

Analytical Studies on Effect of Brick Elemental Properties on Static Pushover Analysis of Multi-Storey Frame

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ABSTRACT: The current study deals with the analysis of the seismic behaviour of multi storey buildings and effect of brick elemental properties on static pushover analysis of multi storey frame.

Three basic multi storey models were chosen- 5 storey, 10 storey and 15 storey buildings. Analysis was carried out considering both 2D and 3D frames. For each model, four types of brick elemental properties were further considered, which include- Shell, Membrane, Plate and Thick Plate. Also, analysis was done for different wall thickness in each case i.e.- **150mm and 230 mm**.

Static pushover analysis was done for the models using ETABS 9.7.4 and the Pushover curves were obtained. The study compared the results of seismic performance of multi storey frames for different brick elemental properties.

Tables containing the results of pushover analysis, which included the number of hinge steps, displacement values, Base shear values, Collapse prevention, Immediate occupancy, Life safety were obtained, for each case.

The different results for different brick elemental properties and wall thickness were tabulated and compared. The primary objective of the study is to determine which brick elemental property is adequate and ideal comparatively. The comparison is based on the base shear value obtained for different cases, (maximum value ideal) and also the displacement values.

KEYWORDS: Pushover analysis, base shear, displacement, storey drift, Plastic hinges.

I. INTRODUCTION

Pushover Analysis predicts the structural response similar to that of the other 2 methods- response spectra and time history analysis since it incorporates $p - \Delta$ effects and material non linearity which is true in real structures. Performances of structures are normally predicted accurately by analysing carefully, the performance parameters obtained from pushover analysis results. The demand curve, capacity curve and the category of performance level it belongs to like Immediate occupancy, Life Safety or Collapse Prevention directly tells us if the structure is safe or about to collapse.

Pushover analysis is a series of incremental static analysis carried out to develop a capacity curve for the building. This procedure needs the execution of a nonlinear static analysis of the structure that allows the monitoring of the

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progressive yielding of the structure component. The building is subjected to a lateral load. The load magnitude increases until the building reaches the targeted displacement. This target displacement is determined to represent the top displacement when the building is subjected to design level ground excitation. Pushover analysis produces a pushover curve or capacity curve that presents the relationship between the base shear (V) and roof displacement (Δ).

The Pushover curve depends on the strength and deformation capacities of the structure and describes how the structure behaves beyond the elastic limit. Structural response to ground motion during earthquake cannot be accurately predicted because of the complexity of the structural properties and ground motion parameters. In pushover analysis, a set of lateral displacement is used directly as design condition. The displacement is an estimate of the maximum expected response of the structure during ground motion.

The analysis is carried out upto failure, thus it enables determination of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified.

II. LITERATURE REVIEW

A large number of literatures available on the above topic were collected, systematically reviewed and some of the useful reviews are given here. Ms. Nivedita N. Raut & Ms. Swati D. Ambadkar [1] investigated the effect of the layout of masonry infill panels over the elevation of masonry in filled R/C frames on the seismic performance and potential seismic damage of the frame under strong ground motions using nonlinear static push-over analysis based on realistic and efficient computational models. They observed that the seismic performance of a masonry infill R/C adversely and significantly affected if the infill panels were discontinued in the ground story resulting in the structural configuration with an open story, commonly termed as 'weak' story, at the ground levels. Madhusudan G. Kalibhat, Kiran Kamath, Prasad S. K, Ramya R. Pai [2] analysed a six storied steel building for different types of bracing system such as concentric (crossed X) bracing and eccentric (V-type) bracing using HSS sections. They observed that steel frames with insufficient lateral stiffness can be retrofitted with braces. Braces are the viable solutions to provide both global lateral stiffness and strength of the frame. The provision of bracing enhances the base shear carrying capacity of frames and reduces roof displacement undergone by the structures. [2] S. I. Khan, Prof. P. O. Modani [12] studied the variation of load-displacement graph and checked the maximum base shear and displacement of RC frame using SAP 2000.

III. MODELLING AND ANALYSIS

Scope of present work

After understanding the literature, the objectives of the present investigation were carved. Analysis of the 3D models of the **5, 10 and 15** storey model for wall thickness of **200mm and 230mm** located in zone 2 has been performed and overall seismic evaluation of the structures were carried out using the performance parameters obtained from the Pushover analysis using the software ETABS 9.7.4 for the cases given below:

CASE 1: Brick infill as **SHELL** element

CASE 2: Brick infill as **MEMBRANE** element

CASE 3: Brick infill as **PLATE** element

CASE 4: Brick infill as **THICK PLATE** element

Structural details and material properties

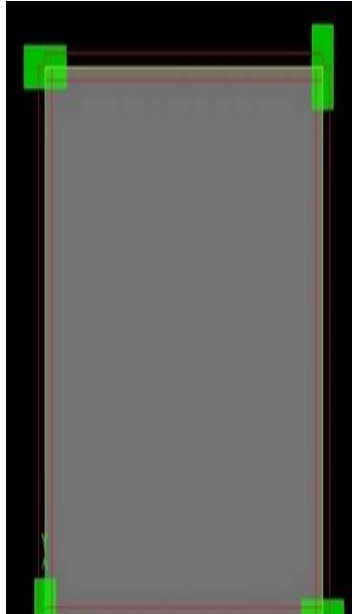
In the present study, **5, 10 and 15** storey model with plan area 3m x 3m was considered. The typical floor height was taken as 3m giving a total height of the structure **15m, 30m and 45m** respectively. Two cases of **150mm and 230mm** wall thickness were considered. The beams, columns were assumed as concrete structure and the wall as brick masonry.

The Plan & 3D view of RC frame with brick masonry walls of all the three models has been shown in the figure 1(a) and figure 1(b), 1(c) and 1(d) respectively.

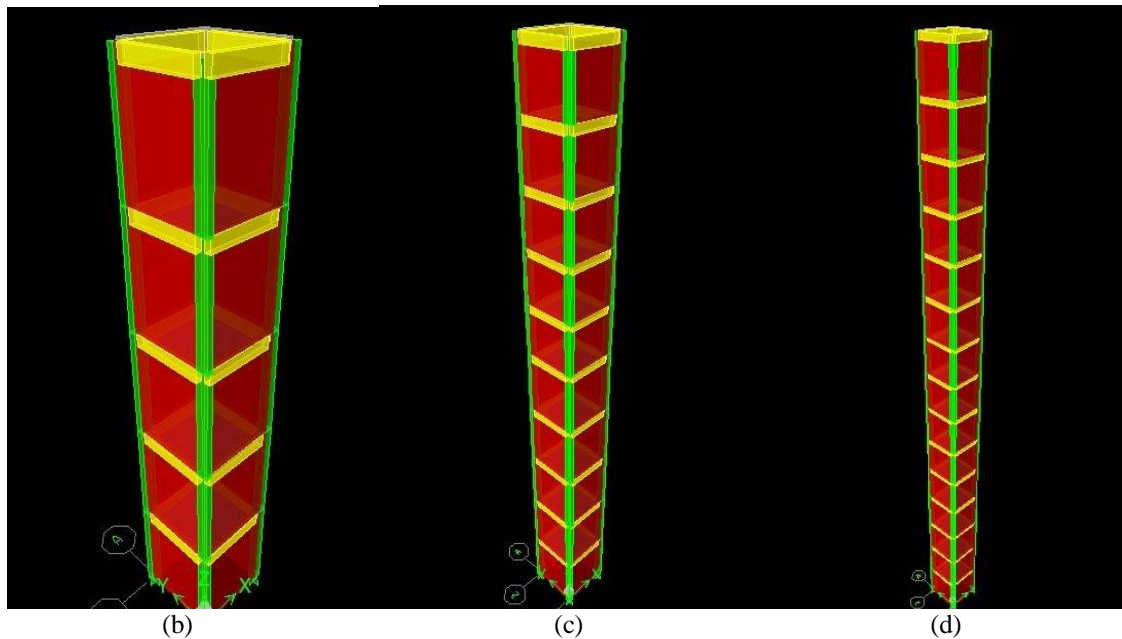
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(a)



(b)

(c)

(d)

Figure 1: Plan & 3D view of the 5, 10, and 15 storey models

The geometric properties, material properties and the structural properties in the form of the data to be given in the ETABS are outlined in the table 1

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Table 1: Geometric properties, Material properties and the Structural properties assigned to the models

Spacing	
In X-direction	3m
In Y-direction	3m
Support condition	Fixed
Conventional Slab thickness	150mm
Infill wall thickness	200mm and 230mm
Column size	230mm*450mm
Beam size	230mm*450mm
Grade of concrete	M25
Grade of steel	Fe415
Modulus of elasticity of M25	25000000kN/m ²
Poisson's ratio	0.2
Coefficient of thermal expansion	9.900E-06
Shear modulus	10416666.7 kN/m ²

Modelling and Analysis

Modelling is an important stage in the analysis of multi storied buildings. The steps followed in modelling the structure are listed below:

1. Creating the basic computer model (without the pushover data)
2. Choosing the concrete frame design code preference.
3. Defining material properties
4. Evaluation of the sectional properties of the beams, columns, slabs using trial runs.
5. Positioning of the beams, columns, slabs and Infill walls.
6. Assigning boundary conditions- In all the models, base was considered to be fixed support.
7. Defining the static load cases- Dead load, live load, and seismic loadings as per IS 1893-2002 were considered. In order to have a realistic analysis, the structural properties and model details were arrived based on the previous literatures and is given in the table 2. User defined time period, seismic coefficients, factors and storey ranges were input in to the software.
8. Defining mass source as per IS 1893(Part 1): 2002

Table 2: Structural properties and Model details

Seismic details conforming to IS 1893(Part 1): 2002	
Zone factor	0.1
Importance factor	1
Type of soil	Type II (Medium)
Reduction Factor	3

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Analysis in ETABS 9.7.4

A detailed analysis was carried out in the PG lab at the department of Civil Engineering, MSRIT, Bangalore, affiliated to VTU, Belagavi. Analysis of the models consists of 3 stages, viz., Static analysis, Designing and Pushover analysis. After the modelling, the basic static analysis was run followed by the designing process of the concrete frame structure. For the next stage, which is pushover analysis, prefixing of the hinge points were carried out. The software Etabs includes several built in default hinge properties that are based on average values from ATC-40 (Applied Technology Council) for concrete and average values from FEMA-273 (Federal Emergency Management Agency) for steel members. In this analysis, only user defined hinge properties were considered. For the columns, default PMM hinges were assigned and for the beams, default M3 hinges were taken.

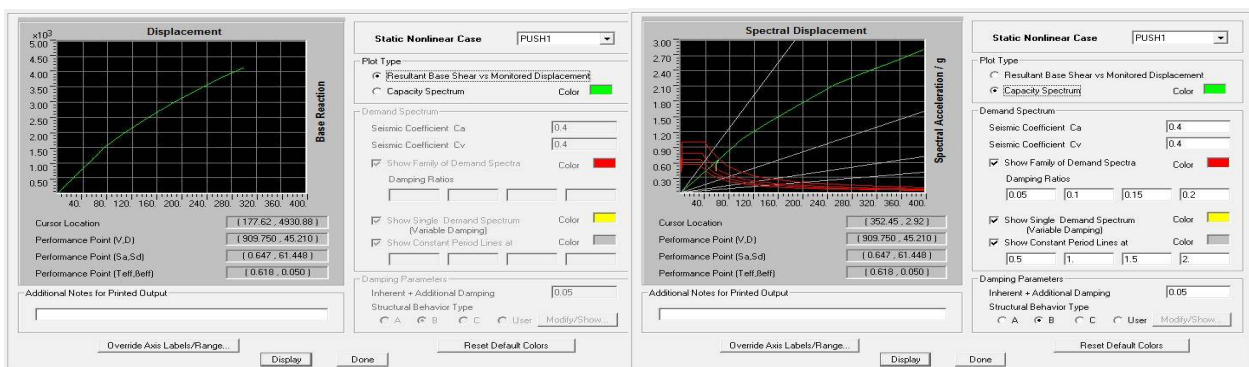
Typically a gravity load pushover is force controlled and lateral pushover is displacement controlled. In our analysis in Etabs 9.7.4 more than 1 pushover load cases were defined and were run in the same analysis. The user defined pushover displacement magnitude of 3.66m obtained by default for each model was applied and load pattern was taken as acceleration in direction X for a scale factor of -1. Finally, the static non linear pushover analysis was run.

After the analysis was complete, static nonlinear pushover curve and the pushover table was obtained. As the values of seismic coefficient of acceleration, C_a & seismic coefficient of velocity C_v , damping ratios etc., were varied, the pushover curves and performance point values changed accordingly. The required C_a & C_v values were entered depending on the soil type and seismic zone considered and the observations were made regarding the performance of the model and relevant conclusions were drawn by reviewing the pushover displaced shaped, the performance point and sequence of hinge formation.

IV. RESULTS AND DISCUSSION

Static pushover analysis was done for the models using ETABS 9.7.4 and the Pushover curves were obtained. The study compared the results of seismic performance of multi storey frames for different brick elemental properties and for different wall thickness, i.e. **150mm and 230mm**.

Fig.2 and 3 shows the different pushover curves obtained and the Tables containing the results of pushover analysis, which included the number of hinge steps, displacement values, base shear values, collapse prevention, immediate occupancy, life safety.



(a) Base shear v/s Displacement

(b) Capacity spectrum

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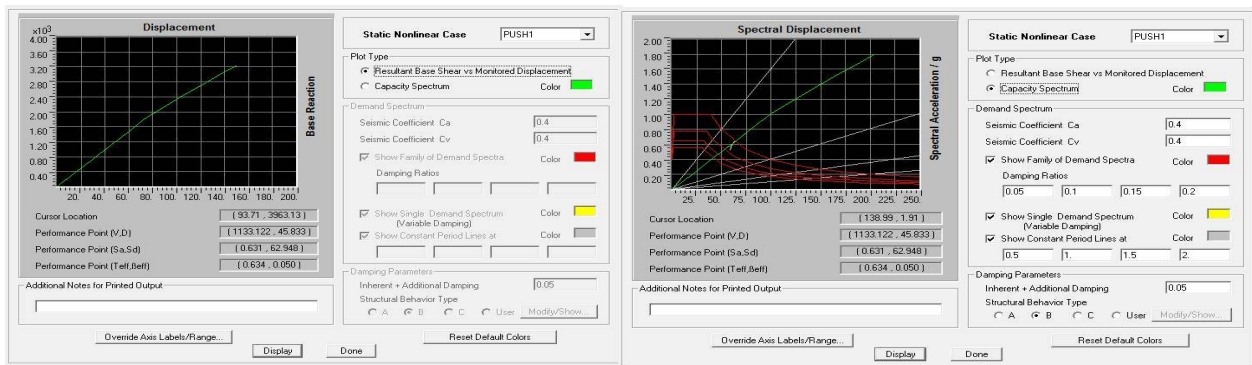
ETABS v9.7.4 File:10 STOREY .3D Units:KN-mm April 23, 2016 10:32 PAGE 1

PUSHOVER CURVE

Pushover Case PUSH1

Step	Displacement	Base Force	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0000	0.0000	240	0	0	0	0	0	0	0	240
1	30.0000	603.6870	240	0	0	0	0	0	0	0	240
2	60.0000	1207.3772	236	4	0	0	0	0	0	0	240
3	74.0696	1490.5031	236	4	0	0	0	0	0	0	240
4	104.0717	1935.1942	232	8	0	0	0	0	0	0	240
5	145.0005	2483.9390	227	12	1	0	0	0	0	0	240
6	186.8073	3005.4353	224	12	4	0	0	0	0	0	240
7	223.7441	3392.4763	223	13	3	1	0	0	0	0	240
8	263.5272	3792.5789	221	14	3	2	0	0	0	0	240
9	300.0588	4156.1157	240	0	0	0	0	0	0	0	240

Figure 2: The pushover curves and table obtained for 150mm membrane element



(a) Base shear v/s Displacement (b) Capacity spectrum

ETABS v9.7.4 File:5 STOREY .3D Units:KN-mm April 22, 2016 12:21 PAGE 1

PUSHOVER CURVE

Pushover Case PUSH1

Step	Displacement	Base Force	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0000	0.0000	240	0	0	0	0	0	0	0	240
1	15.0000	370.8432	240	0	0	0	0	0	0	0	240
2	30.0000	741.6870	240	0	0	0	0	0	0	0	240
3	45.0000	1112.5316	240	0	0	0	0	0	0	0	240
4	60.0000	1483.3772	236	4	0	0	0	0	0	0	240
5	72.8701	1891.5659	236	4	0	0	0	0	0	0	240
6	87.8708	2099.0371	236	4	0	0	0	0	0	0	240
7	102.8718	2396.5798	232	8	0	0	0	0	0	0	240
8	121.4172	2734.6824	232	8	0	0	0	0	0	0	240
9	136.4200	3002.6426	231	9	0	0	0	0	0	0	240
10	150.0100	3242.8918	240	0	0	0	0	0	0	0	240

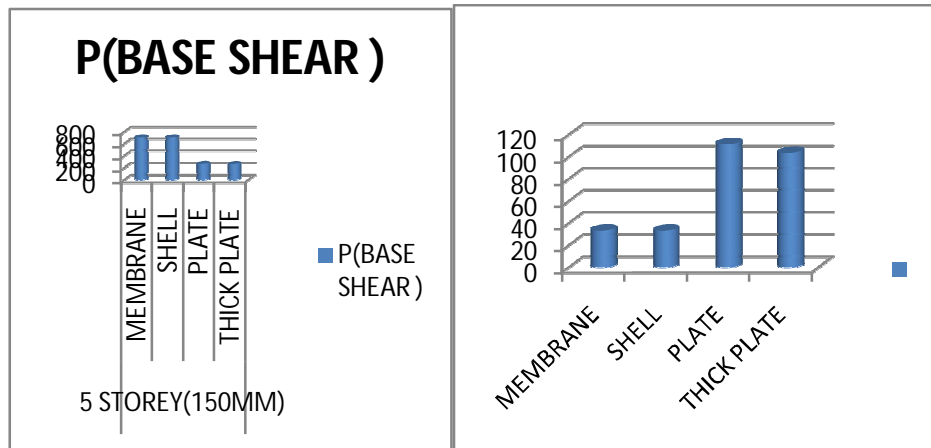
Figure 3: The pushover curves and table obtained for 230mm membrane element

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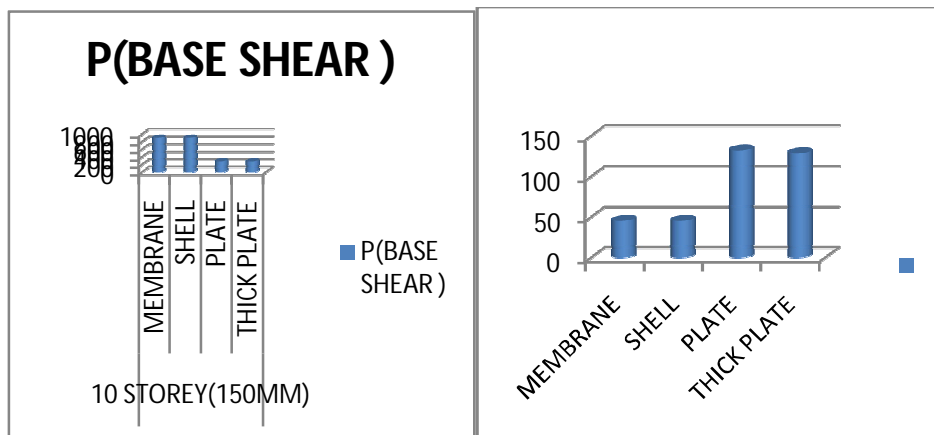
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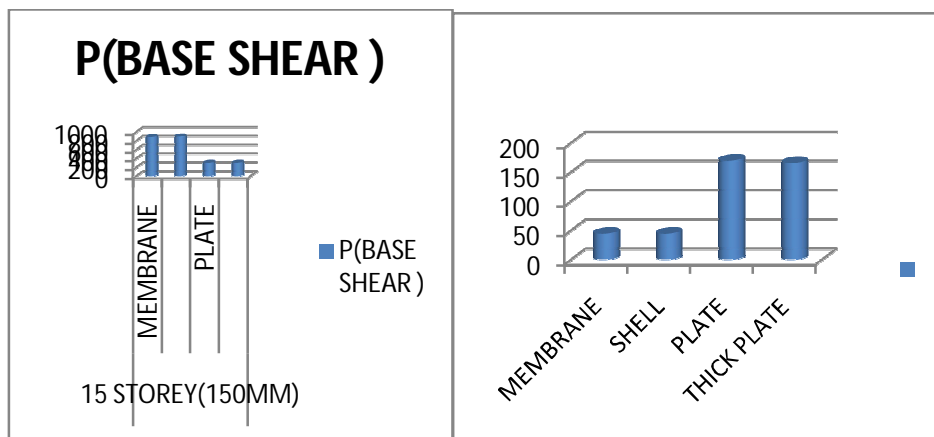
COMPARISON



(a) 5 Storey



(b) 10 Storey



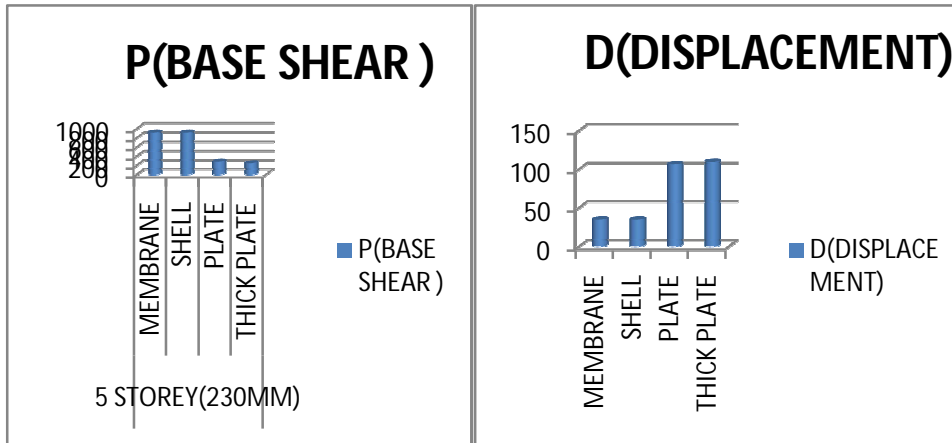
(c) 15 storey

The above figures show the comparison of the base shear and displacement values obtained for different elements for a wall thickness of **150mm** for **5, 10** and **15** storey models.

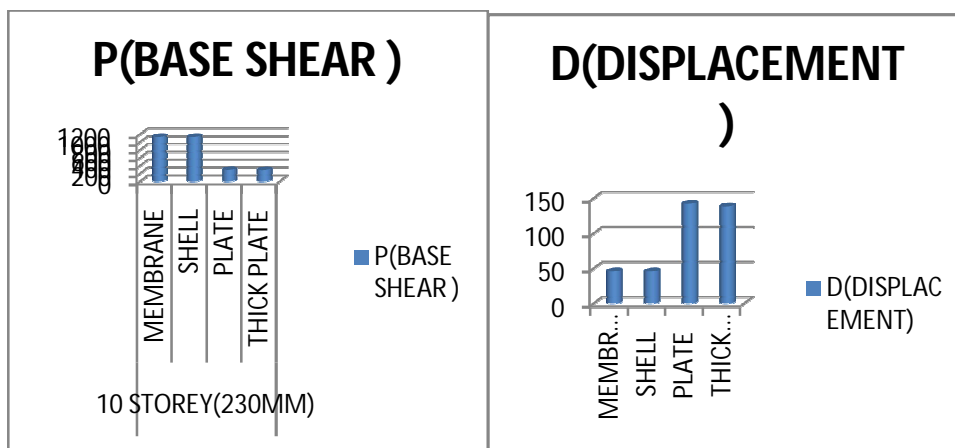
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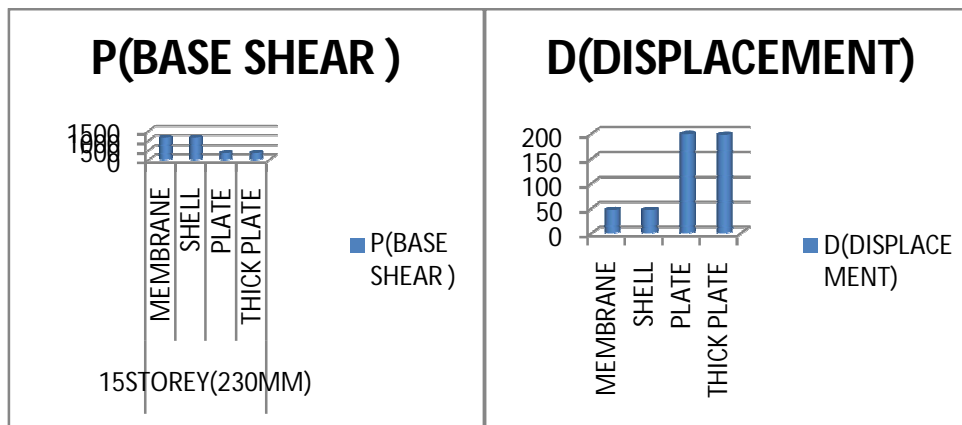
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(a) 5 storey



(b) 10 storey



(c) 15 storey

The above figures show the comparison of the base shear and displacement values obtained for different elements for a wall thickness of **230mm** for **5, 10 and 15** storey models.

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Figure 4: Comparison graphs

In order to have a comparative evaluation of different brick elements, variations of the performance parameters at the performance point for the 2 types of wall thickness, i.e. 150mm and 230mm are given in the following table 3

Table 3

Case	Element	Base force (KN)	Displacement (m)	Sa (m2/s)	Sd (m)	Teff (s)	Beff	Max. storey drift due to EQX
150mm	Membrane	710.387	33.363	1.00	22.678	0.302	0.050	0.0000808
	Shell	710.296	33.40	1.00	22.661	0.302	0.050	0.0000801
	Plate	269.372	111.411	0.337	85.111	1.099	0.098	0.0005665
	Thick plate	267.946	103.711	0.333	79.275	0.978	0.111	0.0005146
230mm	Membrane	909.367	34.517	1.00	23.63	0.306	0.050	0.0000858
	Shell	909.126	34.462	1.00	23.225	0.306	0.050	0.0000858
	Plate	282.513	106.223	0.274	80.62	1.091	0.140	0.0006517
	Thick plate	246.765	109.428	0.227	85.425	1.220	0.174	0.0006044

(a) 5 storey

Case	Element	Base force (KN)	Displacement (m)	Sa (m2/s)	Sd (m)	Teff (s)	Beff	Max. storey drift due to EQX
150mm	Membrane	909.750	45.210	0.647	61.448	0.618	0.050	0.0000927
	Shell	909.895	45.191	0.67	61.432	0.168	0.050	0.0000925
	Plate	288.027	132.147	0.171	128.781	1.738	0.140	0.0006077
	Thick plate	286.094	128.558	0.169	125.204	1.724	0.149	0.0005490
230mm	Membrane	1133.122	45.833	0.631	62.948	0.634	0.050	0.001376
	Shell	1133.597	45.791	0.632	62.910	0.633	0.050	0.0001373
	Plate	290.311	142.307	0.312	137.936	2.053	0.184	0.0005734
	Thick plate	286.520	138.765	0.130	134.204	2.042	0.196	0.0005734

(b) 10 storey

Case	Element	Base force (KN)	Displacement (m)	Sa (m2/s)	Sd (m)	Teff (s)	Beff	Max. storey drift due to EQX
150mm	Membrane	888.974	44.620	0.385	103.189	1.039	0.050	0.0000578
	Shell	889.088	44.600	0.385	103.169	1.038	0.050	0.0000952
	Plate	309.114	169.655	0.108	189.013	2.646	0.155	0.0006166
	Thick plate	310.491	165.554	0.108	184.739	2.614	0.160	0.0005625
230mm	Membrane	1134.221	45.877	0.420	94.606	0.952	0.050	0.0000628
	Shell	1134.648	45.83	0.420	94.556	0.952	0.050	0.0000628
	Plate	344.318	198.408	0.093	219.485	3.081	0.157	0.0003361
	Thick plate	351.362	196.912	0.095	218.288	3.046	0.154	0.0003361

(c) 15 storey

Table 3 is a tabulation of all the values obtained after the analysis of the all the 3 models for 200mm and 230mm wall thickness. These experimental values were further evaluated to come to certain conclusions.

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V. CONCLUSION

- From the comparison of results, using Shell element as the brick elemental property gave the maximum value of Base shear and least values of displacement. Hence, shell element is comparatively ideal.
- As the number of storeys were increased, there was a constant increase in the Base shear and Displacement values.
- Using Plate and Thick Plate as brick elemental property gave smaller values of Base shear and hence is comparatively inadequate.
- Pushover analysis is non-linear static analysis in which there are good reasons for advocating the use for demand prediction since in many cases it will provide much more relevant information than an elastic static or even dynamic analysis, but it would be counterproductive to advocate this method as a general solution technique for all cases.
- Pushover analysis is a useful tool for assessing inelastic strength and deformation demands and for exposing design weaknesses.
- The results of the nonlinear static pushover analysis quantitatively establish that the seismic performance of masonry infill R/C adversely and significantly affected with varying thickness.

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