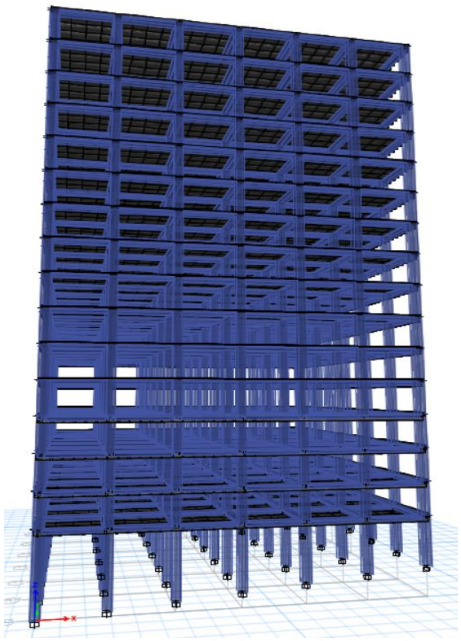




Waffle Slab at 0 Degree Slope

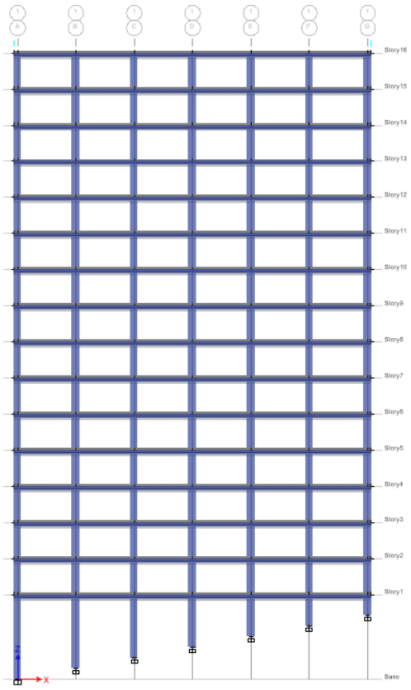
MODEL NO 8

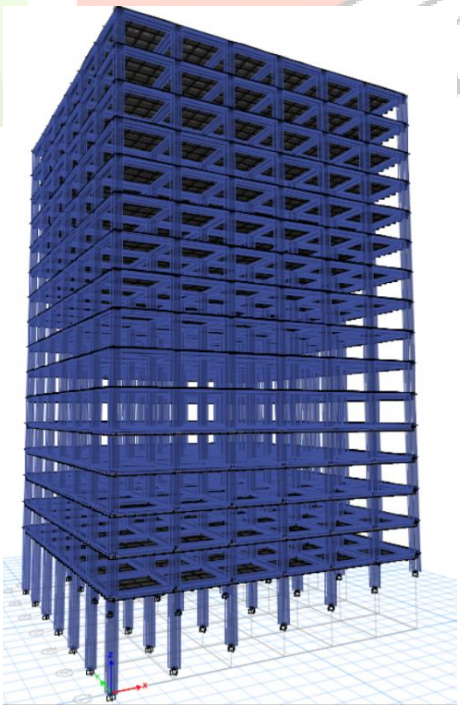




Waffle Slab at 5 Degree Slope

MODEL NO 9



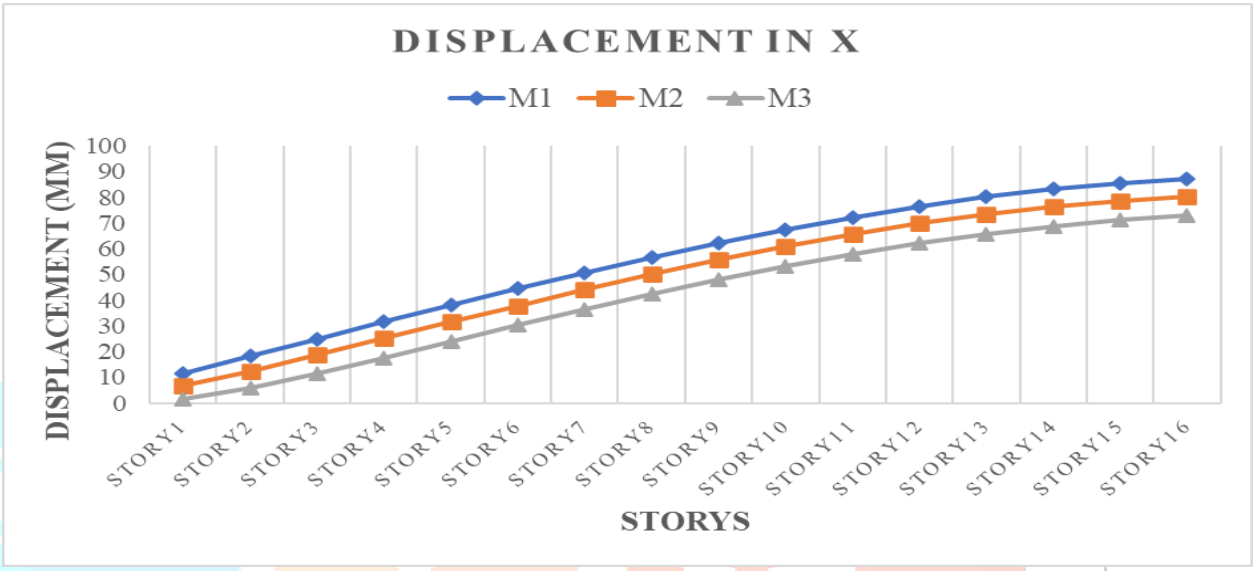


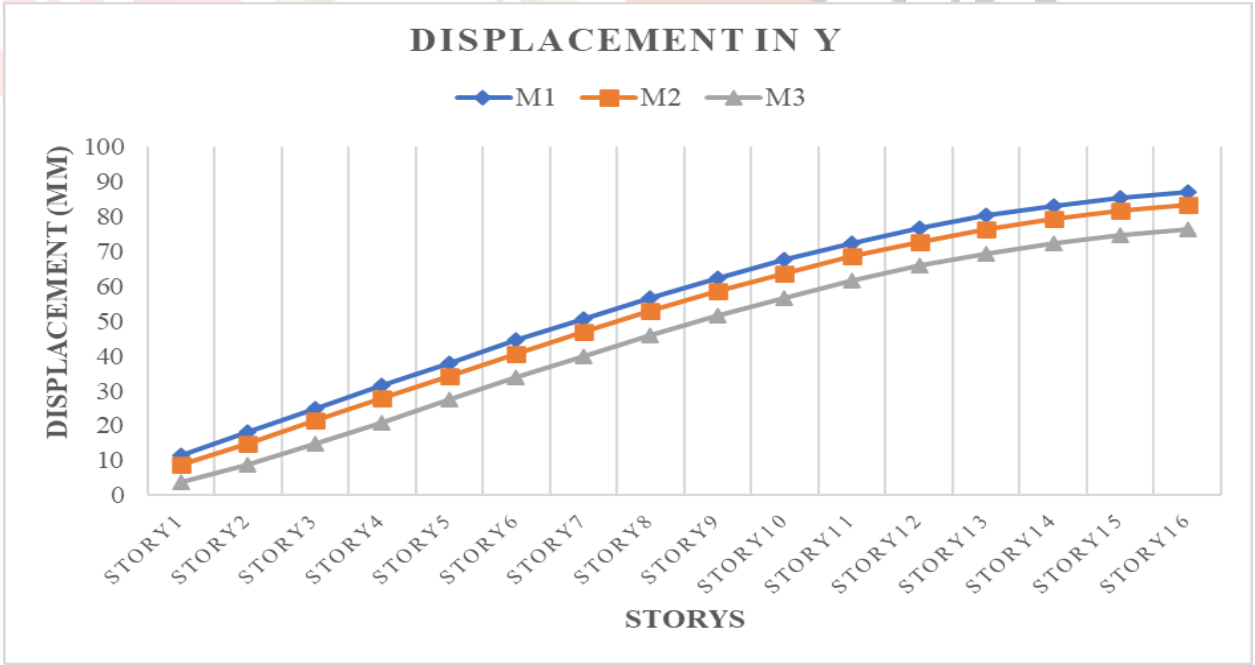
Waffle Slab at 10 Degree Slope

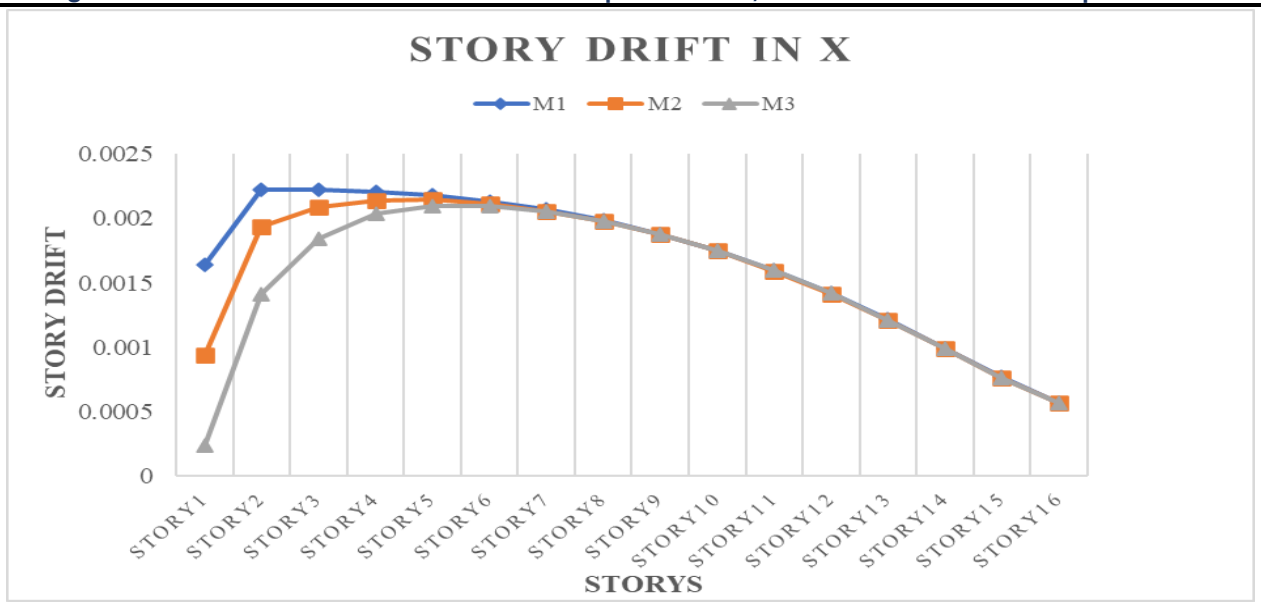
VI. RESULTS AND DISCUSSION

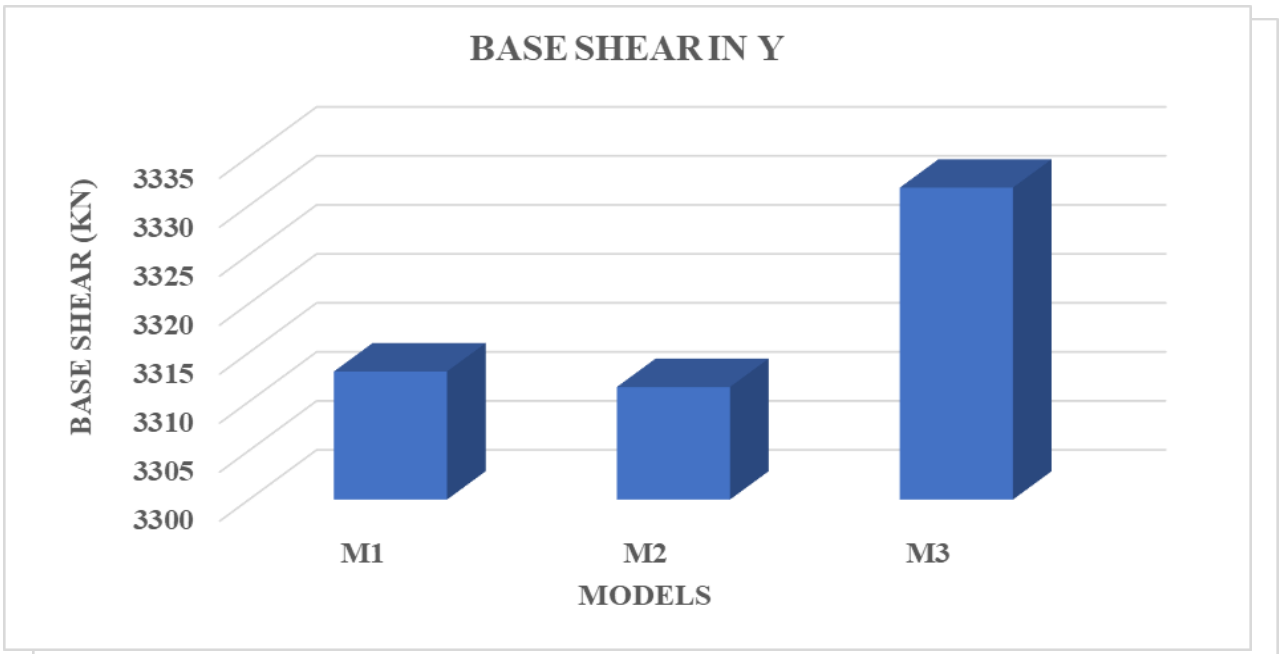
In this study we've taken 9 number of models out of which 3 models of conventional slab, 3 models of flat slab and 3 models of waffle slab are considered. The models MI, M4, M7 are of plain ground models, Models M2, M5, M8 are of 5 degree leaning ground, Models M3, M6, M9 are of 10 degree leaning ground.
The results of displacement, storey drift, base shear for 16 storey model that are obtained are plotted in graphs as shown in Figs

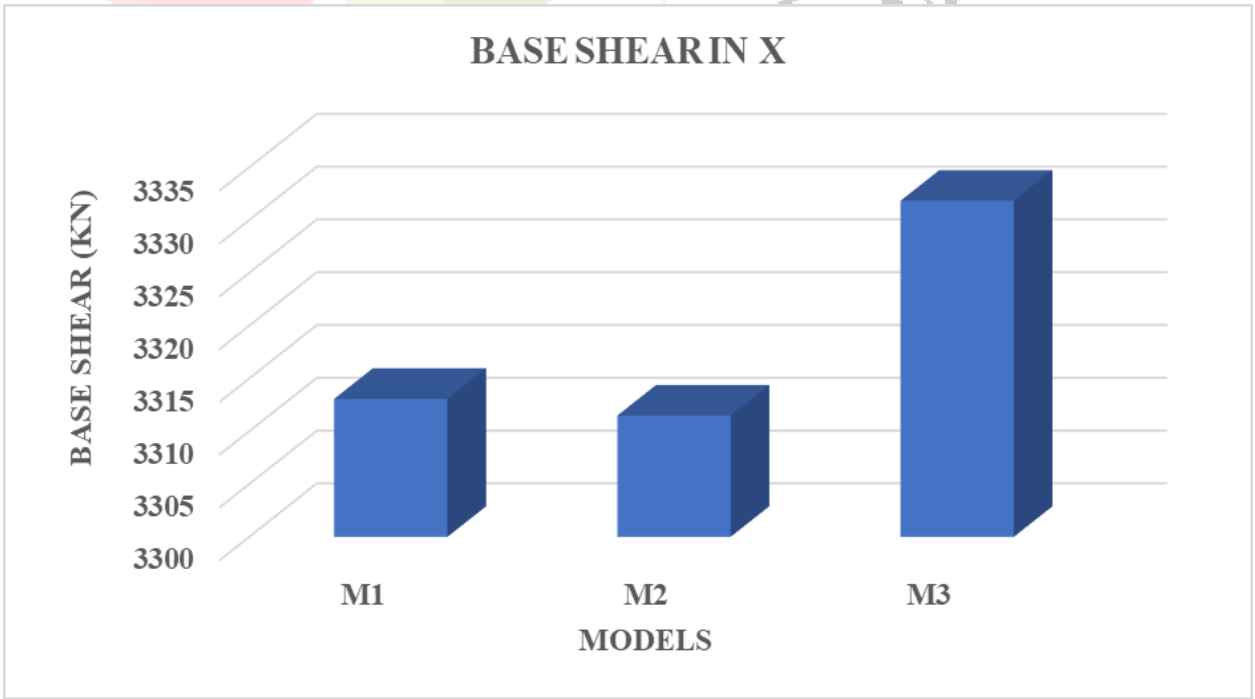
CONVENTIONAL SLAB:



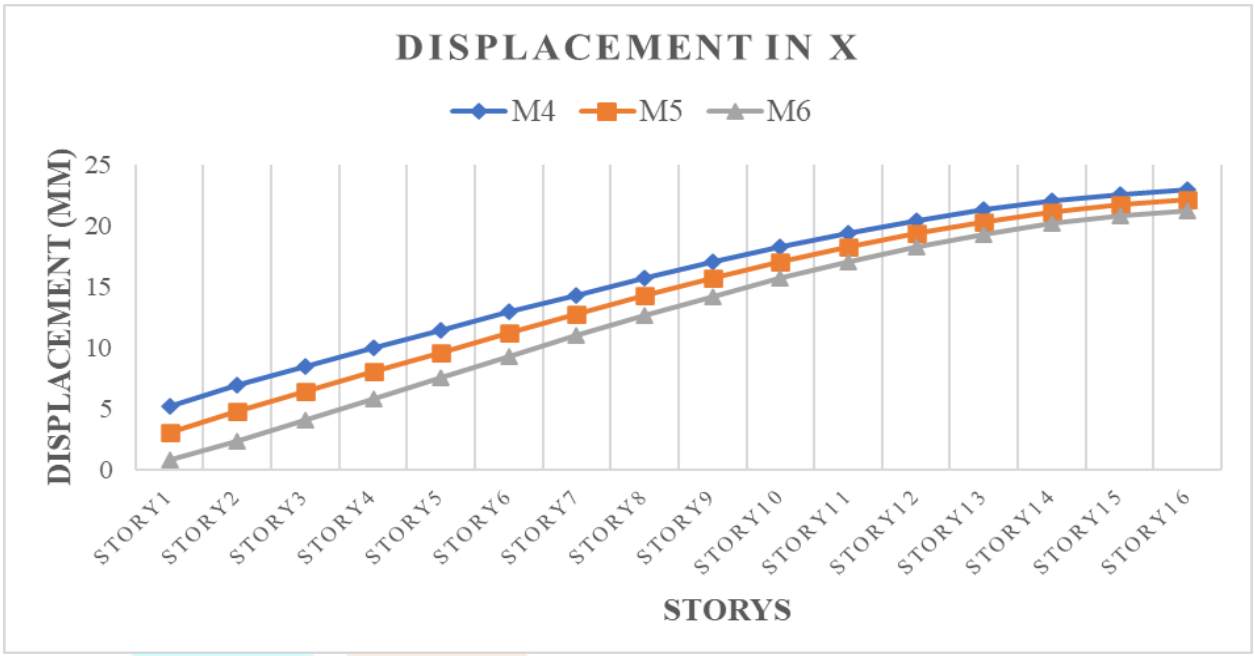


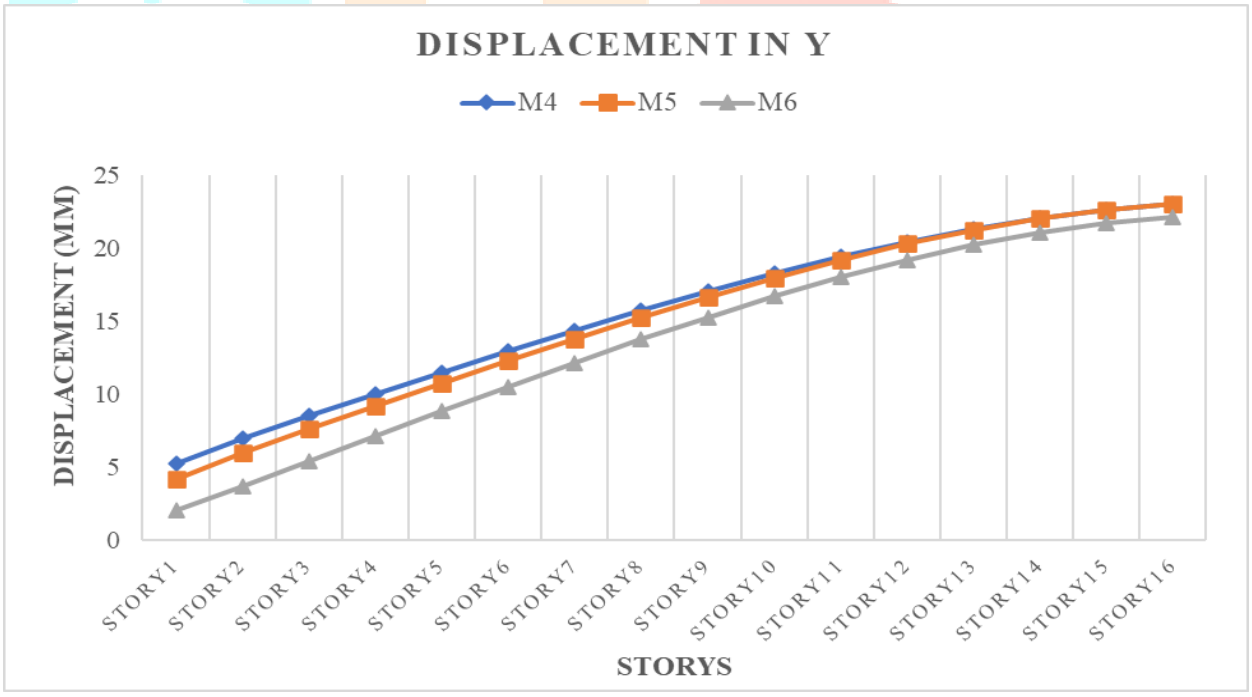

STORY DRIFT IN X
M1
M2
M3
STORY DRIFT
0.0025
0.002
0.0015
0.001
0.0005
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS

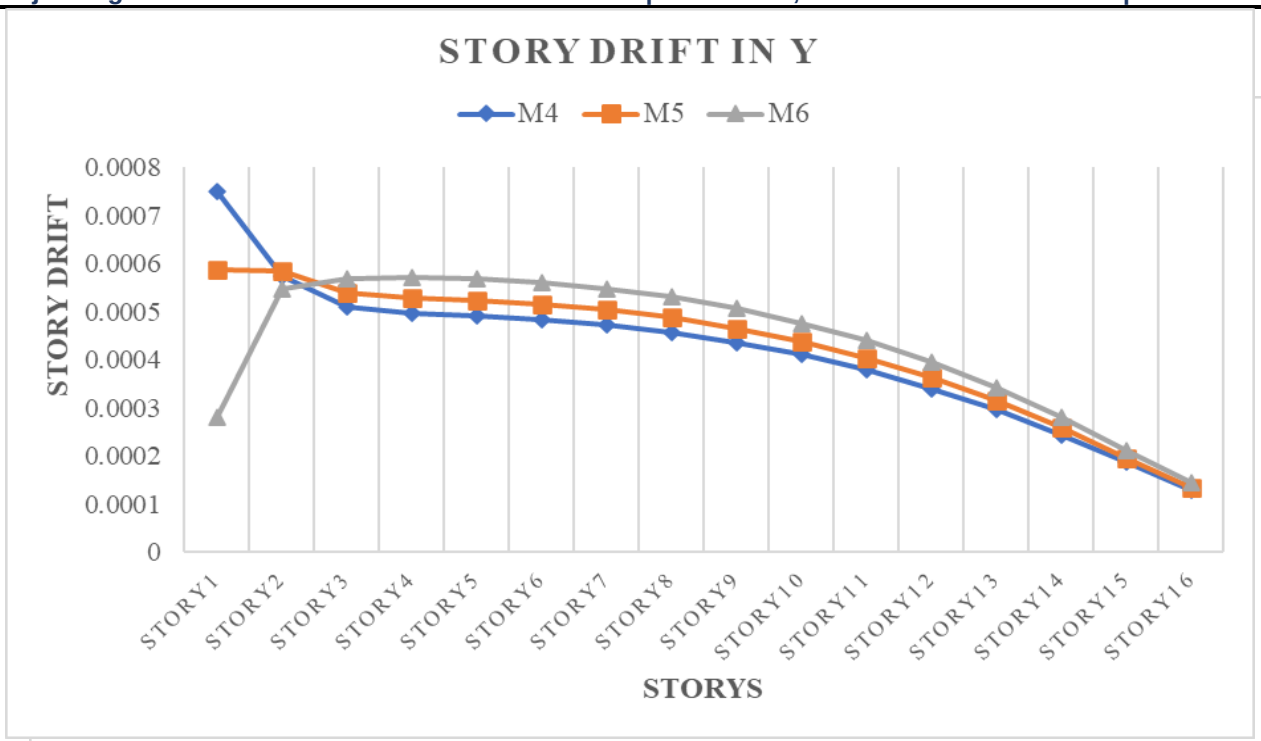

BASE SHEAR IN Y
BASE SHEAR (KN)
3335
3330
3325
3320
3315
3310
3305
3300
M1
M2
M3
MODELS

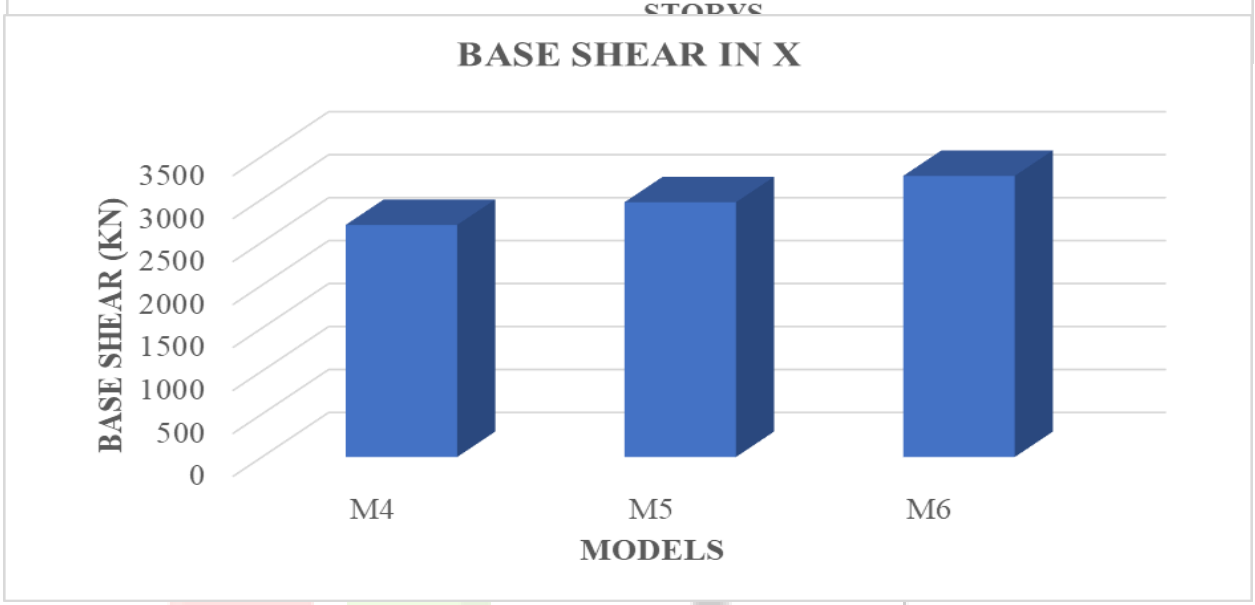

BASE SHEAR IN X
BASE SHEAR (KN)
3335
3330
3325
3320
3315
3310
3305
3300
M1
M2
M3
MODELS

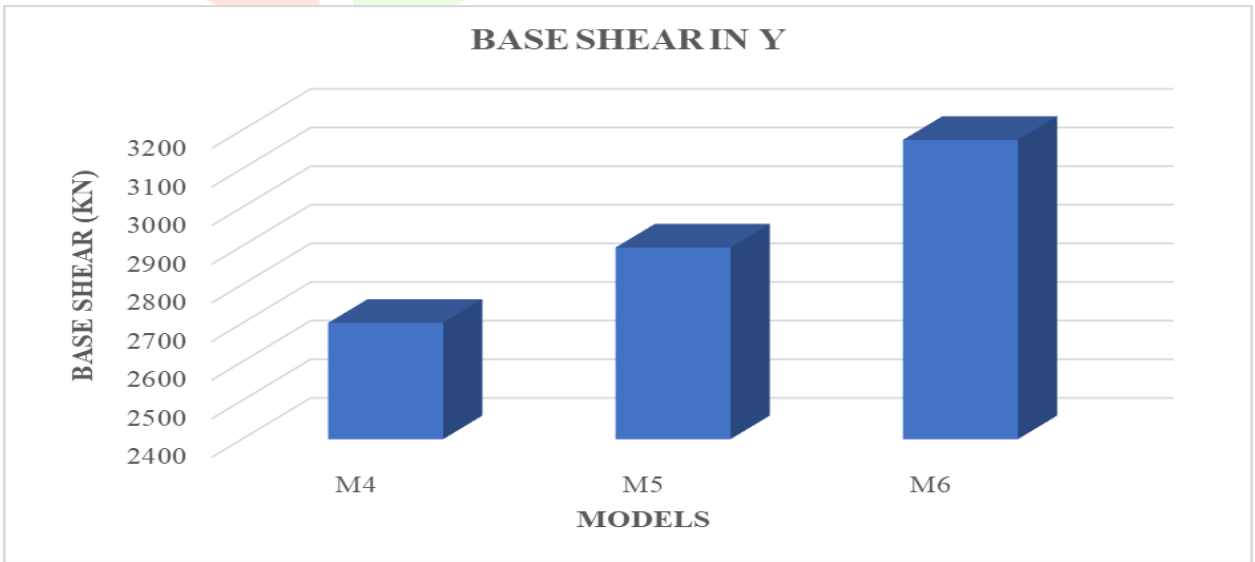
FLAT SLAB:


DISPLACEMENT IN X
M4
M5
M6
DISPLACEMENT (MM)
25
20
15
10
5
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS

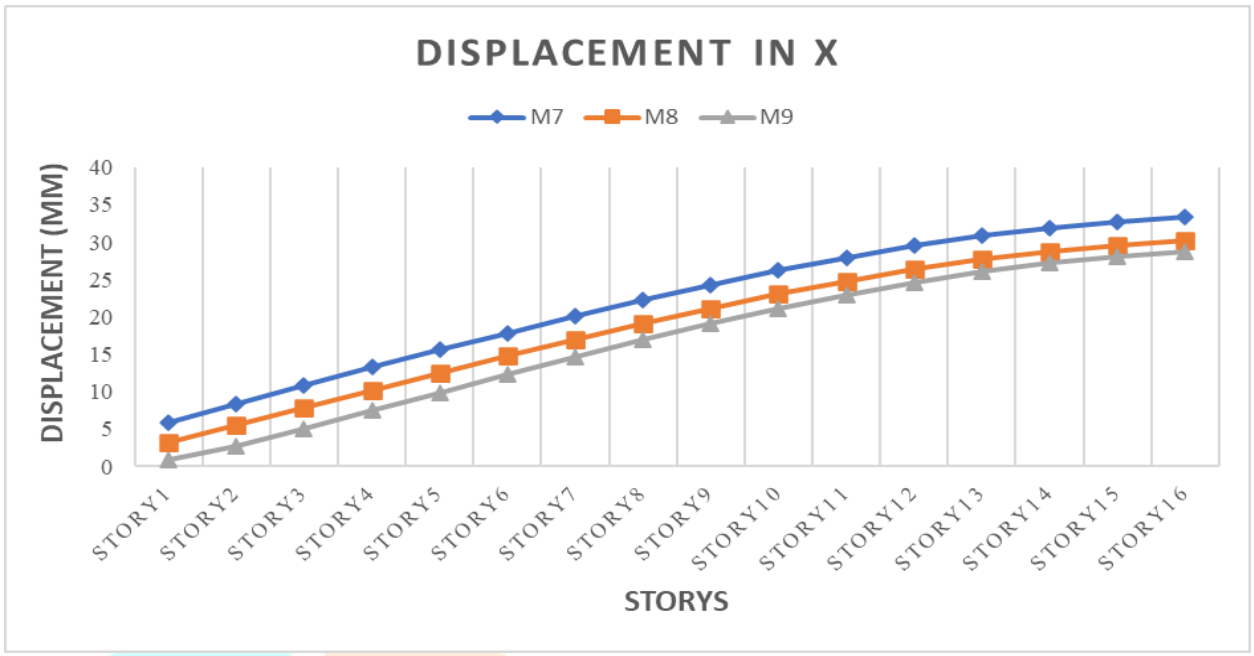

DISPLACEMENT IN Y
M4
M5
M6
DISPLACEMENT (MM)
25
20
15
10
5
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS

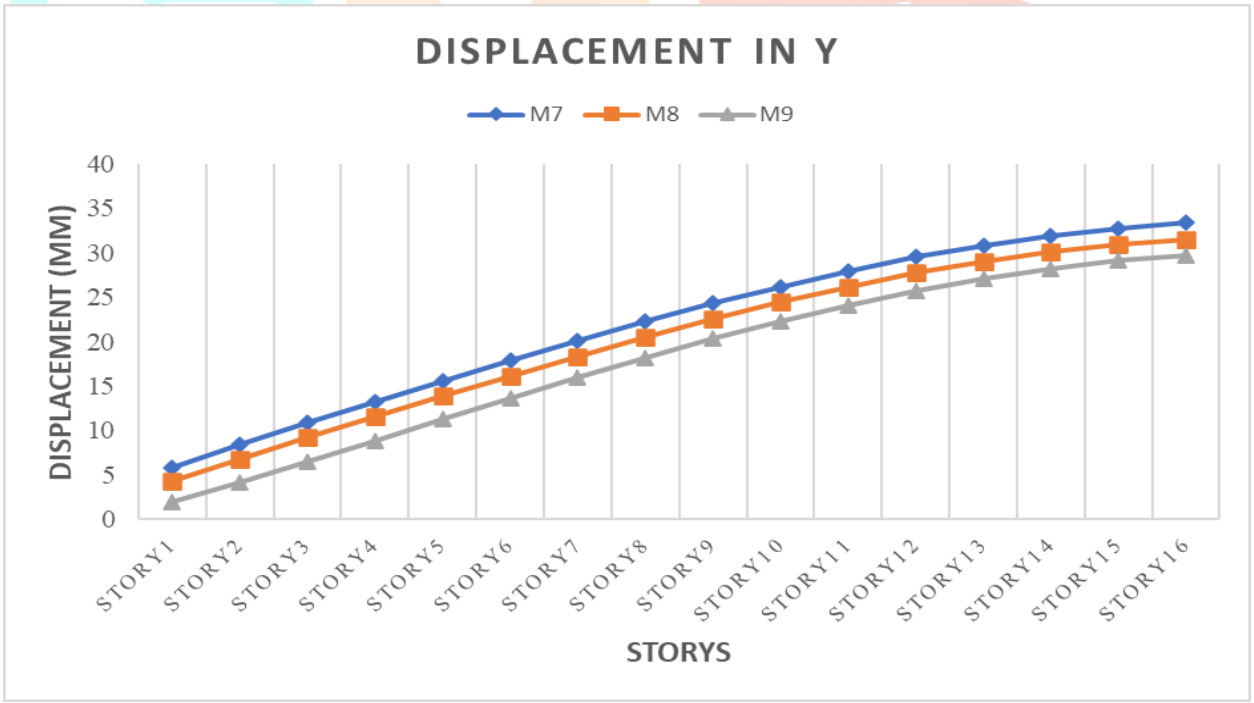

STORY DRIFT IN Y
M4
M5
M6
STORY DRIFT
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS

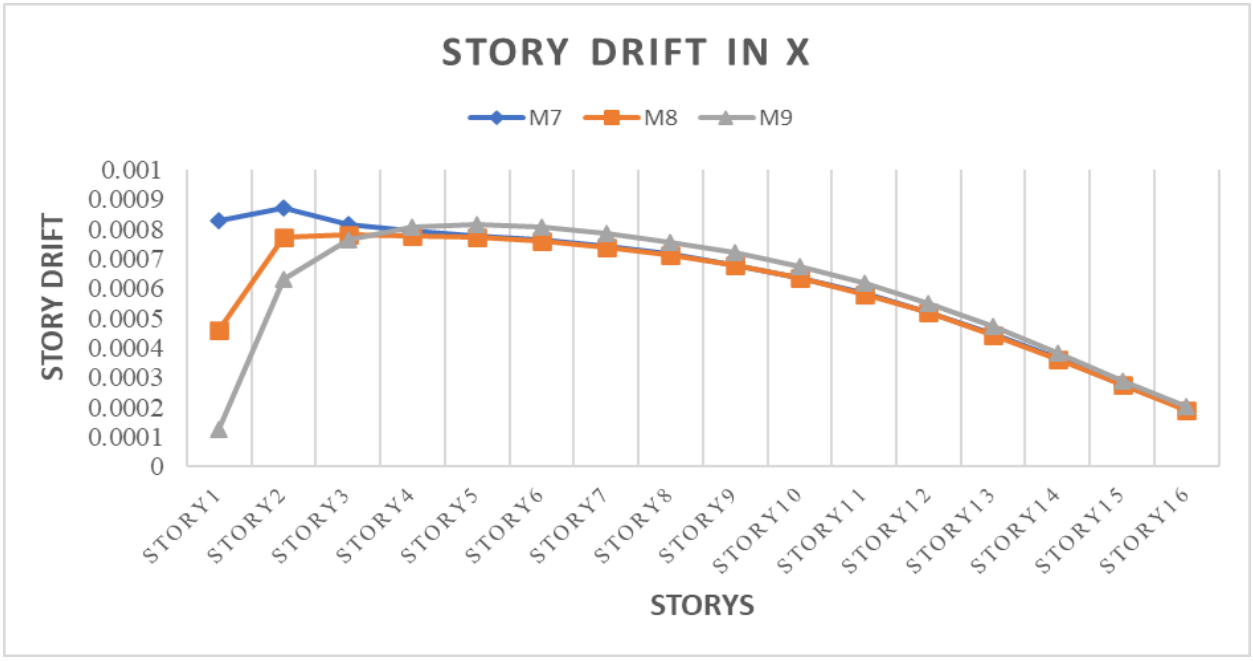

BASE SHEAR IN X
BASE SHEAR (KN)
3500
3000
2500
2000
1500
1000
500
0
M4
M5
M6
MODELS

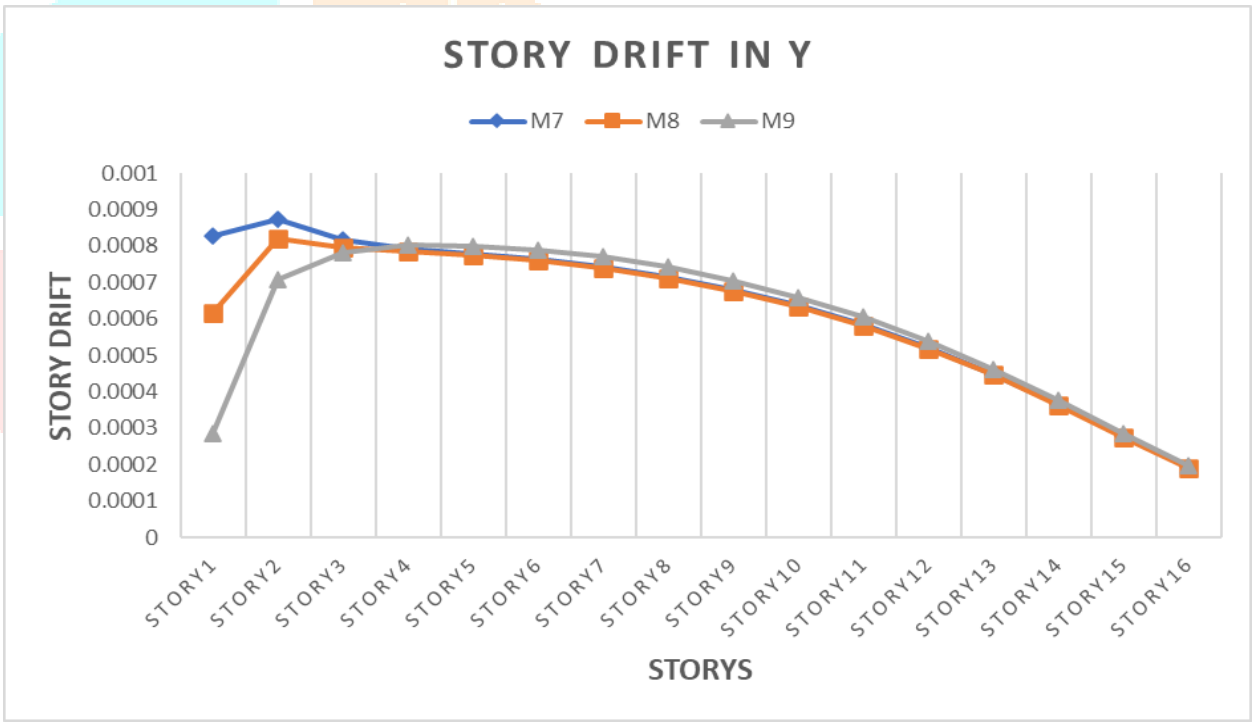

BASE SHEAR IN Y
BASE SHEAR (KN)
3200
3100
3000
2900
2800
2700
2600
2500
2400
M4
M5
M6
MODELS

WAFFLE SLAB:


DISPLACEMENT IN X
M7
M8
M9
DISPLACEMENT (MM)
40
35
30
25
20
15
10
5
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS


DISPLACEMENT IN Y
M7
M8
M9
DISPLACEMENT (MM)
40
35
30
25
20
15
10
5
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS


STORY DRIFT IN X
M7
M8
M9
STORY DRIFT
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS


STORY DRIFT IN Y
M7
M8
M9
STORY DRIFT
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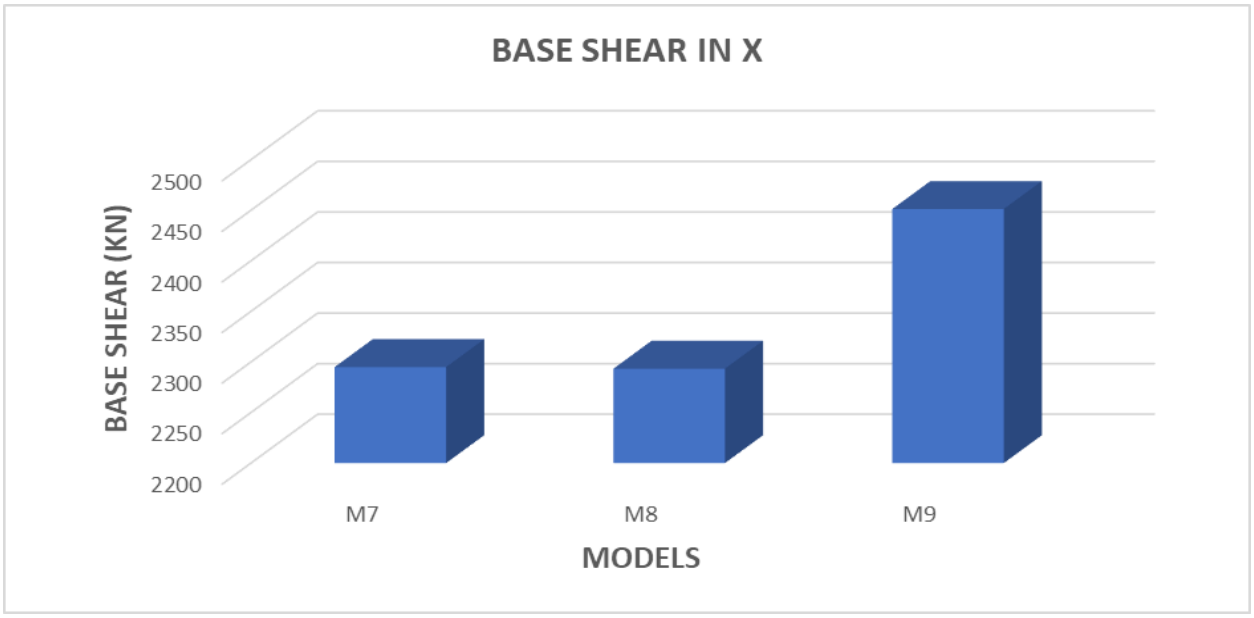
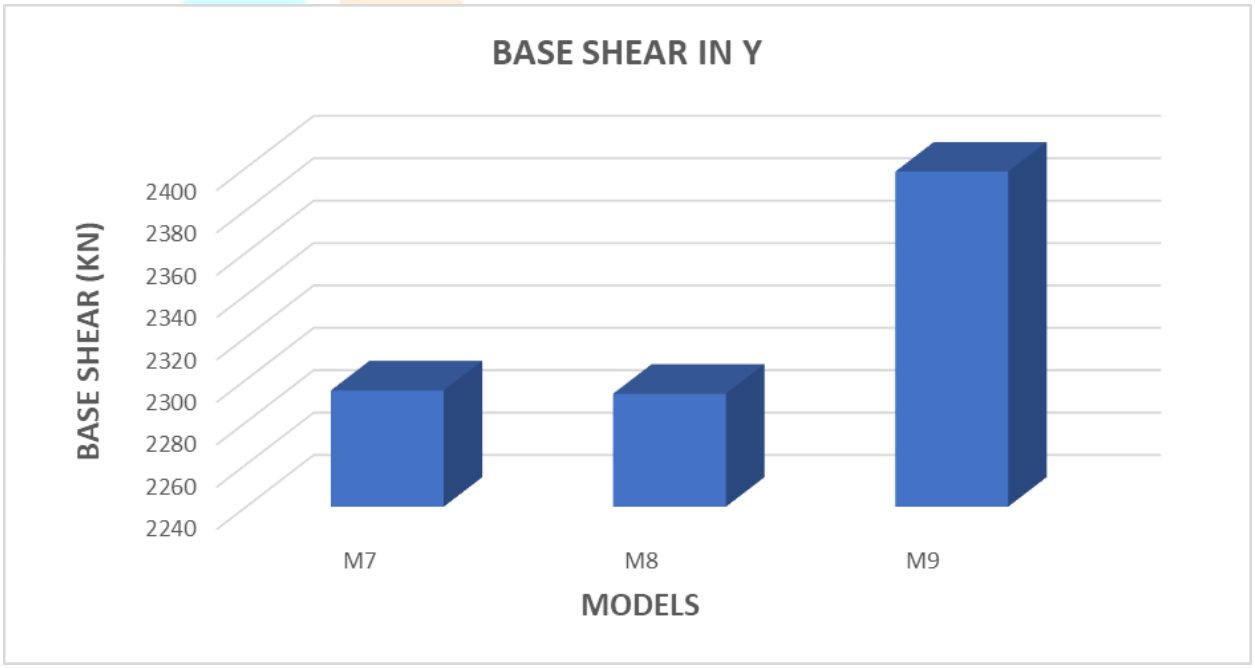
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
STORY1
STORY2
STORY3
STORY4
STORY5
STORY6
STORY7
STORY8
STORY9
STORY10
STORY11
STORY12
STORY13
STORY14
STORY15
STORY16
STORYS





VI.CONCLUSION

1. In all models, displacement is greatest in the x- and y-direction at the top story compared to the bottom story
2. As the angel of slope increases the displacement values are decreasing along x and y-directions
3. Story drift is more on plane ground compared to sloping ground
4. Base shear increases as the angel of slope increases

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