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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 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[1]. 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 [2]. 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[3].

Punching failure have led many flat plate structures to collapse, especially during earthquakes [4-5]. 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 [6-7]. 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 [8].

Figure 1 shows the Flat slabs with column head and drop and Figure 2 shows the flat slab with beams.

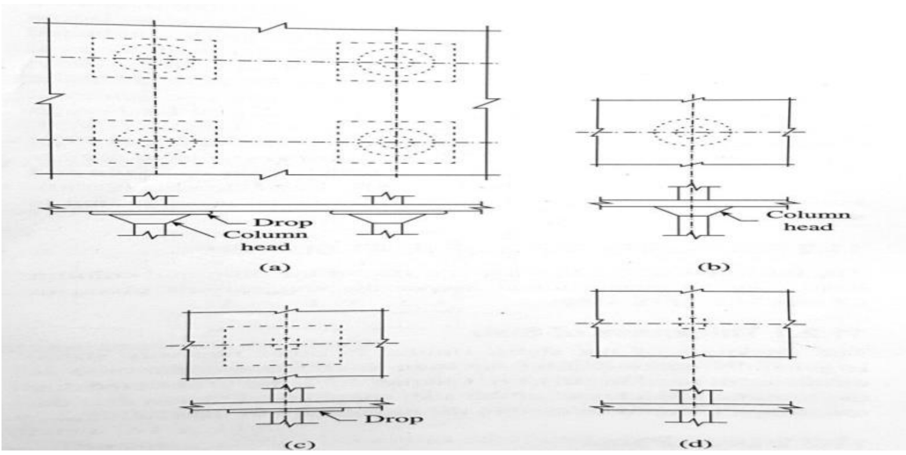
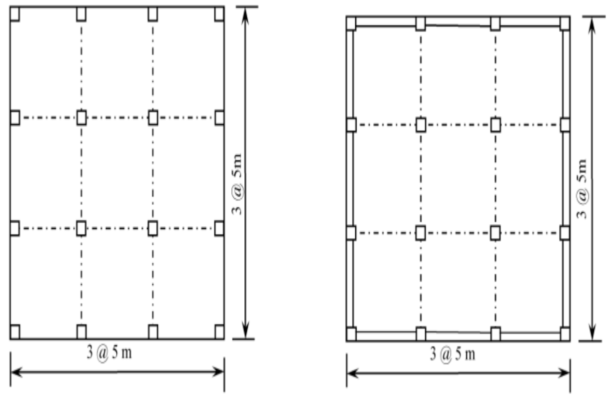


Figure1: Flat Slab accompanied by column head and drop

A. Flat Slab Thickness

In comparison to flat slabs with perimeter beams, all flat slabs with edge beams have a smaller slab thickness.Fig.5 Showing flat slab buildings plan: (a) without edge beams; ii(b) with edge beams;



(a) (b)

Figure 2: Flat slab buildings plan: (a) without edge beams; ii(b) with edge beams

B. Statement of the Problem

In areas designated as High-seismic areas, slab-column frames are prone to brittle punching failure, which leads to structural collapse.

Flat slabs are gradually collapsing as a result of this large lateral displacements are experienced by building, during an earth quake ground moves and they lose their vertical position resulting in loss of load carrying capacity due to induced moments.

II. OBJECTIVES

- 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.
- To compute and investigate the reaction of structures in seismic zone III, as well as to compare them.
- To calculate the safe and stable structure's limit aspect ratio and slenderness ratio.
- To conduct static and dynamic analysis with the help of ETABS.

III. PROJECT WORK SCHEDULE

The current research is limited to the effects of seismic forces on flat slab structures with no lateral force resisting infill features. to learn everything there is to understand structural behaviour, we must investigate structures with infill elements that either resist or do not resist lateral displacement.

A. Planning of Site

1) Location

The location of site is Baner on the Mumbai – Pune Expressway. The intended location as seen on the map Proposed site as shown in location map Number of plot is 35 on the main road.

2) Orientation

The wind is blowing from the north-west in this location. The intensity and direction of the wind can vary from season to season, but for the most part, the wind is blowing from the northwest to the northeast.

3) Direction of Wind

The windows and doors are positioned to allow the wind to freely circulate through the interiors. This contributes for those who work there in giving a good working environment. Most sites have a basic primary direction since wind directions changes from one place to another with respect to time. North west is the conventional direction for wind.

4) Type of Soil & Surrounding Condition

Specification of IS code 1893: 2016, Cl.6.4.2.1 shows the field values of N minimum correction should be as per requirements specified below:

Table 1: shows the field values of N

Seismic Zone	Depth (in m) below the Ground Level	N - Values	Remarks
III, IV & V	≤ 5 ≥ 10	15 25	Interpolation is recommended for values of depths between 5m and 10m linear.
II	≤ 5 ≥ 10	10 20	

As a result, Type B (Medium or Stiff Soils) is considered for design purposes according to IS 1893:2016, Table 2. Sands poorly graded /poorly graded sands with gravel (SP) with little or no particles and N between 10 and 30 are defined under the code. Fine-grained soils with N between 10 and 30 that are stiff to medium stiff, such as silts with low compressibility (ML) or clays with low compressibility (CL).

For this project, the SBC of the soil is 500kN/m2.

IV. STRUCTURAL MODELING

The modeling and assembling of a structure's numerous load-carrying parts is part of the modeling process. The mass distribution, strength, stiffness, and deformability must all be accurately represented in the model. The ETABS 15 software is used for modeling 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 2 below represents all the models classified in different groups, named consequently.

Table 2: Model Classification

S.No	Model Group	Model	Aspect Ratio	Length (in m)	Width (in m)	Column Spacing (in m)		No. of storeys	Height of story (in m)	Ratio of Slenderness
			(R)	L	B	X	Z		3.6	(H:B)
1	N1	N11	1.0	30.25	30.55	6.1	6.1	3	14.3	0.47
2		N12						5	21.5	0.70
3		N13						7	28.7	0.94
4		N14						9	36.4	1.19
5		N15						11	43.1	1.41
6	N2	N21	2.0	40	21	5.84	5.4	3	14.3	0.68
7		N22						5	21.5	1.02
8		N23						7	28.7	1.36
9		N24						9	36.1	1.71
10		N25						11	43.1	2.05
11	N3	N31	3.0	49	17	5.5	6.4	3	14.3	0.84
12		N32						5	21.5	1.26
13		N33						7	28.7	1.68
14		N34						9	36.1	2.11
15		N35						11	43.1	2.53
16	N4	N41	4.0	60	14	5	4	3	14.3	1.0
17		N42						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	N5	N51	5.0	74	11	6.24	5.5	3	14.3	1.30
22		N52						5	21.5	1.95
23		N53						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

- DEAD LOAD [D.L]
- As Per IS code 875 (Part 1)
- LIVE LOAD [L.L] As Per IS code 875 (Part 2)
- AT CONVENTIONAL FLOOR 4 kN/m2 As per IS code 456:2000
- FLOOR FINISH 1 kN/m2 As per IS code 456:2000

B. Data for Seismic Analysis

- EARTHQUAKE LOAD [E.L] As Per IS code 1893 (Part 1)-2016
- FOUNDATION TYPE Isolated Column Footing
- FOUNDATION DEPTH 3.5m
- SOIL TYPE Type II, Medium As Per IS code 1893
- SOIL BEARING CAPACITY 550 kN/m2
- IMPORTANCE FACTOR 1.0
- PERCENTAGE DAMPING 0.50%
- FRAME TYPE Special moment resisting Frame

C. Analysis Method Response Spectrum Method

Table 3 shows the different sizes of structural members.

Table 3: Different sizes of column

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

G* = Ground

D. Load Combination

Table 4 shows the load combination.From IS 1893:2016, Cl.6.3.1. The load combinations shown in Table 8 are considered in the design.
E*Q = Earth Quake Load

Table 4: Combinations of Loads

S.No.	Load Combination
1.	1.5(D.L.+L.L)
2.	1.2(D.L.+L.L+E*QX)
3.	1.2(D.L.+L.L-E*QX)

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

E. Data of Seismic Design

Load Specifications are shown in Table 5

Table 5: Load Specifications

S. No.	Design Parameter	Value
1	Earthquake Load	As Per IS code 1893 (Part 1)-2016
2	Foundation type	Isolated Column Footing
3	Foundation depth	3.50 m
4	Soil Type	Type II, Medium As Per IS 1893-2016
5	Soil Bearing Capacity	550 kN/m2
6	Siesmic Zone	III
7	Zone Factor (Z)	0.16
8	Response Reduction Factor (R)	5
9	Importance Factor	1
10	Percentage Damping	5.0%
11	Type of Frame	Special Moment Resisting Frame

VI. REQUIRED PARAMETER FOR COMPARATIVE STUDY

A. Seismic Analysis Method

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

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

VII. 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 to help comprehend the results. Table 6 shows the Drift & Displacement Values for Model N11

Table 6: Drift & Displacement Values for Model N11

Model N11									
S. no.	Storey [S*]	Shear along X	Drift alongX	Stiffness alongX	Shear alongY	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	309917	1585.56	5.114	309978	0.010	0.011
4	S*B 1	1771.88	3.788	467665	1772.11	3.788	467711	0.004	0.004
5	BASE(B)							0	0

A. Data Analysis

Below values in Table 7 showing the Drift & Displacement

Table 7: Drift & Displacement Values for Model N21

Model N21									
S no.	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear alongY	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

B. Data Analysis

Below values in Table 8 Table 9 & Table 10 showing the Drift & Displacement for Model N31, N41& N51.

Table 8: Drift & Displacement Values for Model N31

Model N31									
S no.	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear alongY	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

Table 9: Drift & Displacement Values for Model N41

Model N41									
S no	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear alongY	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	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

Table 10: Drift & Displacement Values for Model N51

Model N51									
S no.	Storey [S*]	Shear alongX	Drift alongX	Stiffness alongX	Shear alongY	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	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

VIII. RESULT

A. Results for Maximum Deflection

Figure 3, Figure 4, Figure 5 & Figure 6 Shows the maximum deflection for G+5, G+7, G+9 & G+11 Structures.

1) *FOR G*+ 5 STRUCTURES*

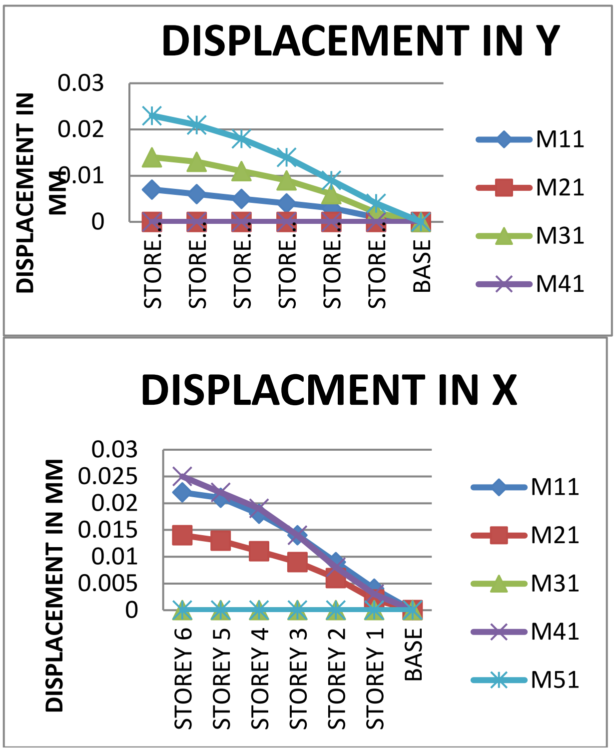


Figure 3: Maximum Deflection

2) *FOR G*+ 7 STRUCTURES*

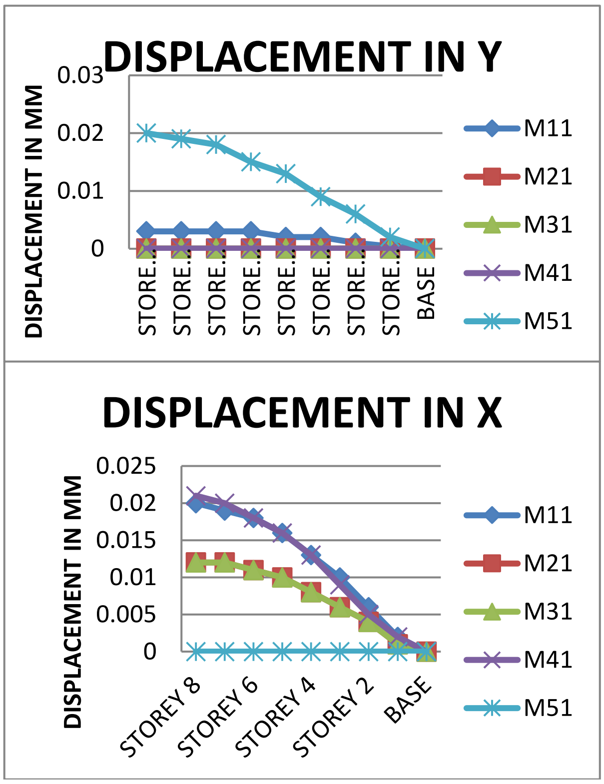


Figure 4: Maximum Deflection

3) *FOR G*+ 9 STRUCTURES*

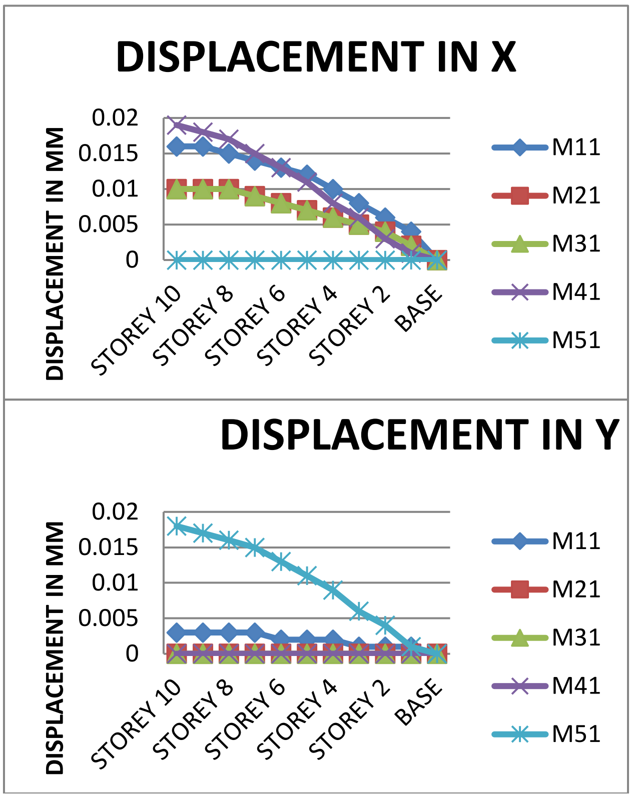


Figure 5: Maximum Deflection

4) *FOR G*+ 11 STRUCTURES*

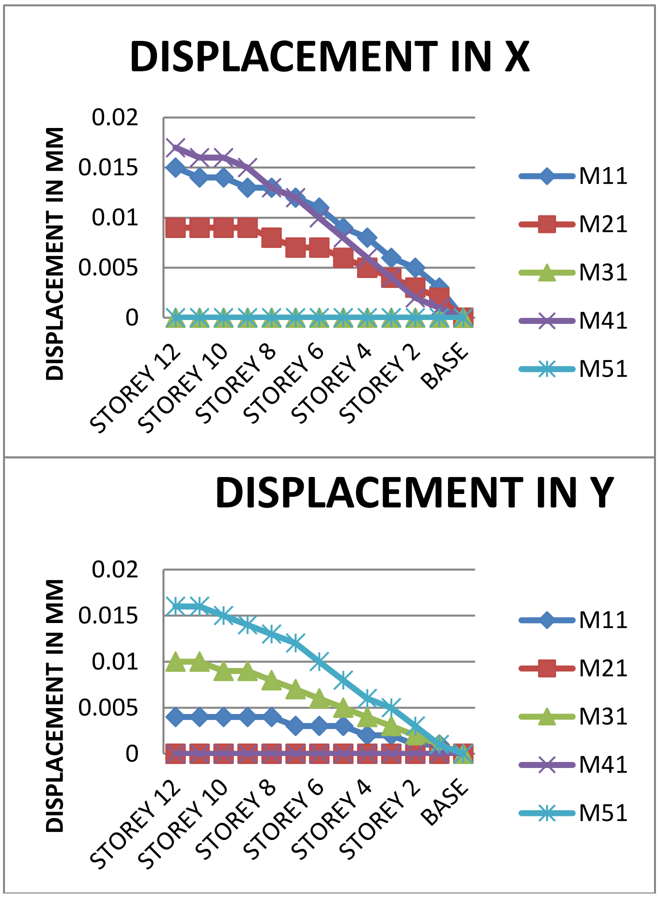


Figure 6: Maximum Deflection

IX. CONCLUSION

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

- The L/B aspect ratio of the limiting plan is 5.0, and the slenderness ratio is 3.9.
- 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.
- Column size reduction reduces the seismic weight of the structure, resulting in decreased seismic weight and base shear.
- 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.
- 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.
- 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.
- Column size reduction minimizes the seismic weight of the structure, resulting in decreased seismic weight and base shear.

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