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Seismic Analysis of Asymmetrical Multi-storey Buildings as Per IS 1893-2016

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Abstract— It is critical to test and perform seismic building analysis as lots of damage and structural losses causes due to earthquake in past. It is compulsorily desired to analyse response of building structure for possible losses. Seismic response of the unsymmetrical structure is required to perform to design building under seismic consideration.
Therefore, the present research work is to analyze 3D numerical models of three G+9 multistory infill building which are unsymmetrical in plan are constructed and performed the analysis by using software SAP 2000 (ver.16.0) using static nonlinear method. This paper highlights the comparing and investigating the performance of infill building which are unsymmetrical in plan subjected to seismic load at performance point. The result of the analysis for displacement, base shear at performance point, storey drift, storey displacement and base moment have been studied.

Index Terms— Multistorey Buildings, SAP2000, Unsymmetrical plan, Non linear analysis, Displacement, Base Shear, Drift.

I. INTRODUCTION

For any structure to perform well in seismic hazard, the structure should possess symmetric and simple configuration, adequate lateral strength, ductility and stiffness. Structures consist simple and symmetric geometry, uniformly distributed mass and stiffness in elevation as well as in plan are suffer much lesser damage than structures with unsymmetrical plan and elevation configurations. But nowadays, due to rapid growth of urbanization and for aesthetic purpose unsymmetrical structural configurations buildings are widely constructed. Due to unsymmetrical configurations in buildings leads to non-uniform distributions in their strength, masses and stiffness therefore they are more prone to damage during seismic hazard. therefore, in the present study an attempt has been made to study the performance of unsymmetrical structures located in severe seismic zone v using IS 1893-2016.
The section 7 of IS 1893(part1):2016 enlists the different buildings irregularity. These irregularities are as follows
1. Vertical irregularities which is due to sudden change of mass, strength, geometry and stiffness results in non-uniform distribution of forces over the height of the building.

2. Plan irregularities due to asymmetrical plan shapes or horizontal resting elements (diaphragms) such as re-entrant corners, cut-outs, large openings and other abrupt changes resulting in stress concentration, torsion and diaphragm deformations Thus, the plan irregularities are due to unsymmetrical buildings plan. Now a day's large number of building are constructed with different plan configuration due to architectural aspect. Therefore, it is essential to analysis the unsymmetrical building subjected to earthquake using SAP 2000 (ver. 16.0) and compares the response of structure in terms of base shear and displacement

II. MODELLING AND ANALYSIS

In this research work, numerical models of G+9 story Brick infilled building with different plan configuration is developed with the help of SAP 2000(ver.16.0) computer software.

A. Material Properties

The material properties of concrete, steel and Brick of assigned sections for all three developed finite element models are discussed in the following sections.

Concrete and Steel Properties

The generic properties of concrete grade M-30 and isotropic behaviour of concrete are considered in the analysis.
For all Three cases, the steel and concrete structures are designed as per IS: 800:2007 and IS: 456:2000 respectively

Table 1 Concrete and steel material properties

SN	Material properties	Concrete	Steel
1	Grade	M30	Fe500
2	Young's Modulus (kN/m^2)	$2.738e^{+007}$(kN/m^2)	$2.05e^{+008}$(kN/m^2)
3	Poisson's ratio	0.2	0.3
4	Coeff. of thermal expansion	$5.500e^{-06}/^0c$	$1.170e^{-05}/^0c$
5	Weight density (kN/m^3)	30	76.98
6	Mass density (kN/m^3)	2.5485	7.85
7	Damping ratio	0.05	0.05

Brick Properties

For the analysis of all three models, the material properties of Brick which are used in nonlinear static analysis are given in Table 2.

Table 2 Properties of brick material

SN	Material properties	BRICK
1	Unit Weight (Dry Density)	1920 Kg/m^3
2	Compressive strength (min)	3.5 N/mm^2
3	Flexural strength	19.3 Kg/cm^2
5	Elastic Modulus	2040 MPa
6	Poision ratio	0.2
7	Coeff. of thermal expansion	8.0x10^{-6}

B. Building Model Details

For the analysis, particulars and details of building model of G+9 story structure for three different cases are listed in the Table 3.

Table 3 Particular and details for all building models

Particulars	Details
Plan size	900 m^2
Storey height	3.0 m
Depth of foundation below ground	1.5 m
Type of soil	Type II, Medium as Per IS:1893
Grade of concrete	M30
Grade of steel	Fe-500
Column size	500 mm x500 mm
Beam size	300 mm x 400 mm
Slab thickness	150 mm
Brick strut thickness	230 mm
Brick strut width	563 mm
Brick wall load	11.48 kN/m^2
Roof live load	1.0 kN/m
Floor live load	3.0 kN/m
Building importance factor	1
Response reduction factor	3
Zone factor	0.36

C. Plan and 3D View of Models

The buildings of plan area 900 m2 are considered. For the performance-based analysis, story height of 3.0 m (floor to floor) is considered in this work. All beam and column joints are considered as a rigid. At each level of the structure diaphragm shall be provided to connect the structure masses to the primary vertical component of the lateral load resisting system. Plan and 3D view of Brick infilled unsymmetrical building is shown below from Figure 1 to Figure 4 respectively

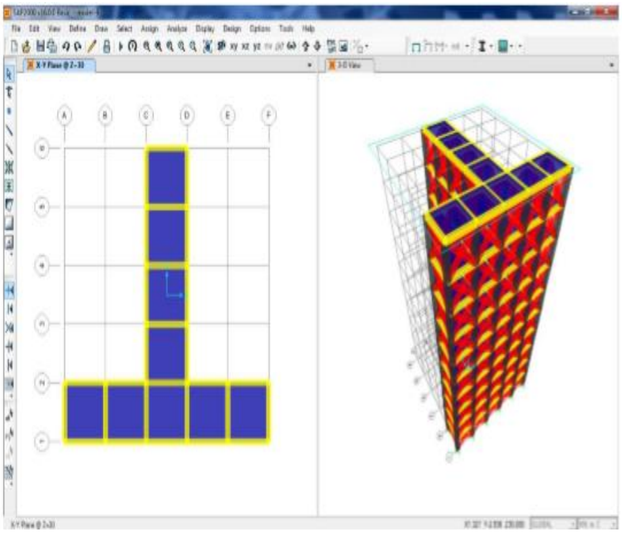

Figure 1: Model-1 Plan and 3D view of brick infilled building

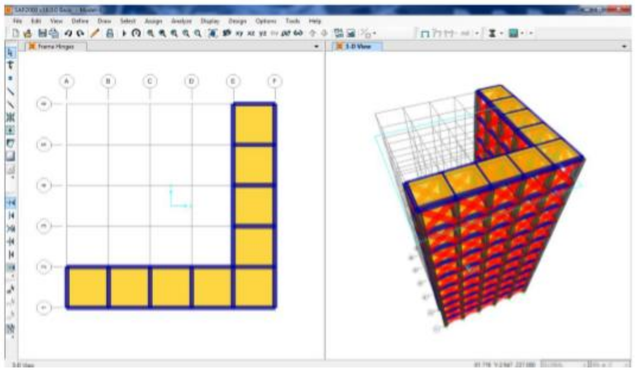

Figure 2: Model-2 Plan and 3D view of brick infilled building

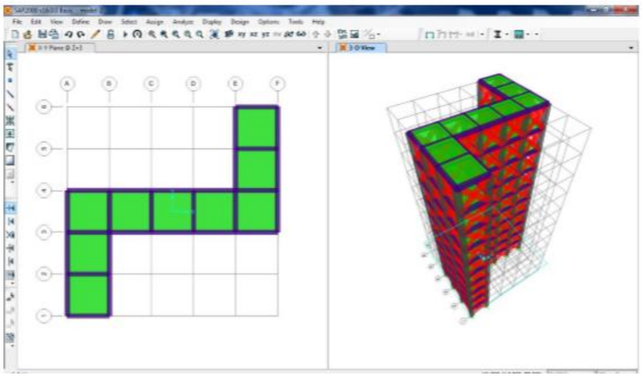

Figure 3: Model-3 Plan and 3D view of brick infilled building

D. Analysis

For the performance-based analysis of all three model load cases such as dead load (selfweight of structure), floor live load, roof live load, wall load which is acting in the gravity direction is considered and seismic earthquake load combination is taken as per IS 1893-2016 code.

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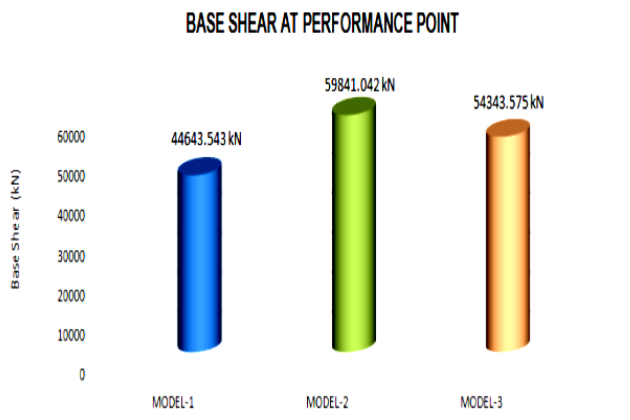
III. RESULT AND DISCUSSION

The results include capacity spectrum showing performance point, location of hinges, number of hinges, base shear, top displacement at performance point, base moment, storey drift, storey height vs displacement curve obtained from the finite element nonlinear analysis of all three brick Infill building model under static loading condition

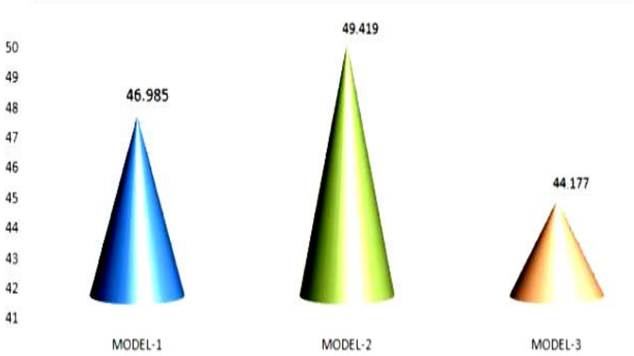
i. Comparison of Base Shear and Top Displacement at Performance Point

Table:4 Base shear and displacement of all three cases at performance point

SN	Building type	Base shear	Displacement
1	L-Shaped Diaphragm Open Building	44643.543 kN	46.985 mm
2	C-Shaped Diaphragm Open Building	59841.042 kN	49.419 mm
3	H-Shaped Diaphragm Open Building	54343.575 kN	44.177 mm



Graph:1 Comparison of Base Shear at performance point

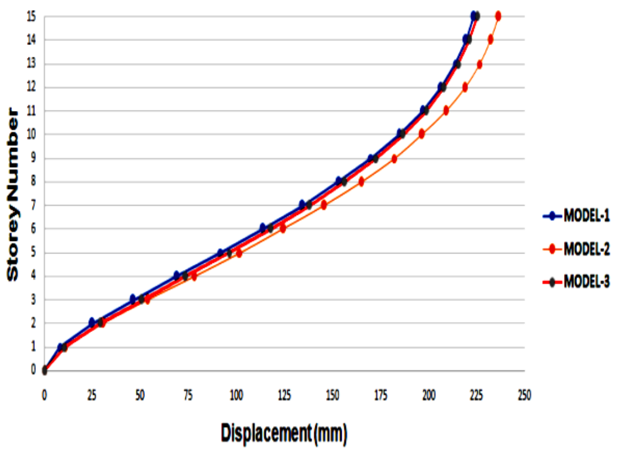


Graph:2 Comparison of Top Displacement at performance point

ii. Comparison of storey displacement in x-direction

Table:5 Storey displacement comparison in x- direction

Storey No.	Displacement of H-shaped opening diaphragm building (mm)	Displacement of C-shaped opening diaphragm building (mm)	Displacement of L-shaped opening diaphragm building (mm)
15	223.3	236.4	225.1
14	219.2	232.0	220.9
13	213.7	226.2	215.3
12	206.3	218.6	207.9
11	196.6	208.8	198.5
10	184.5	196.5	186.7
9	169.9	181.1	172.6
8	153.1	164.7	156.3
7	134.2	145.5	137.9
6	113.6	124.3	117.8
5	91.7	101.6	96.1
4	68.9	77.8	73.5
3	46.2	53.6	50.7
2	25.0	30.5	28.9
1	8.0	10.9	10.4
ground floor	0	0	0



Graph:3 Storey displacement comparisons in x-direction

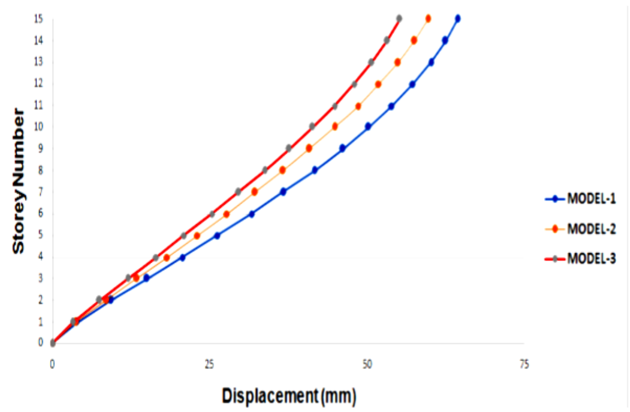
iii. Comparison of storey displacement along y-direction

Comparing result of storey displacement for all the model when major earthquake is along y-direction

Table: 6 Storey displacement comparison in y- direction

Storey No.	Displacement of H-shaped opening diaphragm building	Displacement of C-shaped opening diaphragm	Displacement of L-shaped opening diaphragm building

	(mm)	building (mm)	(mm)
15	64.3	59.6	55.1
14	62.4	57.5	53.1
13	60.1	54.9	50.7
12	57.2	51.8	47.9
11	53.9	48.5	44.8
10	50.2	44.8	41.3
9	46.1	40.8	37.6
8	41.6	36.6	33.7
7	36.7	32.2	29.6
6	31.6	27.7	25.3
5	26.2	23.0	20.9
4	20.6	18.2	16.5
3	15.0	13.4	12.0
2	9.3	8.6	7.5
1	3.9	3.8	3.2
ground floor	0	0	0

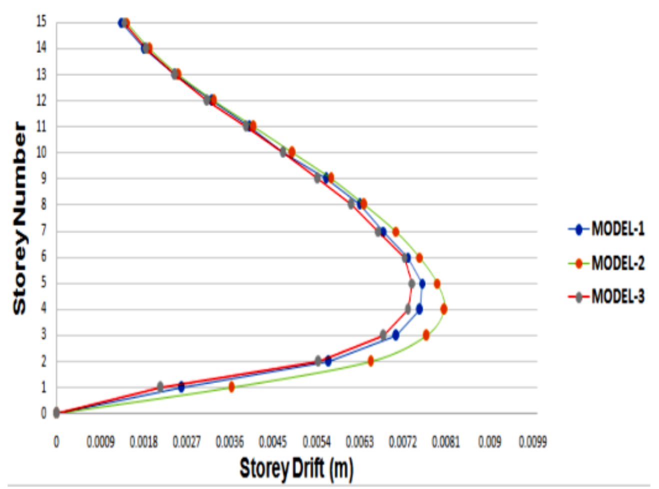


Graph:4 Storey displacement comparisons in y-direction

iv. Comparison of storey drift along x-direction

Drift is the relative motion of each storey with respect to its previous storey. Drifts indicate the lateral movement of the building model. This parameter has been plotted for all the building models. This is one of the parameters to understand the seismic behavior of the building. Also, it gives a better understanding about the choice of building.
Comparing result of storey drift for all the three model when major earthquake is along x-direction
Table: 7 Storey drift comparison in x- direction

Storey No.	Storey Drift of H-shaped opening diaphragm building	Storey Drift of C-shaped opening diaphragm building	Storey Drift of L-shaped opening diaphragm building
15	.00136	.00146	.00140
14	.00183	.00193	.00186
13	.00246	.00253	.00246
12	.00323	.00326	.00313
11	.00400	.00410	.00393
10	.00470	.00490	.00470
9	.00560	.00570	.00543
8	.00630	.00640	.00613
7	.00680	.00706	.00670
6	.00730	.00756	.00723
5	.00760	.00793	.00753
4	.00756	.00806	.00760
3	.00706	.00770	.00726
2	.00566	.00653	.00616
1	.00260	.00363	.00346
ground floor	0	0	0



Graph: 5 Storey drift comparison in x-direction

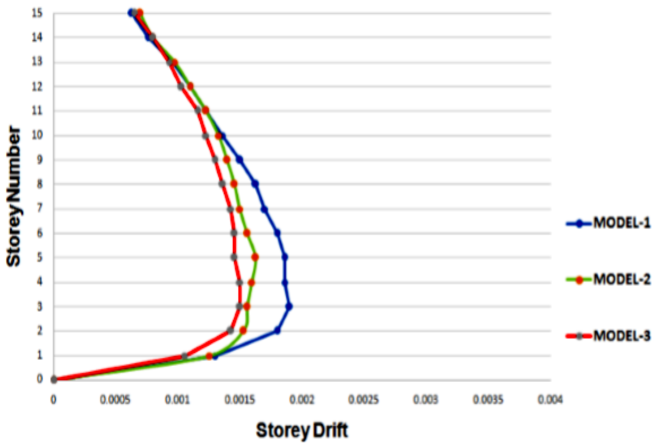
C-shaped open diaphragm building suffers greater drift than H and L- shaped open diaphragm building because C-shaped open diaphragm building having less stiffness then H and L-shaped open diaphragm building in x-direction implying the fact that they are relatively less safe and the most vulnerable configuration when subjected to seismic activity.

v. Comparison of storey drift along y-direction

Comparing result of storey drift for all the three model when major earthquake is along y-direction
Table: 8 Storey drift comparison in y- direction

Storey No.	Storey Drift of H-shaped opening diaphragm building	Storey Drift of C-shaped opening diaphragm building	Storey Drift of L-shaped opening diaphragm building
15	.00063	.00070	.00066
14	.00076	.00086	.00080
13	.00096	.00103	.00093
12	.00110	.00110	.00103

11	.00123	.00123	.00116
10	.00136	.00133	.00123
9	.00150	.00140	.00130
8	.00163	.00146	.00136
7	.00170	.00150	.00143
6	.00180	.00156	.00146
5	.00186	.00163	.00146
4	.00186	.00160	.00150
3	.00190	.00156	.00150
2	.00180	.00153	.00143
1	.00130	.00126	.00106
ground floor	0	0	0



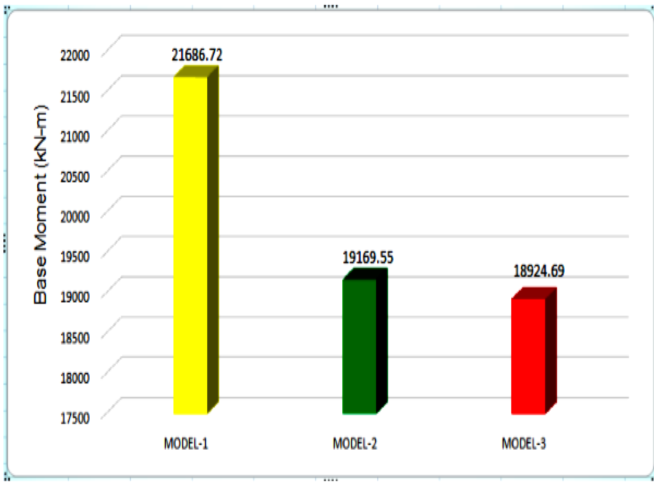
Graph: 6 Storey drift comparison in y-direction

H-shaped open diaphragm building suffers greater drift than C and L- shaped open diaphragm building because H-shaped open diaphragm building having less stiffness then C and L-shaped open diaphragm building in Y-direction implying the fact that they are relatively less safe and the most vulnerable configuration when subjected to seismic activity.

vi. Maximum base moment for all model when major earthquake in x-direction

Table: 9 Base moment comparison in x- direction

MODEL	BASE MOMENT
H-shaped opening diaphragm building	21686.7179kN-m
C-shaped opening diaphragm building	19196.5465kN-m
L-shaped opening diaphragm building	18924.696kN-m

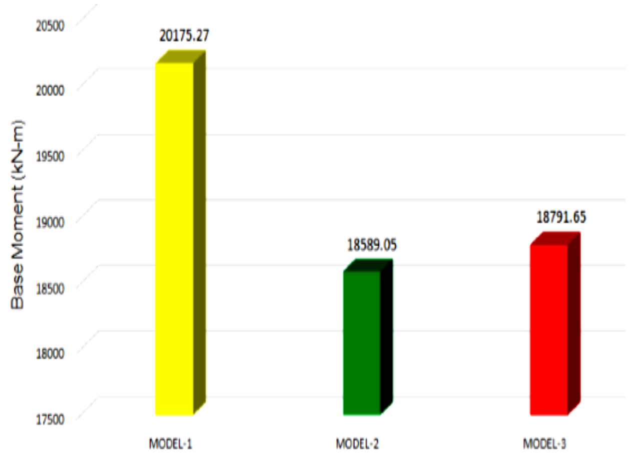


Graph: 7 Base Moment comparison in x-direction

vii. Maximum base moment for all model when major earthquake in x-direction

Table: 10 Base moment comparison in y- direction

MODEL	BASE MOMENT
H-shaped opening diaphragm building	20175.273 kN-m
C-shaped opening diaphragm building	18589.05 kN-m
L-shaped opening diaphragm building	18791.656 kN-m



Graph: 8 Base Moment comparison in y-direction

IV. CONCLUSION

In this research paper, numerical models of G+9 story unsymmetrical buildings with plan area of 900 m2 and story height of 3 m (floor to floor) is developed. The results obtained from the nonlinear static analysis which shows the behavior of structures in terms of base shear, displacement at performance point, storey displacement, base moment and storey drift are presented below:

- The performance of model-2 is in collapse Level and number of hinges is also more than model-1 and model-3. Hence the performance of model-2 is critical than other two model at performance point.
- At performance point model-2 has 34.44% more base shear then model-1 and 10% more base shear then model-3.
- At performance point model-2 has 4.98% more top displacement then model-1 and 10.44% more top displacement then model-3.
- When major earthquake in x-direction model-2 has higher storey displacement then model-1and model-3
- When major earthquake in y-direction model-1 has higher storey displacement then model-2 and model-3
- Inter storey drift of model-2 is higher than model-1 and model-3 when major earthquake in x-direction
- Inter storey drift of model-1 is higher than model-2 and model-3 when major earthquake in y-direction
- Moment at the base in model-1 is more than model-2 and model-3 when major earthquake is along x-direction.
- Moment at the base in model-2 is less then model-1 and model-3 when major earthquake is along y-direction.
- Load combination 1.5[DL+(Eqx+.3Eqy)] is more critical than all other load combination for all the three models
- The storey drift and displacement for all the model within permissible limits as per IS 1893-2016.

Hence, overall Results have been concluded that at performance point model-2 has less lateral stiffness and large number of hinges been moving from collapse prevention to collapse level. It attracted baser shear and Top displacement at performance point is also high in both directions. storey displacement and storey drift are also higher than other two model. Model-2 is more vulnerable compare to other shape building when major earthquake in x-direction.

It is also concluded that behavior of Model-3 in between model-1 and model-2 and it is most suitable configuration in earthquake prone areas in both directions.

IV. FUTURE SCOPE

- Study can be extended by providing shear wall at different location
- Time history analysis can be performed on this model.
- Analysis can be carried out by using steel frame instead of RCC frame
- Different type of infill material can be used in future studies.
- Different shape diaphragm opening with vertical irregularities in structure.

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