

# Impact of fault line on behaviour of flat slab under vertical motion of earthquake

Abhishek Chandrakant Ghela<sup>1</sup>, Aakash Rajeshkumar Suthar<sup>2</sup>

<sup>1</sup> Student Civil Engineering Department, L.J.I.E.T. Ahmadabad, Gujarat, India

<sup>2</sup> Professor Civil Engineering Department, L.J.I.E.T. Ahmadabad, Gujarat, India

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**Abstract** - The effects of vertical acceleration of the ground on flat slab building are presented in this paper. In the current environment, most design standards, including IS 1893-2016, recommend that the vertical acceleration element of an earthquake be designed as 2/3 of the horizontal. During recent quakes, the vertical element of ground motion was discovered to be greater than the horizontal element. It is consequently vital to investigate structural reaction in this sort of earthquake, where the vertical element's peak ground acceleration (PGA) may reach two-thirds of the horizontal element. Time history analysis was done in this study utilising 5 unscaled seismic data. To account for the influence of vertical ground vibrations, 5 various structural systems were investigated, including a drop panel, shear walls, and three flat plates of varying thickness. Variations in several parameters such as axial force for column at several locations in building, punching shear at the junction of slab & column, and deflection of slab have been examined. The results of the calculations demonstrate that vertical ground movement has a significant impact on the flat slab structure in regards to axial force variations, punching shear, and deflection of slab.

**Key Words:** flat slab, flat plate, vertical ground motion, vertical earthquake motion, vertical PGA, response of flat slab, time history analysis

## 1. INTRODUCTION

The reinforced concrete flat slab technique is being used extensively for residential and commercial development in various regions, including high seismic zones. Flat slab is fashionable and easy to construct. It also helps to maximise the height between the ceiling and the floor.

Below are the types of flat slabs:

1. Flat Slabs without drop and column head.
2. Flat Slabs with column head.
3. Flat Slabs with drop
4. Flat Slabs with drop and column head

Due to its low lateral stiffness, flat slabs wobble significantly during seismic events, and the most dangerous failure in flat slabs is punching shear failure. If this occurs, the surrounding connections must be able to handle and redistributed pressures else it might cause a progressive failure of the structure.

Due to the belief that vertical acceleration is often smaller than horizontal acceleration, vertical ground motion has received less study. The vertical component of the ground motion was found to be greater than the horizontal component during the most recent earthquakes. Most design codes, including IS-1893 (2016), accept **Newmark and Hall's (1982)** recommendation that the design vertical spectrum should be 2/3 of the design horizontal spectrum.

Within 30 km of the source, the V/H ratio is crucial, according to **Papazoglou and Elnashai (1996) (1)**, and the 2/3 rule is found to be on the cautious side for events that occur close to the source.

**Nipan Bhandar Kayastha and Rama Debbarma (2016) (2)** performed analysis on G+3 building by SAP 2000. They considered seismic zone V with soft soil strata. They chose 5 different structural configurations consist of conventional RC frame structure, flat slab with dropped, column head & shear wall. Flat slab with shear wall at periphery performs better than general RC frame. It also gives maximum base shear compare to other models. Story displacement, Story drift are minimum in flat slab with shear walls. Natural period is also very less.

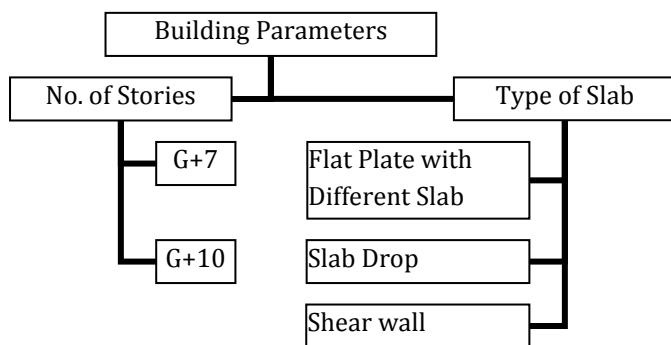
Further, a study on vertical ground motion and its impact on engineered structures by **Bipin Shrestha (2009) (3)** found that the current design process could have catastrophic results. It is advised that sites located within 20 km of the main active fault be designed to account for the combined effect of horizontal and vertical ground motion. The V/H ratios for near-source seismic events can be higher than 2/3. The primary impact of the vertical ground motion on the structure is to put more axial strain on the vertical load bearing element. When a vertical motion with similar amplitude to a horizontal motion occurs, it is seen that the axial force is typically greater than the equivalent transverse loading. It is also noted that variation of axial force is more on upper floor rather than lower floor.

Researchers **Siyun Kim, Sung Jig Kim, and Chunho Chang (4)** The effect of vertical ground movement on the 13 reinforced concrete structures with various geometric shapes was studied analytically. Horizontal ground motion has a greater impact on lateral displacement than vertical movement of the ground. Vertical ground movement caused by earthquakes is incorporated, the axial force fluctuation on the Reinforced concrete columns in the 1st story increases significantly, up to roughly 240%. This significant axial force

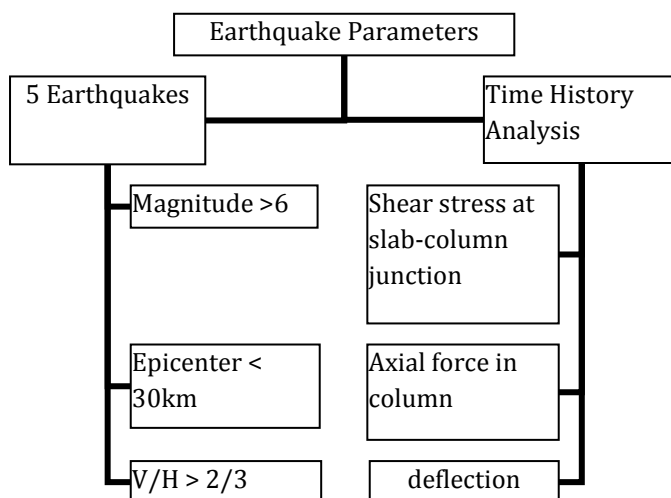
fluctuation reduces shear capacity and raises the possibility for shear failure as the Vertical to horizontal ratio and length ratio rise.

The seismic reaction of Reinforced Concrete structure subjected to both ground movements observed during the 2009 L'Aquila (Italy) quake was researched by **L Di Sarno, A.S. Elnashai, and G. Manfredi (5)**. Four documented ground accelerated movements were used in a nonlinear dynamic analysis. According to the findings of the inelastic dynamic studies, an average rise in column compression load varies between 175%. They used time history analysis to examine the influence of vertical seismic vibrations on a 7-story frame building. When the V/H ratio is 1.31, the axial force of the internal columns decreases 1.3 times compared to the gravity load, indicating that tension force developed. Furthermore, when just lateral ground motion was applied, the plastic hinges were mostly found near the frame's beam ends. However, when combined horizontal and vertical ground movement were applied, the column hinges significantly increased, particularly the plastic hinges at the intermediate floor columns.

**2. METHODOLOGY**



**Chart -1:** building parameters



**Chart -2** earthquake parameters

In this study, three possible structural configurations— flat plate, flat slab with drop, and flat slab drop with shear wall were taken into consideration for each of the two buildings, G+7, G+10. Three alternative Length to Depth ratios 15, 20, and 25 are taken into consideration for the flat plate structural system for determining the impact of slab thickness on punching shear and vertical acceleration. All models includes beams at perimeter to reduce the amount of punching shear stress at slab-column intersections. For all structures, the storey height is maintained to 3 metres.

The following factors were evaluated while selecting ground movement records: (1) Seismic magnitude greater than 6 (2) Epicentre distance less than 30km, (3) Vertical to Horizontal ratio should be greater than 2/3 (4) non-pulse ground movement data. We investigated 5 unscaled seismic ground movements after screening out earthquake recordings from the strongmotioncenter & NGA-West2 database using these criteria, as indicated. As a result, we examined around 50 models for various vertical ground movements. The linear time history approach and ETABS v17 were used to analyse all buildings subjected to both vertical and horizontal ground motion acceleration.

**Table -1:** structural member sizes

Structural member sizes in (mm)	
Column size	530 x 530
Peripheral beam size	230 x 450
Shear wall size	2750 (L) x 230 (T)
Flat slab thickness (L/D)	
15	365
20	375
25	225
Drop thickness	100
Drop panel size	2750 x 2750
Storey height	3000
Bay spacing in both	5500

**Table -2:** gravity loads and material grade

Gravity loads and material grade	
Self-weight	Per ETABS software
Floor finish	1.5 KN/m <sup>2</sup>
Floor live load	3 KN/m <sup>2</sup>
Terrace lice load	1.5 KN/m <sup>2</sup>
Concrete grade	M30
Steel grade	Fe- 415

Table -3: ground motion records

GROUND MOTION RECORDS									
REF. NO	EVENT	YEAR	STATION	M	EP	Hor1	Hor2	Ver	V/H RATIO
L1	Kozani, Greece	1995	Kozani	6.4	19.5	0.21	0.13	0.09	0.69
L2	Chamoli, India	1999	Gopeshwar	6.6	17.3	1.95	3.53	1.54	0.79
L3	Uttarkashi, India	1991	Bhatwari	7	21.7	2.48	2.42	2.89	1.19
L4	Northridge California	1994	Northridge	6.7	12.9	0.2	0.18	0.12	0.67
L5	Chi-chi, Taiwan	1999	Taichung	6.3	10.2	0.47	0.54	0.48	1.02

\*EP= epicenter distance, M= Magnitude of earthquake, Hor1= Long. PGA, Hor2= Trans. PGA, Ver= Vertical PGA

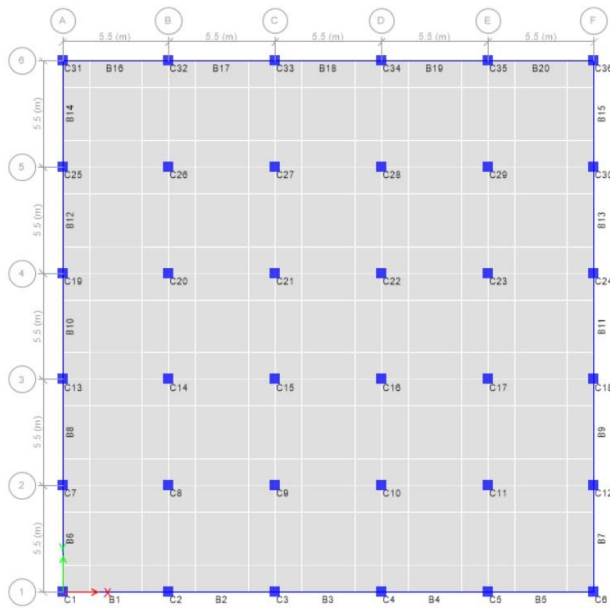


Fig -1: Flat Slab Building Plan

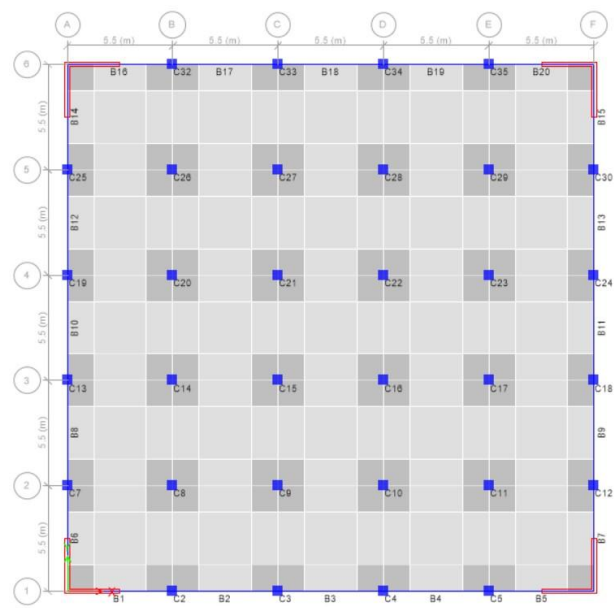


Fig -3: Flat Slab with Drop & Shear wall Building Plan

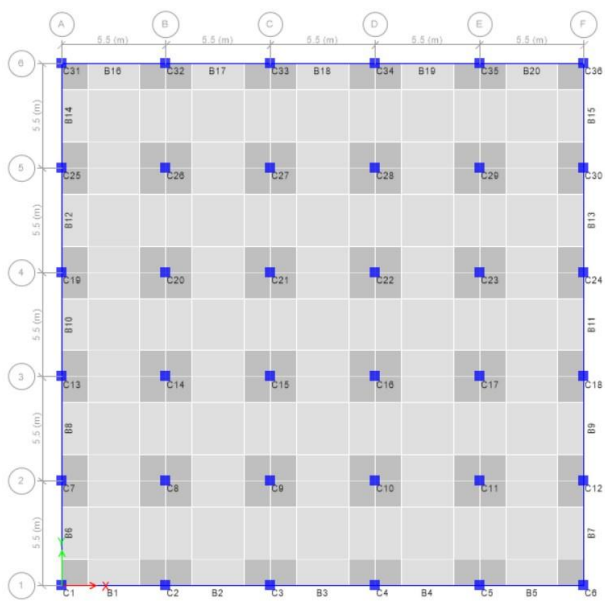


Fig -2: Flat Slab with Drop Building Plan

### 3. EXPLORATION FINDINGS DISCUSSION

For 5 chosen ground motion records, a linear time history analysis is carried out and applied to (5+5) various buildings. G+7 and G+10 will be used to denote building height in the study, while D, SW, LD15, LD20, and LD25 will denote structural system drop and shear wall, respectively.

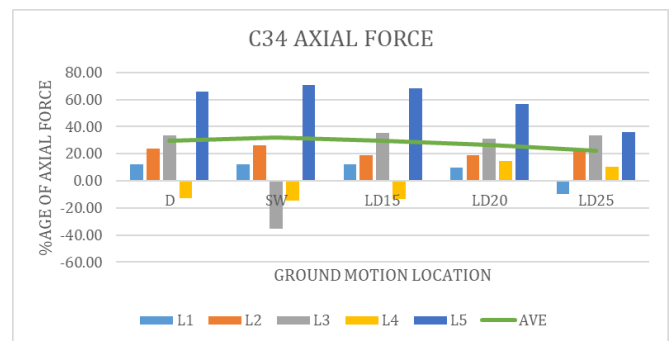


Chart -3 axial force in column C34 in G+7













