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BY USING ETABS PLANNING, DESIGNING AND ANALYSIS OF A COMMERCIAL BUILDING CONSISTING OF FLAT SLABS CONSIDERING EARTHQUAKE INDUCED FORCES.

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ABSTRACT*-Structures consisting of Flat slabs posses' great advantage over conventional structures with usual slab beam design. Because of the freedom to design space, shorter construction time, architectural functional as well as economical elements, flat slab building structures have significant benefits. Flat slab structural systems are substantially much more flexible than standard RC frame systems due to the lack of deep beams and shear walls, making them more vulnerable during seismic occurrences. The slab column connections, i.e., the shear force in the slab at the connection, should always keep its bearing capacity even at maximum displacements, is altogether a vital moment in the design of these systems. Building construction has a significant impact on the behaviour of flat slab buildings during earthquakes. As a result of this fact, it is necessary to take due consideration and to discover how to assure the safety of tall structures against earthquake forces.

***KEYWORDS* - Aspect Ratio, Flat slab structures, Punching shear, Ratio of Slenderness (H/B), Response Spectrum.**

I. INTRODUCTION

Slab-column or flat plate framed systems are framed reinforced cement concrete structures with slabs that are directly supported by columns, where girders or beams are not used. When compared to framed systems with beams, this system renders economy and greater open spaces with lower floor heights. Though, the current as well as previous failures of flat-slab structures have mandated the need of reconsidering the present design and construction standards, particularly for flat-slab systems subjected to seismic actions. The more severe of two mechanisms being beam action or two-way action, governs the shear strength of a connection in general. The critical region for beam type or one way shear failure extends throughout the entire slab width. Possible diagonal cracks resulting due to tension that arise along a truncated cone or pyramid stirring through the critical area in punching or two-way shear failure.

Punching failure have led many flat plate structures to collapse, especially during earthquakes. The connections in frames of slab-column in high-risk seismic areas must be proficient to transfer loads due to gravity, where the structure is subjected to lateral displacements induced by earthquake. Apart from causing an imbalanced moment, these displacements might also result in substantial inelastic rotations in connections, which could reduce connection punching shear capacity. Because of the negative impact of lateral displacements on connection strength, shear reinforcement may be needed in slab-column connections which could else be able to withstand the induced shear pressures.

As a result, punching failure is a major design challenge in flat plate systems, and active methods to eliminate punching failure are of very critical status. The weakest link in the chain is the resilience of slab systems to punching shear in the area around the supporting column. Without the use of beams, a flat slab is a reinforced concrete slab supported directly by concrete columns. The term "flat slab" refers to a one- or two-sided support system with the slab's sheer stress concentrated on the supporting columns and a square slab known as "drop panels. “Flat plates, or two-way slabs directly supported on columns, are popular in many regions of the world because of their relatively simple formwork and reinforcement scheme, as well as the potential for shorter storey heights (thereby increasing the number of floors that can be built within a specific height), Construction is quick, the ceiling is flat, and the cost is low. Flat plates also provide for more versatility when it comes to the layout of columns, walls, and small openings, among many other things.

Drop panels are important because they increase the total sturdiness as well as capacity of the flooring system underneath the loads that are vertical, consequently increasing the construction's cost effectiveness. Drop panels are nearly twice as tall as regular panels of the slab.
Flat Slabs are appropriate for most types of construction as well as asymmetrical column layouts such as curving floors and ramps. There are numerous advantages to using flat slabs, including depth solution, level soffit, and design arrangement liberty.

The Advantages of Using Flat Slab Construction can be summed up as:

- Room layout flexibility
- Building height savings:
- It in turn reduces building weight
- Saves 10% vertically
- Foundation load is reduced
- Construction time is reduced.
- Installation of M&E services is simple
- The use of large table formwork and flat slabs saves time during construction.
- Use of Prefabricated Welded Mesh Flat slab installation time is reduced by using prefabricated welded mesh. These meshes come in regular sizes and allow improved quality control in flat slab building.
- Effective Building Score: -This enables for the use of standardized structural components and prefabricated parts into the design for simplicity of construction. This procedure increases the likelihood of achieving a higher Buildable score by making the structure more buildable, reducing the number of site employees and increasing site productivity.
- Flat Slab Thickness In comparison to flat slabs with perimeter beams, all flat slabs with edge beams have a smaller slab thickness.

II. OBJECTIVES OF STUDY

1. Using "Response Spectrum Analysis," compute design lateral forces on a multi-storied flat slab construction made of RCC with a regular but a variable aspect ratio.
2. To compute and investigate the reaction of structures in seismic zone III, as well as to compare them.
3. To calculate the safe and stable structure's limit aspect ratio and slenderness ratio.
4. To conduct static and dynamic analysis with the help of ETABS.

III. LITERATURE REVIEW

A. Apostolska R.P. et al 2008 [1]

The findings of the analysis for a few different types of construction systems presented in the paper show that a flat slab system with certain modifications (design of perimeter beams and/or RC walls) can achieve a rational factor of behaviour when considering EC8 and can be considered a system with acceptable seismic risk. Modifications with extra construction parts improve the system's tiny bearing capacity as well as its strength and stiffness, enhancing the flat-slab construction system's seismic behaviour.

B. K. N. & Sahana T. et al 2014 [2]

Six different conventional RC frame and Flat Slab building types of G+3, G+8, and G+12 storeys are explored in the report work. The performance of flat slabs as well as the vulnerability of purely frame and purely flat slab models under various load situations were investigated, and seismic zone IV was used in the analysis. E-Tabs software is used to do the analysis. The purpose of this article was to compare the behaviour of multi-story commercial buildings with flat slabs and traditional RC frames to those with two-way slabs and beams, as well as to investigate the effect of building height on the performance of these two types of buildings under seismic stresses.

C. H.S. Mohana & Kavan M., et al 2015 [3]

A G+5 commercial multistory structure with a flat slab and a conventional slab was investigated for parameters such as base shear, storey drift, axial force, and displacement in this paper. The performance and behaviour of these structures have been studied in all of India's seismic zones. The research provides reasonable information on the appropriateness of flat slab structures for various seismic zones without compromising their performance over traditional slab buildings.

D. Rasna P. et al 2017 [4]

In the report, a direct approach was used for the manual design of a flat slab and the use of software to check for punching shear. Due to the lack of a beam, flat slabs are more susceptible to punching shear. ETABS software was used to analyze flat and conventional slab constructions.

E. Vikunj k.Tilva et al 2011 [5]

The goal of the study was to compare the costs of flat slab panels with and without drops in a four-story lateral load resisting construction. In ETABS (Extended 3D Analysis of Building Systems) software, a four-story building (with 6mx6m panels) is subjected to gravity and lateral loads, and then each storey is exported to SAFE (Slab Analysis by the Finite Element Method) programme, for lateral load punching analysis. Economical thickness of flat slab with drop and without drop were selected based on permitted punching shear parameters according to IS 456, and cost comparison was done using S.O.R. (Schedule of Rates 2008-09).

IV. STRUCTURAL MODELING

The modelling and assembling of a structure's numerous load-carrying parts is part of the modelling process. The mass distribution, strength, stiffness, and deformability must all be accurately represented in the model. The ETABS 15 software is used for modelling and analysis. RSM models and analyses each of the 25 structures separately.

Models are created in ETABS software using a template for a flat slab with a drop, with correct material properties and joint restrains assigned, and a fixed support at the base assigned to the column. Diaphragms are assigned to slabs and drops that resist in-plane deflection.

The table 1 given below represents all the models classified in different groups, named consequently

Table 1: Model Classification

S. no	Model Group	Model	Aspect Ratio	Length (in m)	Width (in m)	Column Spacing (in m)		No. of storeys	Height of storey (in m)	Ratio of Slenderness
			(R)	L	B	X	Z		3.6	(H:B)
1		N11						3	14.3	0.47
2		N12						5	21.5	0.70
3	N1	N13	1.0	30.25	30.55	6.1	6.1	7	28.7	0.94
4		N14						9	36.4	1.19
5		N15						11	43.1	1.41
6		N21						3	14.3	0.68
7		N22						5	21.5	1.02
8	N2	N23	2.0	40	21	5.84	5.4	7	28.7	1.36
9		N24						9	36.1	1.71
10		N25						11	43.1	2.05
11		N31						3	14.3	0.84
12		N32						5	21.5	1.26
13	N3	N33	3.0	49	17	5.5	6.4	7	28.7	1.68
14		N34						9	36.1	2.11
15		N35						11	43.1	2.53
16		N41						3	14.3	1.0
17	N4	N42	4.0	60	14	5	4	5	21.5	1.53
18		N43						7	28.7	2.05

19		N44						9	36.1	2.56
20		N45						11	43.1	3.07
21		N51						3	14.3	1.30
22		N52						5	21.5	1.95
23	N5	N53	5.0	74	11	6.24	5.5	7	28.7	2.60
24		N54						9	35.5	3.22
25		N55						11	43.1	3.90

V. PRELIMINARY DATA FOR ANALYSIS

[A] LOADING

a. DEAD LOAD [D.L]

b. As Per IS code 875 (Part 1)

c. LIVE LOAD [L.L] As Per IS code 875 (Part 2)

d. AT CONVENTIONAL FLOOR 4 KN/m2 as per IS code 456:2000

e. FLOOR FINISH 1 KN/m2 as per IS code 456:2000

[B] DATA FOR SEISMIC ANALYSIS

f. EARTHQUAKE LOAD [E.L] As Per IS code 1893 (Part 1)-2016

g. FOUNDATION TYPE Isolated Column Footing

h. FOUNDATION DEPTH 3.5m

i. SOIL TYPE Type II, Medium as Per IS code 1893

j. SOIL BEARING CAPACITY 550 KN/m^2

k. IMPORTANCE FACTOR 1.0

l. PERCENTAGE DAMPING 0.50%

m. FRAME TYPE Special moment resisting Frame

[C] ANALYSIS METHOD

RESPONSE SPECTRUM METHOD

Size of columns for different stories are shown in table 2 below:

Table 2: Considerations Regarding Preliminary Selection of Sizes of Structural Members.

S. No.	Structure Type	Size of column (mm ×mm)
1	G*+3 (5 storey)	450 X 450
2	G*+5 (7 storey)	450X 450
3	G*+7 (9 storey)	450 X 450
4	G*+9 (11 storey)	600 X 600
5	G*+11 (13 storey)	600 X 600

LOAD COMBINATION

From IS 1893:2016, Cl.6.3.1. The load combinations shown in Table 3 are considered in the design.

E*Q = Earth Quake Load

Table 3: Combinations of Loads

S.no.	Load Combination
1.	1.5(D.L.+L.L)
2.	1.2(D.L.+L.L+E*Q_X)
3.	1.2(D.L.+L.L-E*Q_X)
4.	1.2(D.L.+L.L.+E*Q_Y)
5.	1.2(D.L.+L.L-E*Q_Y)
6.	1.5(D.L.+E*Q_X)
7.	1.5(D.L.-E*Q_X)
8.	1.5(D.L.+E*Q_Y)
9.	1.5(D.L.-E*Q_Y)
10.	0.9D.L.+1.5E*Q_X
11.	0.9D.L.-1.5E*Q_X
12.	0.9D.L.+1.5E*Q_Y
13.	0.9D.L.-1.5E*Q_Y

DATA OF SEISMIC DESIGN:

REQUIRED PARAMETER FOR COMPARATIVE STUDY

For a comparison study of model analysis outcomes, the following parameters are taken into account and the results of the software analysis of the models were filtered and then structured in order to compare them to the values of other models. Graphs are plotted to help comprehend the results.

A) BASE SHEAR (VB): - Design codes express earthquake-induced inertia forces in the form of design equivalent static lateral force as the net effect of such random shaking**.**

The total design lateral force at the structure's base is known as base shear. Thus, base shear is the greatest predicted lateral force that will occur at the base of a structure due to seismic ground motion.

B) MAXIMUM: - The lateral movement of a building caused by earthquake-induced vibrations is known as drift. The lateral movement of one level relative to the level above or below is known as Storey drift. It can also be described as the displacement of one floor of a multistory building from the level below. It's the difference between adjacent storey lateral displacements.

C) NATURAL PERIOD: -A building's Natural Period (Tn) is the amount of time it takes to complete one complete cycle of oscillation. It is a quality of a structure that is regulated by its mass m and stiffness k. Seconds are its units (s). As a result, buildings that are hefty (mass m) and flexible (stiffness k) have a longer natural period than light and stiff structures.

D) NATURAL FREQUENCY: -The Natural Frequency fn is the reciprocal (1/Tn) of a building's natural period; its unit is Hertz (Hz). When shaken at its normal frequency, the building offers the least resistance (or natural period)

- **Seismic Analysis Method:**

Response Spectrum and Time History techniques are the most extensively utilized approaches for dynamic seismic analysis**.**

a. Response spectrum methods can be used to determine the maximum modal responses of a single-supported structural system or a system with numerous supports receiving the same load.

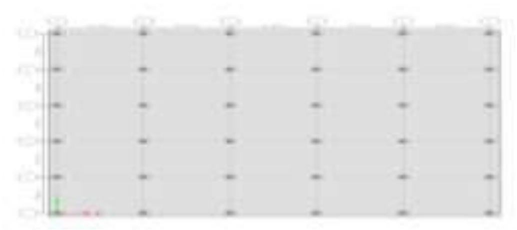
b. Response Spectrum and Time History techniques are the most extensively utilized approaches for dynamic seismic analysis.

VI. DESIGN & ANALYSIS

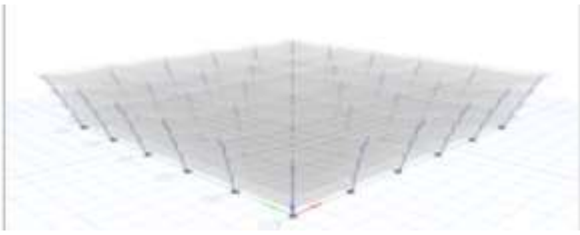
The results of the software analysis of the models were filtered and then structured in order to compare them to the values of other models. Graphs are plotted below to help comprehend the results.

⇒ PLAN ASPECT RATIO(R) = 01

- STRUCTURE- (G*+3)
  RATIO OF SLENDERNESS (H/B): 0.47



PLAN



ELEVATION

DATA ANALYSIS:

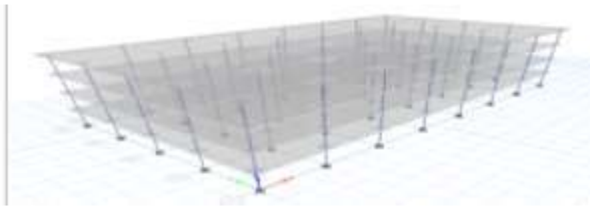
Values of various parameters for model 11 is shown below in table indicated as Model 11:

Model N11									
S. no.	Storey [S*]	Shear along X	Drift alongX	Stiffness alongX	Shear along Y	Drift along Y	Stiffness alongY	Displacement alongX	Displacement alongY
		[KN]	[mm]	[KN/m]	[KN]	[mm]	[KN/M]	[mm]	[mm]
	1	2	3	4	5	6	7	8	9
1	S*B 4	665.218	2.366	281000	665.341	2.366	281046	0.01	0.019
2	S*B 3	1205.32	4.064	296546	1205.64	4.064	296612	0.016	0.016
3	S*B 2	1585.21	5.114	30991	1585.	5.114	30997	0.010	0.011

				7	56		8		
4	S*B 1	1771.88	3.788	467665	1772.11	3.788	467711	0.004	0.004
5	BASE(B)							0	0

⇒PLAN ASPECT RATIO(R) = 2

- STRUCTURE-(G*+3)
  RATIO OF SLENDERNESS (H/B): 0.68



PLAN ELEVATION

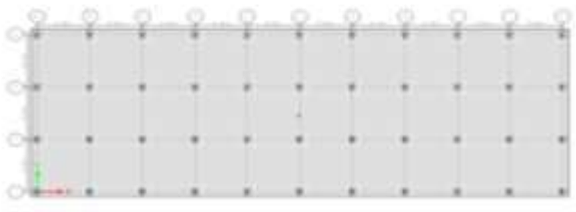
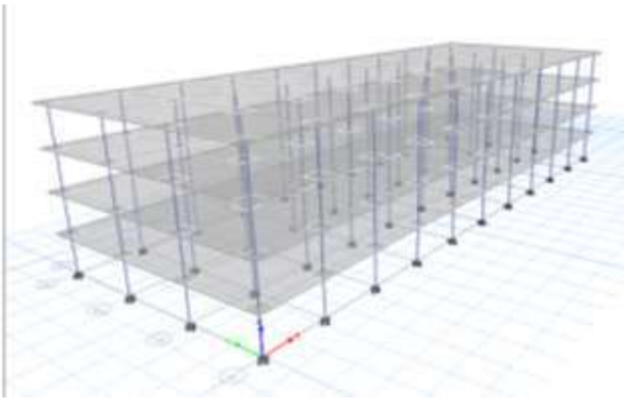
DATA ANALYSIS

Values of various parameters for model 21 is shown below in table indicated as Model 21:

Model N21									
S no.	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear along Y	Drift alongY	Stiffness alongY	Displacement alongX	Displacement alongY
		[KN]	[mm]	[KN/m]	[KN]	[mm]	[KN/M]	[mm]	[mm]
	1	2	3	4	5	6	7	8	9
1	S* 4	1040.16	3.457	300805	1044.47	3.436	303872	0.016	1.72E*-06
2	S* 3	1675.27	5.507	304132	1685.51	5.463	308477	0.014	3.43E*-06
3	S* 2	2142.80	6.762	316863	2156.58	6.707	321515	0.009	1.61E*-06
4	S* 1	2464.17	4.955	497189	2477.86	4.934	502060	0.003	5.65E*-06
5	BASE(B)							0	0

⇒ PLAN ASPECT RATIO(R) = 3

- STRUCTURE-(G*+3)
  RATIO OF SLENDERNESS (H/B): 0.84

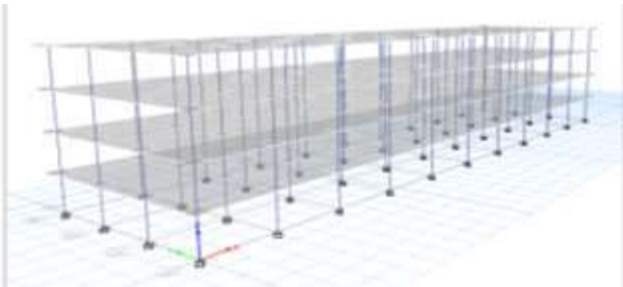
PLAN ELEVATION

DATA ANALYSIS

Values of various parameters for model 31 is shown below in table indicated as Model 31:

Model N31										
S no.	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear along Y	Drift alongY	Stiffness alongY	Displacement alongX	Displacement alongY
		[KN]	[mm]	[KN/m]	[KN]	[mm]	[KN/M]	[mm]	[mm]
	1	2	3	4	5	6	7	8	9
1	S* 4	5030.13	13.511	372280	5074.02	16.594	305761	5.385E*-05	0.016
2	S*3	9212.40	23.600	390341	9244.42	28.153	328349	8.725E*-05	0.013
3	S*2	12180.5	30.00	405882	12179	35.110	346904	6.242E*-05	0.009
4	S*1	13645.7	22.795	598605	13599.8	25.231	538982	0.00001445	0.003
5	BASE(B)							0	0

⇒PLAN ASPECT RATIO(R) = 4
STRUCTURE- (G*+3)
RATIO OF SLENDERNESS (H/B): 1.0

PLAN ELEVATION

DATA ANALYSIS

Values of various parameters for model 41 is shown below in table indicated as Model 41:

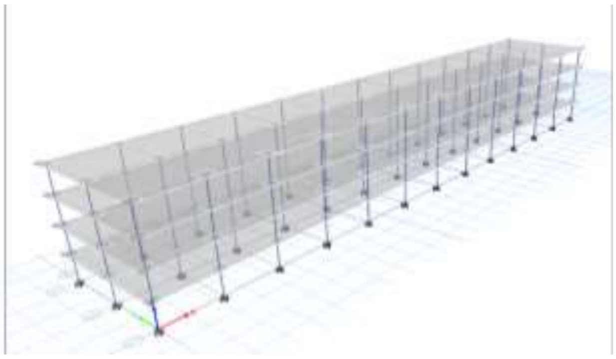
Model N41										
S no	Storey [S*]	Shear alongX [KN]	Drift alongX [mm]	Stiffness alongX [KN/m]	Shear alongY [KN]	Drift alongY [mm]	Stiffness alongY [KN/M]	Displacement alongX [mm]	Displacement alongY [Mm]
	1	2	3	4	5	6	7	8	9
1	S* 4	447.705	3.392	131943	449.83	3.370	133426	0.02	1.16E*-05
2	S* 3	731.327	4.857	150548	736.195	4.827	152493	0.023	3.23E*-05
3	S* 2	934.491	5.394	173214	941.007	5.365	175363	0.014	1.53E*-05
4	S* 1	1051.68	3.178	330803	1058.67	3.168	334043	0.005	2.85E*-05
5	BASE(B)							0	0

⇒PLAN ASPECT RATIO = 5

- STRUCTURE- (G+3)

  RATIO OF SLENDERNESS (H/B): 1.30

PLAN



ELEVATION

DATA ANALYSIS

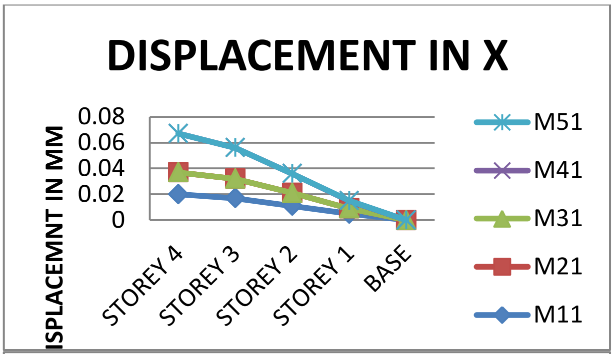
Values of various parameters for model 51 is shown below in table indicated as Model 51:

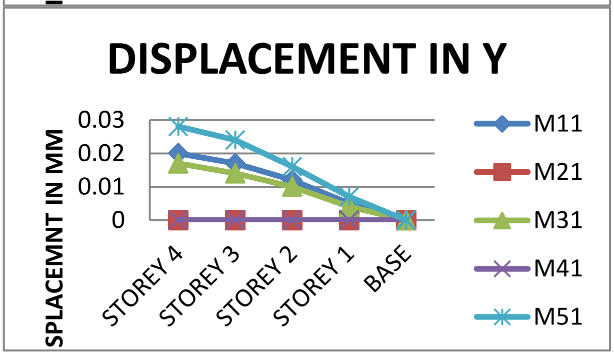
Model N51									
S no.	Storey [S*]	Shear alongX [KN]	Drift alongX [mm]	Stiffness alongX [KN/m]	Shear along Y [KN]	Drift alongY [mm]	Stiffness alongY [KN/M]	Displacement alongX [mm]	Displacement alongY [Mm]
	1	2	3	4	5	6	7	8	9
1	S* 4	577.977	2.034	284018	563.574	2.138	263491	3.18E*-06	0.027
2	S* 3	1023.94	3.437	297820	990.59	3.52	280603	4.06E*-05	0.023
3	S*2	1338.68	4.283	312489	1291.62	4.351	296772	3.6E*-05	0.015
4	S*1	1501.13	3.103	483555	1448.48	3.092	468347	4.4E*-05	0.006
5	BASE(B)							0	0

VII. RESULT

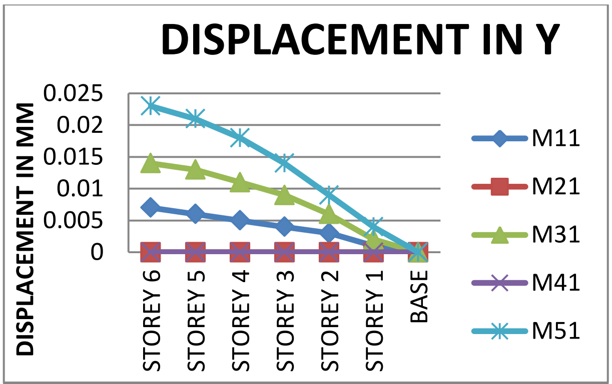
RESULTS FOR MAXIMUM DEFLECTION

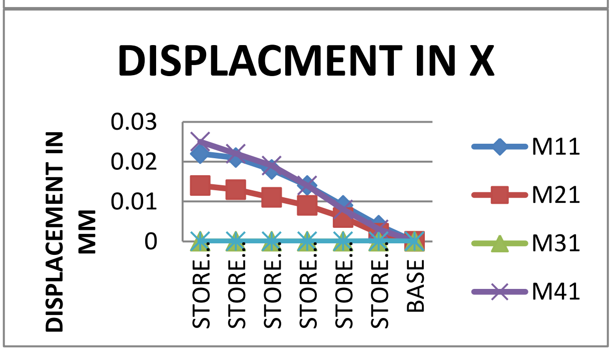
- FOR G*+ 3 STRUCTURES:



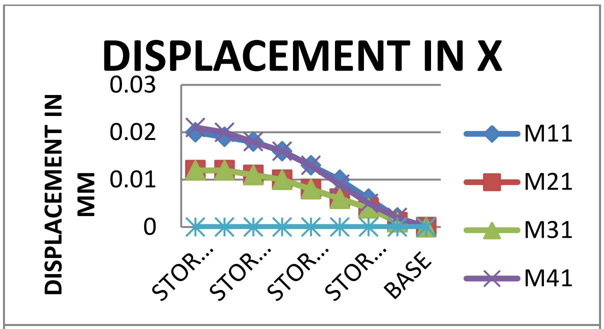


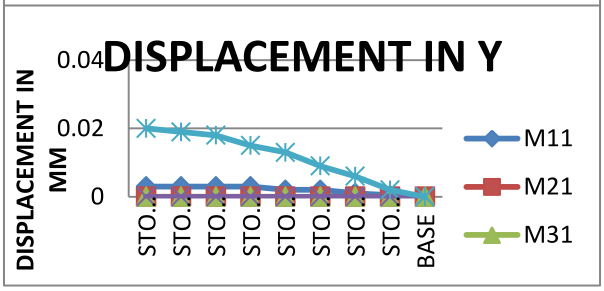
- FOR G*+ 5 STRUCTURE:



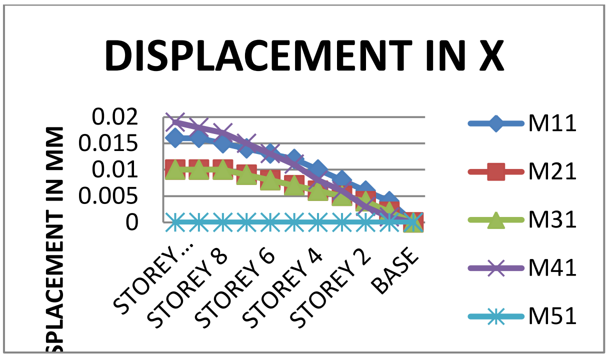


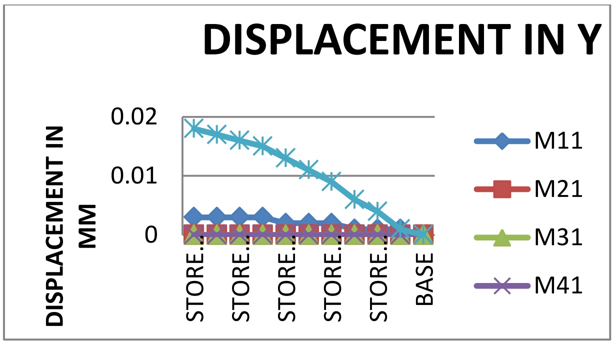
- FOR G*+ 7 STRUCTURES:



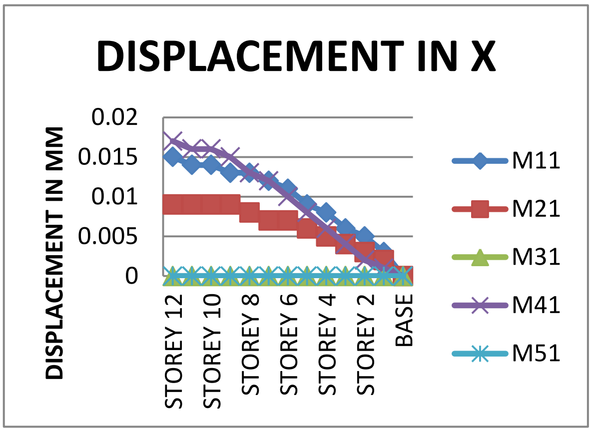


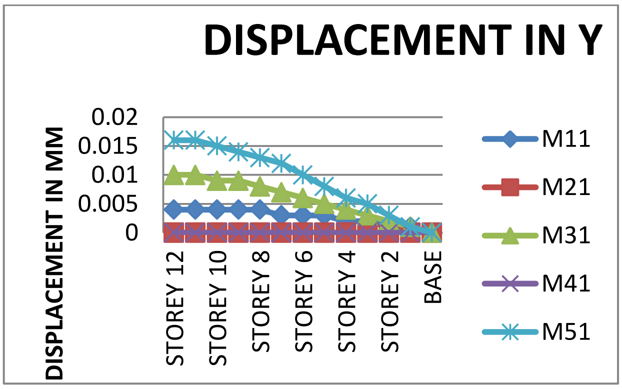
- FOR G*+ 9 STRUCTURES:





- FOR G*+ 11 STRUCTURES:





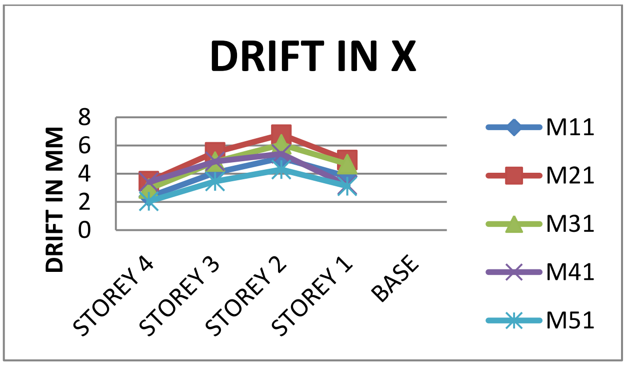
Observations for displacement

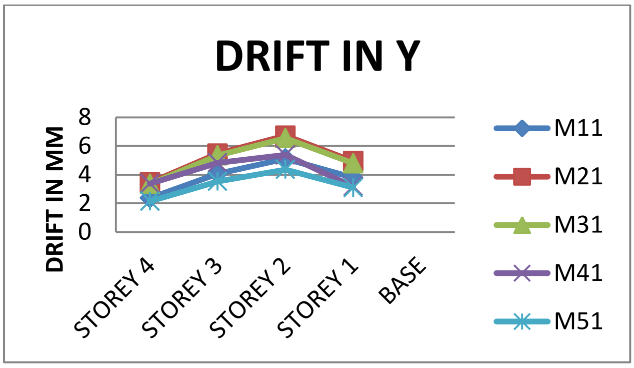
Points observed from the above graphs are as follows:

- Displacement for aspect ratio L/B = 5.0 is max.
- Displacement decreases with increase in aspect ratio up to L/B = 3.0.

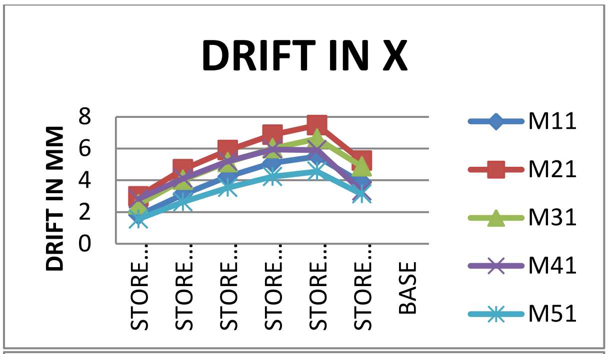
RESULTS FOR MAXIMUM STOREY DRIFT

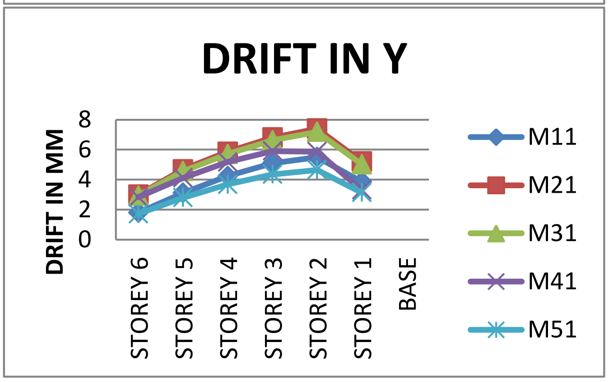
- FOR G*+ 3 STRUCTURES:



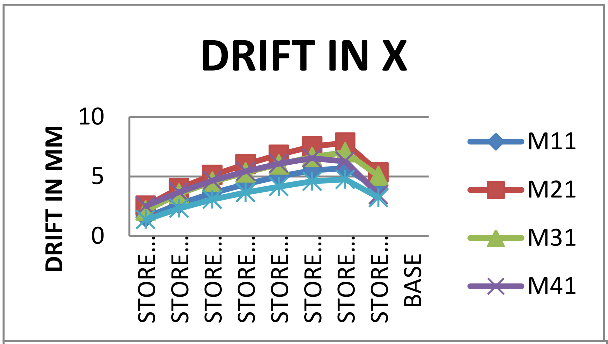


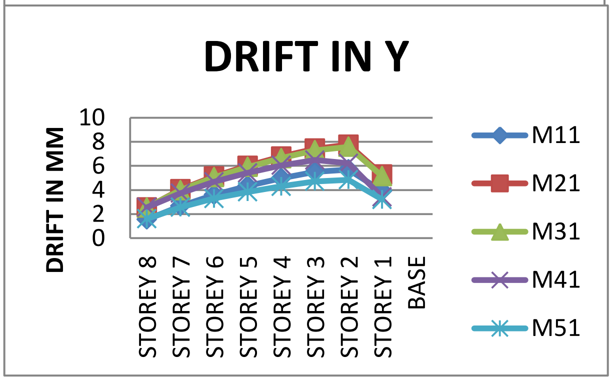
- FOR G*+ 5 STRUCTURES:



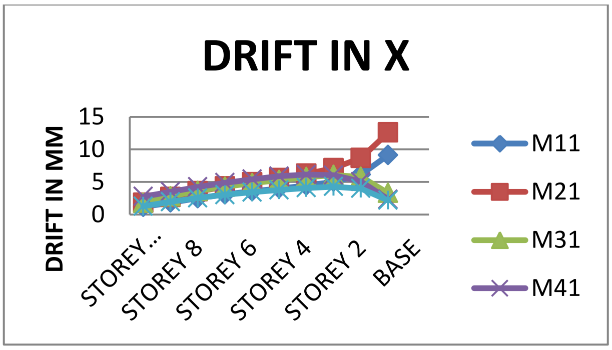


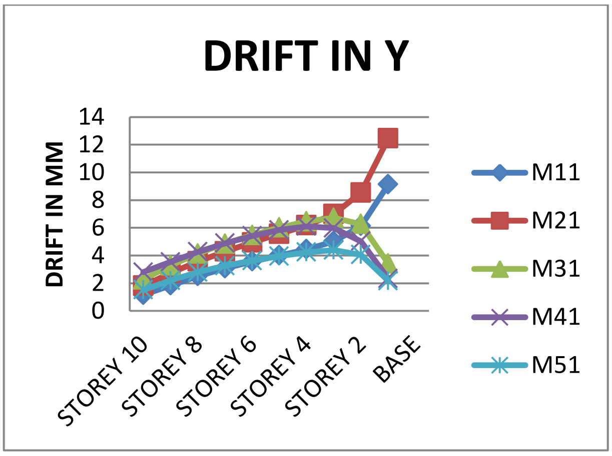
- FOR G*+ 7 STRUCTURES:



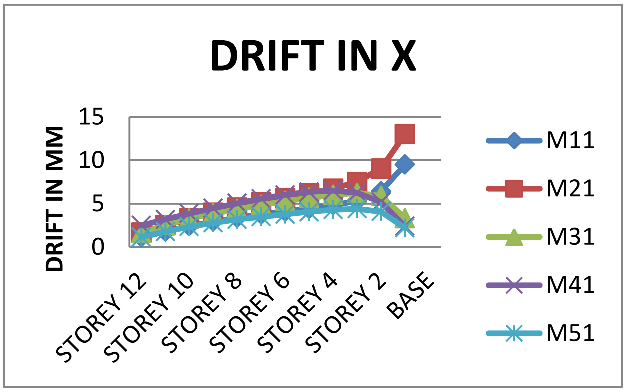


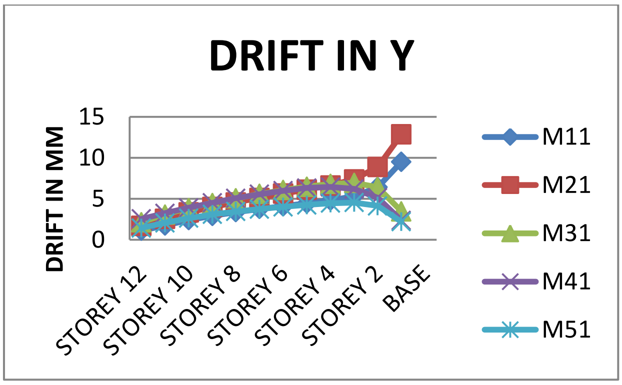
- FOR G*+ 9 STRUCTURES:





- FOR G*+ 11 STRUCTURES:





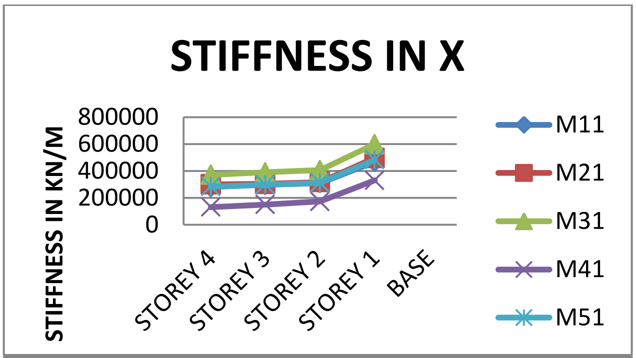
The following are the observations made from the graphs above:

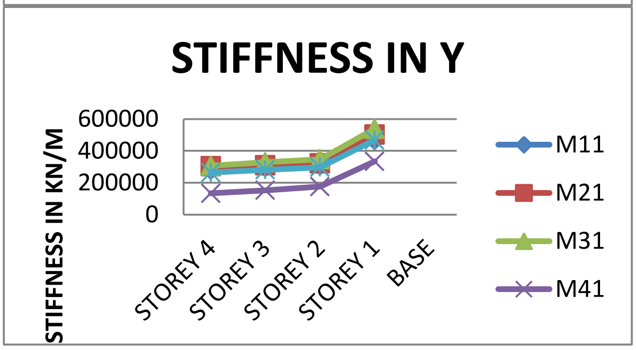
• If the structure is a flat slab, For the same slenderness ratio, Storey drift in the x direction is greater than Storey drift in the y direction.

• The maximum drift should not exceed 0.004 times the storey height, which is 0.0143 m, according to IS 1893 (Part 1) 2002. The aspect ratio L/B= 5 and the slenderness ratio 3.9 both surpass this drift limit.

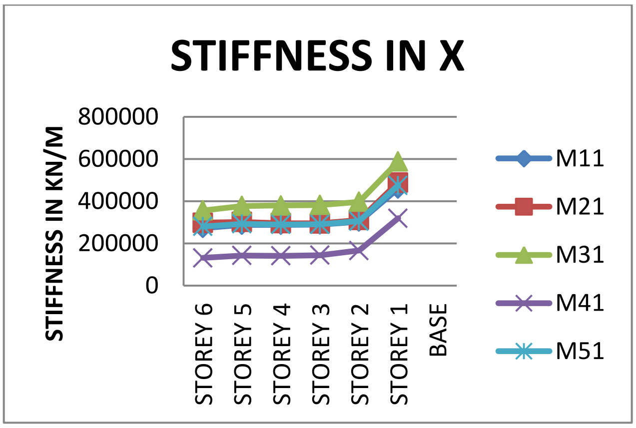
RESULTS FOR MAXIMUM STOREY STIFFNESS

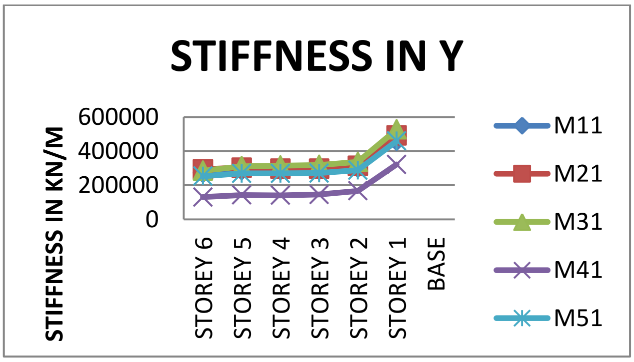
- FOR G*+ 3 STRUCTURES:



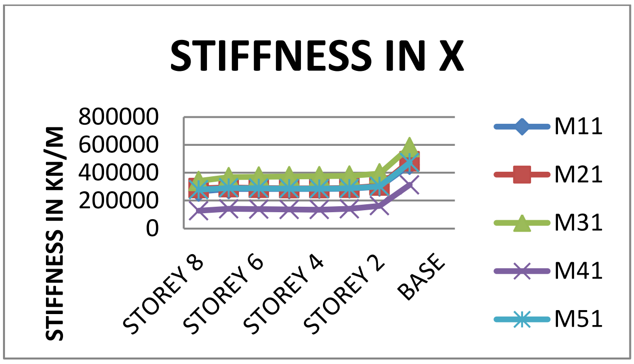


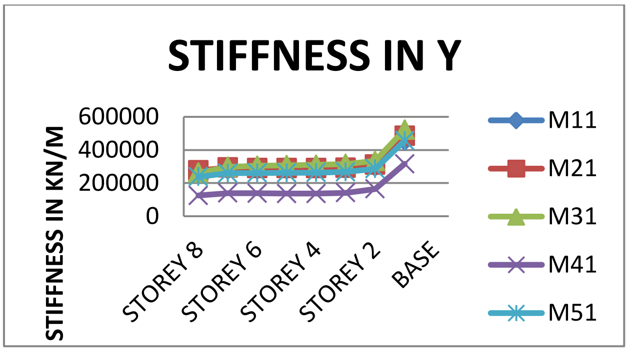
- FOR G*+ 5 STRUCTURES:



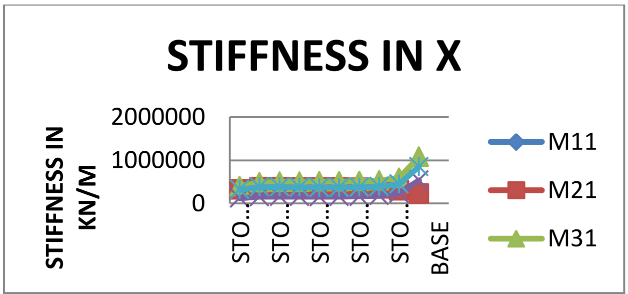


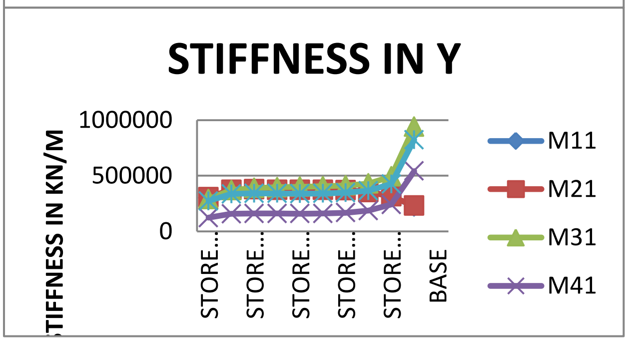
- FOR G*+ 7 STRUCTURES:



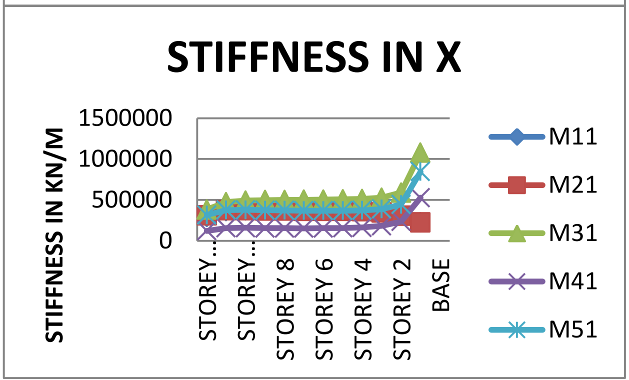


- FOR G*+9 STRUCTURES:





- FOR G*+ 11 STRUCTURES:



Maximum storey stiffness observations

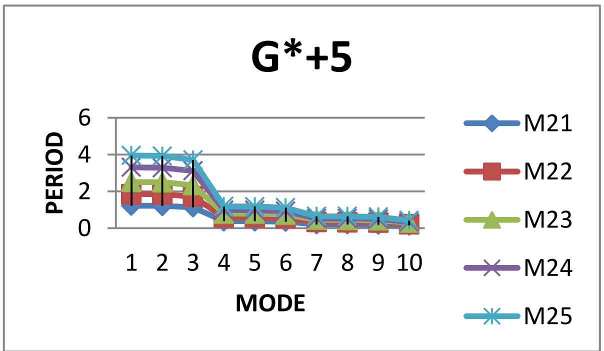
The following points may be seen in the graphs:

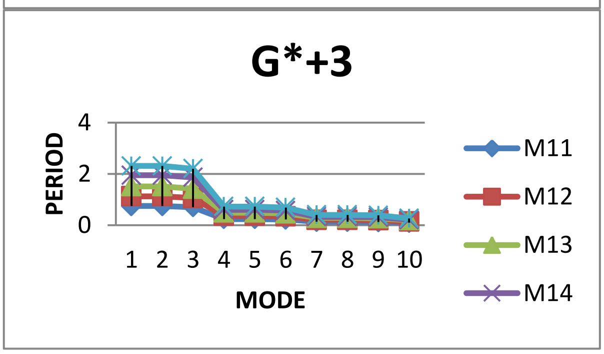
• Storey stiffness increases with column size

• Storey stiffness increases with column number in respective direction for same size column.

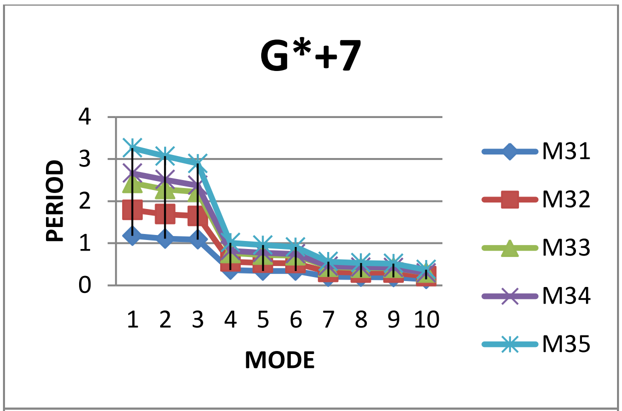
RESULTS FOR TIME PERIO

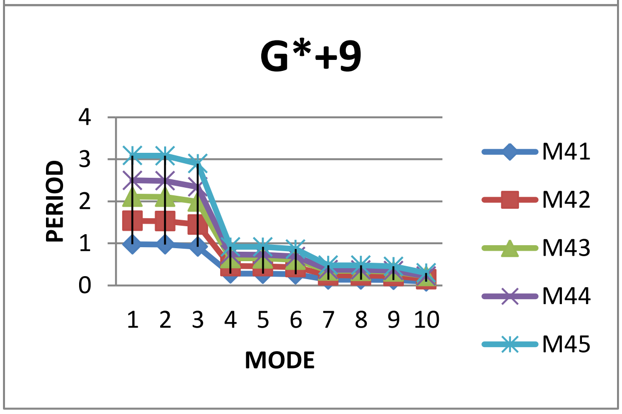
- FOR G*+ 3 STRUCTURES & FOR G*+ 5 STRUCTURES:



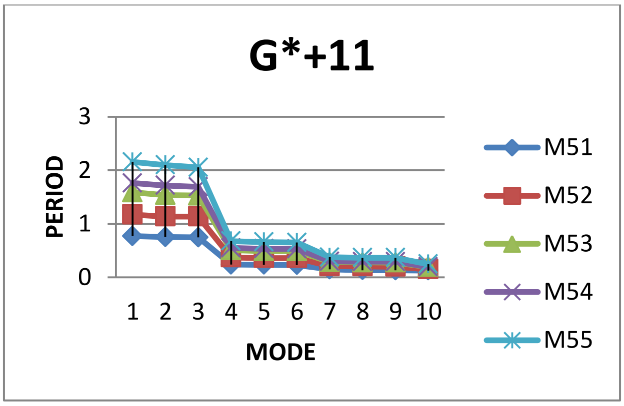


- FOR G*+ 7 STRUCTURES & FOR G*+ 9 STRUCTURES:





- FOR G*+ 11 STRUCTURES:



RESULT SUMMARY

Base Shear: a. According to the tables of results, the value of the base shear increases as the slenderness ratio and aspect ratio rise.

b. As column size and seismic weight grows, the percentage increase in base shear for aspect ratios 4 and 5 is greater than for other ratios.

c. When the number of storeys(S*) remains constant, the base shear does not rise linearly with the aspect ratio.

Drift of Storey

a. Buildings with aspect ratio 1 have the same drift in both directions
b. Slenderness ratio increases as a result, the maximum storey drift has increased.
c. For the same slenderness ratio, Storey drift in the x direction is greater than Storey drift in the y direction in the case of flat slab structures.
d. In the case of G*+3, G*+5, G*+7 buildings, the maximum Storey drift was discovered at the second storey level, however in the case of G*+9 and G*+11 storey structures, it was third storey level where the highest Storey drift was revealed.
e. Model 55 has a maximum storey drift of 20.1 mm, which is greater than the limiting value of 14.4 mm for a storey height of 3600 mm.
f. By increasing the size of the column, the lateral rigidity of the structure is increased, resulting in a higher storey level of maximum storey drift.
g. IS 1893 imposes restrictions. (Part 1) 2002, The maximum drift shall not exceed 0.004 times the storey height, which is 0.0144 m. The aspect ratio L/B= 5 and the slenderness ratio 3.9 both surpass this drift limit.

Stiffness

a. As the lateral storey grows the fundamental time period of stiffness decreases.
b. An increase in the rigidity of the lateral storey. As a result, there are reductions. Maximum storey displacement and storey drift
c. Column sizes are not set in the same aspect ratio; hence stiffness varies with column size. As a result, the structure's behaviour for lateral loading changes.
d. Increasing the lateral stiffness of a building by increasing the size of the column results in an increase in the maximum storey drift storey level.

Natural Time Period

a. As the slenderness ratio rises, the value of time period rises as well.

b. The numerical values for modal period and frequency reveal that the value of period raises linearly with the linear increase in the slenderness ratio, but did not increase, when the aspect ratio changes.

c. The structure's reaction to lateral loads is governed by the first three types of displacement. Because the natural time period of the first three modes is longer and the frequency is lower, lesser quantities of excitation result in the greatest lateral deflection.

VIII. CONCLUSION

The following conclusions can be taken from the work done in this dissertation:

i. The L/B aspect ratio of the limiting plan is 5.0, and the slenderness ratio is 3.9.
ii. Structures with an aspect ratio larger than 3.0 have a larger magnitude of design base shear in both the X and Y directions, while having a lower seismic weight than structures with an aspect ratio of 3.0.
iii. Column size reduction reduces the seismic weight of the structure, resulting in decreased seismic weight and base shear.
iv. Buildings with a square plan shape, or aspect ratio 1, are the safest because: a. There is less and equal base shear acting in both the X and Y directions.
v. The fundamental time period for a square plan construction is shorter than for a rectangular plan structure. As a result, it will function well in earthquakes with higher frequencies.
vi. For all storey levels, lateral deformation (i.e., lateral displacement and storey drift) is the same along both X and Y axes. The X and Y axes.
Structures with an aspect ratio greater than 3 have a greater magnitude of design base shear in both the X and Y directions, but having a lower seismic weight than structures with an aspect ratio of 3.
vii. Column size reduction minimizes the seismic weight of the structure, resulting in decreased seismic weight and base shear.
Buildings with a square plan shape, or an aspect ratio of 1, are the safest because:
a. Base shear is acting in both the X and Y directions at a lower and equal rate.
b. The fundamental time period for a square plan construction is shorter than for a rectangular plan structure.
c. Make a blueprint for the construction. As a result, it will work well in earthquakes with higher frequencies.
d. For all storey levels, lateral deformation (i.e., lateral displacement and storey drift) is the same in both the X and Y directions.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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