Pushover Analysis of Multi-Storey Buildings with Flat Slab along with Shear Wall and Core Wall

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Abstract - Flat Slabs are widely in use, especially in commercial buildings in urban areas. Buildings with flat slabs are susceptible to failure due to earthquake loading as beams are absent in such frames. Present study is made to determine the capacity of the RC Building with Flat Slab with Shear Walls and Core Walls. Hence Pushover Analysis is carried. The modelling and analysis are done using SAP2000. Six models of G+9 in seismic zone II is considered to study time period, base shear, displacement, performance point and state of the building.
In this study, an attempt to obtain Time Period, Base Shear, Storey Displacement, Pushover Curves and Performance Point is carried out.

Keywords— Pushover Analysis, Performance Point, Shear Wall, Core Wall, Displacement, Base Shear, SAP2000, Seismic Analysis

1.INTRODUCTION

Earthquake resistant design of RC structures are a continuing area of research since earthquake engineering has gained importance in the present day. Severely damaged and collapsed concrete structures need to be evaluated. The seismic adequacy of existing buildings too is to be examined. About 60% of the land area of our country is vulnerable for damaging levels of seismic hazard. Earthquakes of future can't be avoided, but remedy and safe building construction practices can certainly be adopted to reduce the extent of damage and loss. In order to strengthen and resist the buildings for future earthquakes, some procedures have to be adopted.

One such procedure is the static pushover analysis. It is gaining importance and is a popular tool for seismic performance evaluation of existing and new structures. By conducting push over analysis, weak zones in the structure can be identified, retrofitting or rehabilitation can be carried out accordingly.

Nowadays, flat slabs are one common solution for buildings as they are economical, easy to construct, less time consuming and offer better head room as compared to a framed structure with conventional beams and slabs. Hence, reinforced concrete flat slabs also called as beamless slabs, supported directly by columns without beams or girders. A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions.

Many pre-existinging flat slab buildings may not have designed for seismic forces. So, it is important to study their response under seismic conditions and to perform seismic retrofit schemes. But, when compared to beam-column connections, flat slabs are becoming prominent and gaining importance.

2. OBJECTIVE OF THE PROJECT

1. To assess the suitability of the RC building with flat slab by SAP2000.
2. Finite Element Analysis on RC building with flat slab using modal analysis by Equivalent Static Method, Response Spectrum.
3. Analysis of Flat Slab RC buildings with shear walls and core walls at different locations are considered.
4. Pushover analysis is carried out to evaluate the performance of the building according to ATC 40, FEMA 356 and FEMA 440.

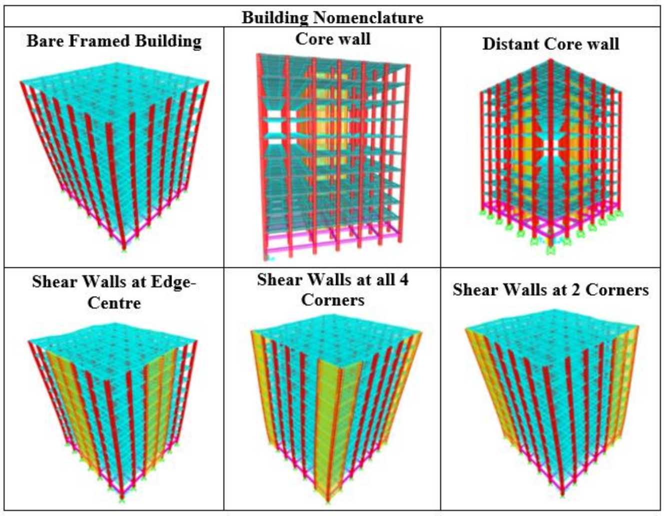
2.1 STRUCTURAL DETAILS OF MODEL

- Number of stories = 10
- Storey height = 3 m
- Number of bays in x-direction = 4
- Number of bays in y-direction = 4
- Bay length = 4m c/c
- Total height of the building = 31.5 m
- Slab thickness = 200mm
- Beam Cross Section = 300mm x 450mm
- Column Cross Section = 500mm x 500mm
- Shear Wall thickness = 500mm
- Drop thickness = 100mm
- Seismic Zone – II, Z = 0.10
- Structure type: RC buildings with special moment-resisting frame (SMRF)
- Response Reduction Factor, R = 5
- Importance factor, I = 1
- Soil profile type II = Medium Soil

Table -1*: Material Properties of Structural Members*

1.	**Concrete**	
	Grade of Concrete	M30
	Density of Concrete	2500 kg/m^3
	Elastic modulus	5000 ($f_{ck}^{0.5}$)
	Concrete Poisson's ratio	0.15
2.	**Steel**	
	Grade of Steel	Fe500
	Density of Steel	7850 kg/m^3
	Elastic modulus	2x10^5 N/mm^2
	Steel Poisson's ratio	0.3

Table -2: *BUILDING NOMENCLATURE*



2.2 DESIGN SPECIFICATION OF BUILDINGS

Multi-Storied buildings modelled and analysed using FEM based software SAP 2000. The model consists of ten storey with a storey height of 3 m having 6 bays with a spacing of 4 m along longitudinal direction and transverse direction. Shear walls and Core walls have been added at certain locations as shown in Table-2.

2.3 RESULTS AND DISCUSSIONS

Table -3: *FREQUENCIES AND TIME PERIOD*

Building Nomenclature	Frequency (Hz)	Time Period (s)
Bare Framed Building	0.78628	1.2718
Core walls	2.53954	0.39377
Distant Core walls	1.8104	0.55237
Shear Walls at Edge-Centre	1.71874	0.58182
Shear Walls at all 4 Corners	1.45915	0.68533
Shear Walls at 2 Corners	1.66737	0.59975

Table 3 represents Time Period and Frequencies, Table 4 and 5 represents Displacements, Base shear and pushover curves are represented in table 5 and 6. Fig.1 and 2 represents displacements along X and Y direction. Fig 3 represents Base Shear.

❖ *STOREY DISPLACEMENT*

Table -4: *Storey Displacement -RSx*

RSx Displacement (mm)						
NUMBER OF STOREY	BARE FRAME	SHEAR WALL AT EDGE CENTRE	SHEAR WALLS AT ALL 4 CORNERS	SHEAR WALLS AT 2 CORNERS	CORE WALL	DISTANT CORE WALL
10	6.58	4.08	4.73	3.38	1.93	3.80
9	6.38	3.65	4.24	3.03	1.73	3.40
8	6.07	3.16	3.69	2.63	1.51	2.96
7	5.61	2.67	3.12	2.22	1.29	2.51
6	5.049	2.18	2.55	1.82	1.07	2.06
5	4.37	1.70	2.003	1.42	0.85	1.61
4	3.59	1.25	1.46	1.05	0.64	1.19
3	2.73	0.83	0.98	0.71	0.44	0.80
2	1.81	0.48	0.56	0.42	0.27	0.47
1	0.88	0.21	0.23	0.18	0.13	0.20
0	0	0	0	0	0	0

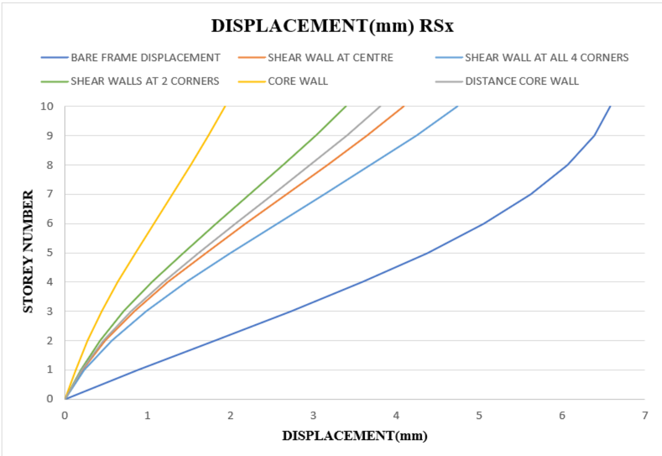


Fig -1: Storey displacement(mm) of buildings X Direction

Table -5: *Storey Displacement -RSy*

RSy Displacement (mm)						
NUMBER OF STOREY	BARE FRAME	SHEAR WALL AT CENTRE	SHEAR WALLS AT ALL 4 CORNERS	SHEAR WALLS AT 2 CORNERS	CORE WALL	DISTANT CORE WALL
10	6.58	4.08	4.73	3.24	1.93	3.80
9	6.38	3.65	4.24	2.90	1.73	3.40
8	6.07	3.16	3.69	2.51	1.51	2.96
7	5.61	2.67	3.12	2.12	1.29	2.51
6	5.049	2.18	2.55	1.73	1.07	2.06
5	4.37	1.70	2.003	1.35	0.85	1.61
4	3.59	1.25	1.46	1.00	0.64	1.19
3	2.73	0.83	0.98	0.67	0.44	0.80
2	1.81	0.48	0.56	0.39	0.27	0.47
1	0.88	0.21	0.23	0.17	0.13	0.20
0	0	0	0	0	0	0

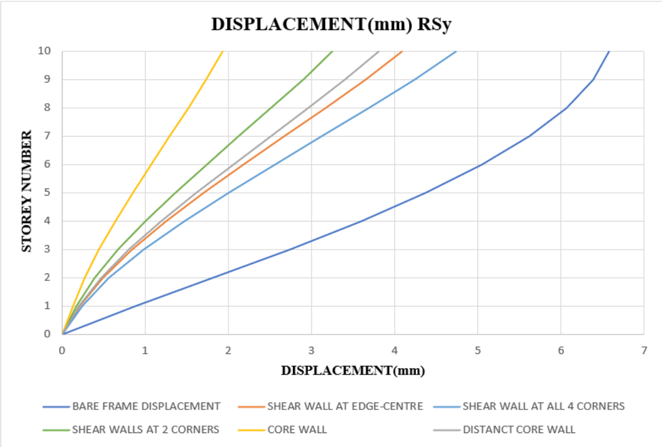


Fig -2: Storey displacement(mm) of buildings Y-Direction

❖ *Base Shear*

Obtained Base Shear values are identical in X and Y directions. Hence, values of Base Shears in X direction are shown.

Table -6: *BASE SHEAR*

Models →	Bare Frame	Core wall	Distant Core Wall	Shear wall at Edge Centre	Shear wall at 2 Corners	Shear wall at all 4 Corners
Base Shear (kN)	576.191	1654.47	1629.416	1546.925	1653.59	1313.286

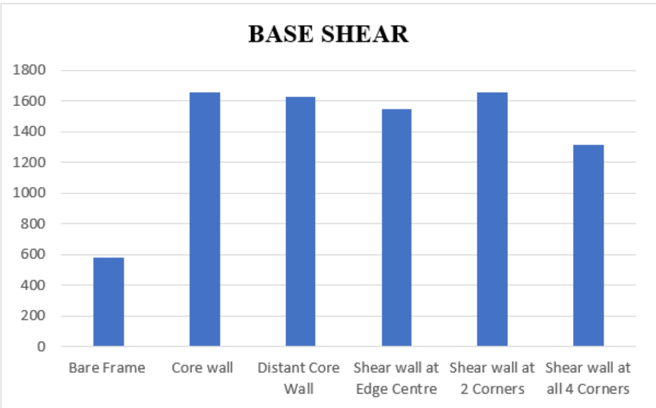


Fig -3: Base Shear of buildings with different Building Nomenclature

❖ *Pushover Curves and Hinge Results*

1. *Performance point:*

Performance point of the structure is calculated by two methods. ATC 40 capacity spectrum method, FEMA 356 and FEMA 440. Displacement coefficient method. In this study capacity spectrum method is followed. The figures show the performance point for Spectrum curve in X and Y directions.

Table -7: *Performance Points*

Building Nomenclature	V_b (kN)	D (mm)
Bare Framed Building	5266.619	49.896
Core walls	12155.741	9.951
Distant Core walls	13769.909	24.33
Shear Walls at Edge-Centre	17947.157	33.159
Shear Walls at all 4 Corners	18379.583	46.895
Shear Walls at 2 Corners	4068.366	5.65

Fig- 4 Performance Point of Bare Framed Model in X direction, Fig 5 Performance Point of Core Wall Model in X direction, Fig 6 Performance Point of Distant Core Wall Model, Fig 7 Performance Point of Shear Wall Edge Center Model, Fig 8 Performance Point of Shear Wall at all 4 corners Model, Fig 9 Performance Point of Shear Wall at 2 Corners Model.

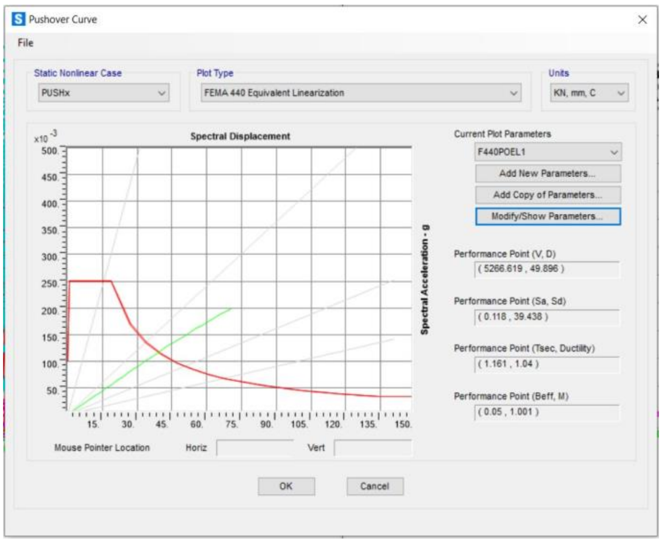


Fig- 4: *Performance Point of Bare Framed Model in X direction*

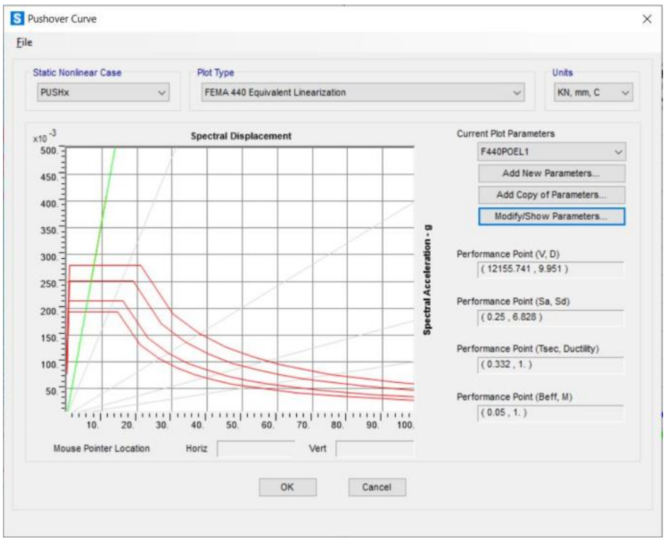


Fig-5: *Performance Point of Core Wall Model in X direction*

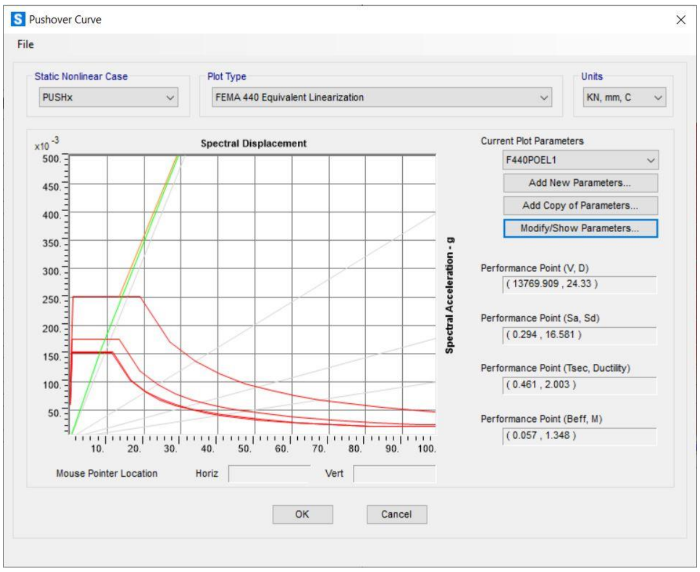


Fig-6: *Performance Point of Distant Core Wall Model*

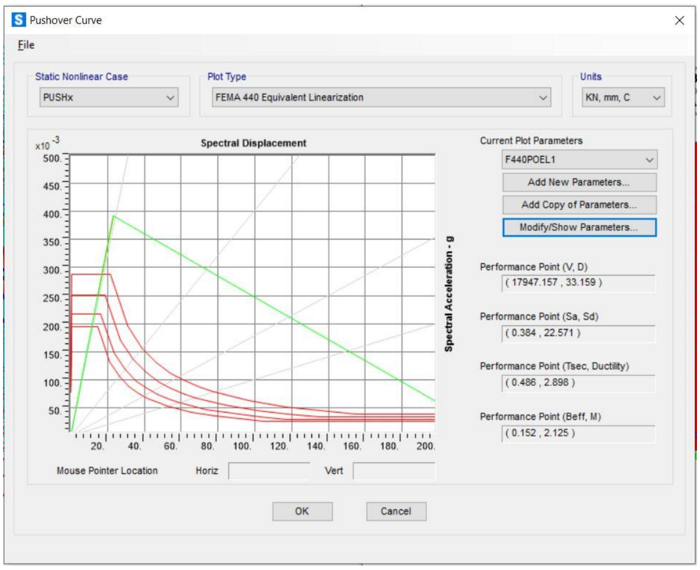


Fig-7*: Performance Point of Shear Wall Edge Center Model*

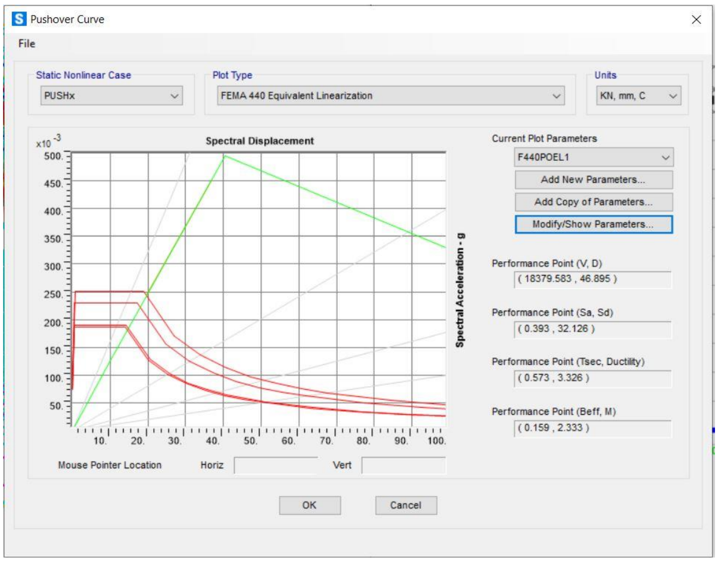


Fig- 8*: Performance Point of Shear Wall at all corners*

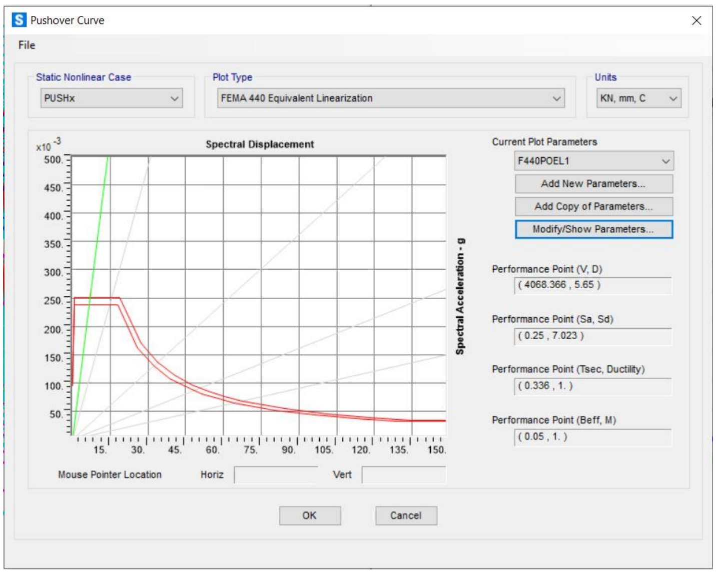


Fig-9: *Performance Point of Shear Wall at 2 Corners*

3. CONCLUSIONS

- The structure is analysed and designed for seismic zone II; it satisfies all the requirements according to IS 1893–2016.
- The Base Shear was maximum for Core Wall Model.
- The Displacement was observed to be maximum for Bare Framed Building reduced for Buildings with Shear Walls further reduced for Buildings with Core Walls.
- By referring to 11.3 of ATC 40 "Global building acceptability limits" it is found that the designed bare frame building performance shall be "Immediate Occupancy level".
- By referring to 11.3 of ATC 40 "Global building acceptability limits" it is found that the designed

buildings other than bare frame building performance shall be "Immediate Occupancy - Life Safety level"
- Time Period of bare framed building is more compared to frames with shear walls and core walls.
- Base Shear of bare framed building is less compared to frames with shear walls and core walls.
- Top Storey Displacement is least in case of buildings with Core Walls, is more in case of Shear Walls and is maximum in case of Bare Framed Building.
- Based on the pushover analysis results, shear wall at all 4 corners models is suggested.

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