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Research Paper

Seismic Vulnerability of RC Buildings by Considering the Effect of Shear Wall

Engineering

KEYWORDS : Shear wall, performance levels, Pushover analysis, Storey Shear, Performance points.

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ABSTRACT

Shear walls are often introduced in multistoried buildings to resist lateral forces when frame systems alone are insufficient. The term "shear wall" as used for elevator shafts, stairwells and central core units, in addition to plane walls. Analysis for lateral loads of buildings containing shear walls is generally carried out by assigning all lateral loads to the shear walls, since it was felt that the very big difference in stiffness between the shear walls and the frame would cause the shear walls to accept the total lateral loads. Adding structural walls is one of the most common structure-level retrofitting methods to strengthen existing structures. This approach is effective for controlling global lateral drifts and for reducing damage in frame members.

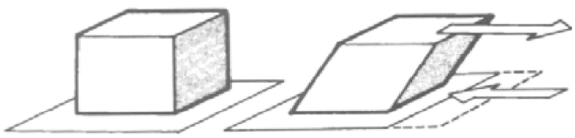
Shear walls resist two types of forces, shear forces and uplift forces. Shear forces are generated in stationary buildings by accelerations resulting from ground movement and by external forces like wind and waves. This action creates shear forces throughout the height of the wall between the top and bottom shear wall connections.

INTRODUCTION

Starting from the very beginning of civilization, manind has faced several threat of extinction due to invasion of severe natural disasters. Earthquake is the most disastrous among them due to its huge power of devastation and total unpredictability. Unlike other natural catastrophes, earthquakes themselves do not kill people, rather the colossal loss of human lives and properties occur due to the destruction of man-made structures. Building structures are one of such creations of mankind, which collapse during severe earthquakes, and cause direct loss of human lives. Numerous research works have been directed worldwide in last few decades to investigate the cause of failure of different types of buildings under severe seismic excitations. Massive destruction of high-rise as well as low-rise buildings in recent devastating earthquake of Gujarat on 26th January,

2001 proves that also in developing counties like ours, such investigation is the need of the hour.

The horizontal force or base shear created by ground motion resulting from an earthquake must be resisted by the building. The more the ground moves, or the greater the weight of the building, the more force must be resisted by the building. When an architect or engineer designs a building, he or she must determine the maximum force a building might have to resist in the future. Buildings are always designed to handle normal vertical and lateral forces. However, once you introduce the possibility of an earthquake, a building must be designed for extraordinary horizontal or lateral forces. The horizontal (lateral) forces associated with an earthquake can be thought of as a lateral force applied to each floor and to the roof of a building. Figure b shows the vertical and horizontal forces on a building during an earthquake. Panel (a) shows the direction of gravitational forces on a building, panel (b) shows the horizontal force of seismic waves, and panel.



(a) (b)

Fig.1

OBJECTIVES OF THE STUDY

- The present project work is aimed at evaluating RC framed building with the following objectives:
- Creation of 3D building model for both elastic and inelastic method of analyses.
- To perform lateral load analysis on different building models as per code.
- To Study the behaviour of building on influence of Shear wall on the overall behaviour of structure when subjected to lateral seismic forces.
- Finding out the Lateral Displacement and storey Shear at each storey using linear static, and Pushover analysis
- To find out the performance level of the structure during earthquake.
- To determine the collapse strength of the building models to resist earthquake loading.

EFFECT OF SHEARWALL

Reinforced concrete walls are strength and important elements frequently used in constructions in seismic areas because they have a high lateral stiffness and resistance to external horizontal loads, these shear walls may be added solely to resist horizontal forces or concrete walls enclosing stairways elevated shafts and utility cores may serve as shear walls. Shear walls not only have a very large in plane stiffness and therefore resist lateral load and control deflection very efficiently but they also helps in reductions of structural & nonstructural damage. The building incorporated with shear wall sufficiently ductile will be much away from seismic vulnerability and building failure in the earthquake sensitive zones thus resulting in increased life safe ty & low property loss.

BEHAVIOUR OF SHEARWALL

Shear wall constructed in the high rise buildings generally behave as vertical cantilever beam with their Strength controlled by flexure rather than by shear . Such walls are subjected to bending moments and Shears originating from lateral loads and to axial compression caused by gravity these may therefore be designed in same manner as regular flexural element. When acting as a vertical cantilever beam the behavior of a shear wall which is properly reinforced for shear, will be governed by the yielding of the tension reinforcement located at the vertical edge of the wall and, to some degree, by the

SCOPE OF THE STUDY

The present study is an attempt in the state of art of seismic evaluation of multi-storeyed reinforced concrete buildings. The focus of attention is to find the performance level of the building with the help of capacity and demand of the building for designed earthquake using nonlinear static pushover analysis.

MODELING AND ANALYSIS METHOD

- 3D modeling for analyses using ETABS Nonlinear Analysis
- The building is analyzed by linear static, as well as pushover analysis.
- The building models are pushed along positive orthogonal directions.

PARAMETRIC STUDIES

- The overall behaviour of RCC framed building when subjected to seismic forces are examined.
- The effects of Shear Wall on the overall behaviour of the structure when subjected to seismic forces are examined.

SEISMIC ANALYSIS PROCEDURES

The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behaviour of the overall structure. The analysis may be static or dynamic in approach as per the code provisions. The analysis procedures can be divided into linear procedures (linear static & linear dynamic) and Nonlinear procedures (Nonlinear static and Nonlinear dynamic)

LINEAR ANALYSIS METHODS

The two different linear analysis methods recommended in IS 1893: 2002 (Part1) are explained in this Section. Any one of these methods can be used to calculate the expected Seismic demands on the lateral load resisting elements.

NONLINEAR ANALYSIS METHOD

NONLINEAR STATIC PUSHOVER ANALYSIS

The use of the nonlinear static analysis (pushover analysis) came in to practice in 1970's but the potential of the pushover analysis has been recognized for last 10-15 years. This procedure is mainly used to estimate the strength and drift capacity of existing structure

Pushover analysis is defined as an analysis wherein a mathematical model directly incorporating the nonlinear load-deformation characteristics of individual components and elements of the building shall be subjected to monotonically increasing lateral loads representing inertia forces in an earthquake until a 'target displacement' is exceeded. Response characteristics that can be obtained from the pushover analysis are summarised as follows:

- Estimates of force and displacement capacities of the structure. Sequence of the member yielding and the progress of the overall capacity curve.
- Estimates of force (axial, shear and moment) demands on potentially brittle elements and deformation demands on ductile elements.
- Estimates of global displacement demand, corresponding inter-storey drifts and damages on structural and non-structural elements expected under the earthquake ground motion considered.
- Sequences of the failure of elements and the consequent effect on the overall structural stability.
- Identification of the critical regions, where the inelastic deformations are expected to be high and identification of strength irregularities (in plan or in elevation) of the building

The following are the definitions which are most commonly used in Pushover Analysis.

PERFORMANCE POINT

It is the point where capacity spectrum intersects the appropriate demand spectrum (capacity equals demand). To have desired performance, every structure has to be designed for this level of forces.

BUILDING PERFORMANCE LEVELS

Building performance is a combination of the performance of both structural and nonstructural components. Different building performance levels, used to describe the performance of buildings in pushover analysis are shown in fig.2

OPERATIONAL LEVEL (OL)

Buildings meeting this performance level are expected to sustain no permanent drift and the structure substantially retains original strengths and stiffness. Minor cracking of facades, partitions and ceilings as well as structural elements are seen.All systems important to normal operation are functional. Nonstructural components are expected to sustain negligible damage. Power and other utilities are available, possibly from standby source.

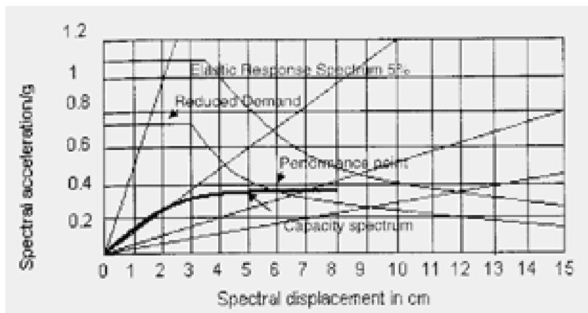


Figure 2- Determination of performance point

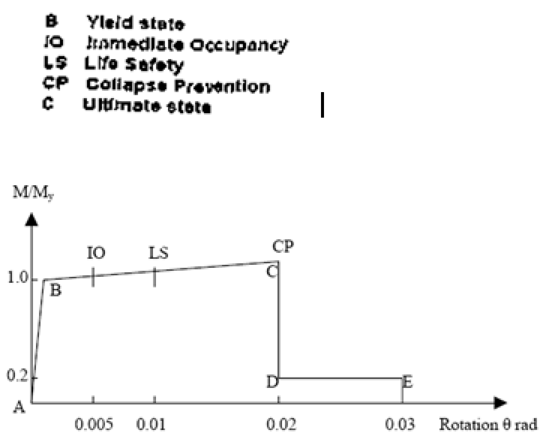


Figure 3- Hinge property

IMMEDIATE OCCUPANCY LEVEL

Nonstructural Performance Level NP-B, Immediate Occupancy, means the post- earthquake damage state in which only limited nonstructural damage has occurred. In general, components of mechanical and electrical systems in the building are structurally secured and should be able to function if necessary utility service is available. The risk of life-threatening injury due to nonstructural damage is very low.

LIFE SAFETY LEVEL

Nonstructural Performance Level NP-C, Life Safety, is the post-earthquake damage state in which potentially significant and costly damage has occurred to nonstructural components but they have not become dislodged and fallen, threatening life safety either within or outside the building. While injuries may occur during the earthquake from the failure of nonstructural components, it is expected that, overall, the risk of life-threatening injury is very low.

COLLAPSE PREVENTION LEVEL
Building meeting this performance level are expected to have little residual stiffness and strength, but load bearing columns and walls function. The building is expected to sustain large permanent drifts, some exit blocked, infill and un-braced parapet failure. Extensive damage is expected to occur to nonstructural components. At this level of performance, the building remains near Collapse State.

PLASTIC HINGE
It is a location of inelastic action on a structural member.

FORMATION OF PLASTIC HINGES
The maximum moments caused by earthquake occur near the ends of beams and columns, the plastic hinges are likely to occur there and most of the ductility requirements apply to sections near the junctions.

Parameters considered for the study

STRUCTURE TYPE	SMRF RESPONSE REDUCTION FACTOR
SEISMIC ZONE	ZONE III and ZONE-V
SEISMIC ZONE FACTOR	0.16 and 0.36
HEIGHT OF THE BUILDING	3.2m
SOIL CONDITION	Medium
THICKNESS OF SLAB	0.125 m
BEAM SIZE	230 mm X 350 mm
COLUMN SIZE	230 mm X 400 mm
LIVE LOAD	3.5 kN/m2
FLOOR FINISH	1k N/m2

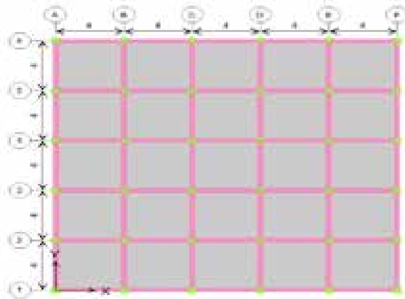
DESCRIPTION OF THE SAMPLE BUILDING
In this study models are studied as described below in two zones zone III and zone V and different storey buildings are considered

MODEL 1: BARE FRAME
Building has no walls at all stories and is modelled as bare frame. However masses of the walls are included. In addition to wall masses the other load like floor finish and imposed live load is added at each Storey

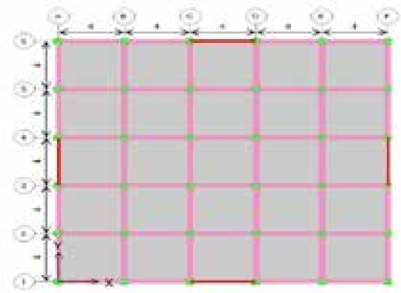
MODEL 2: SHEAR WALL LOCATED AT THE PERIPHERY
In this building shear wall is located at the periphery region of the entire structure for all the storey building . However masses of the walls are included. In addition to wall masses the other load like floor finish and imposed live load is added at each Storey.

MODEL 3: SHEAR WALL LOCATED AT THE CORNER
In this building shear wall is located at the corner of the structure for all the storey building. However masses of the walls are included. In addition to wall masses the other load like floor finish and imposed live load is added at each Storey.

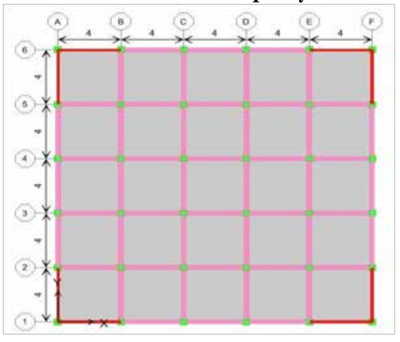
MODEL 4: SHEAR WALL LOCATED AT THE CENTER
In this building shear wall is located at the centre of the structure for all the storey building However masses of the walls are included. In addition to wall masses the other load like floor finish and imposed live load is added at each Storey.



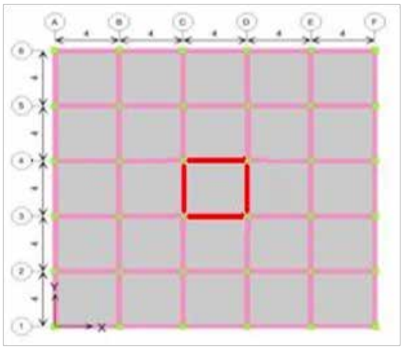
Model-1 Bareframe



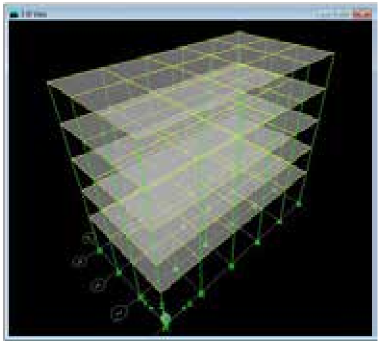
Model-2 Shear Wall at Periphery



Model 3 Shear wall at the Corner

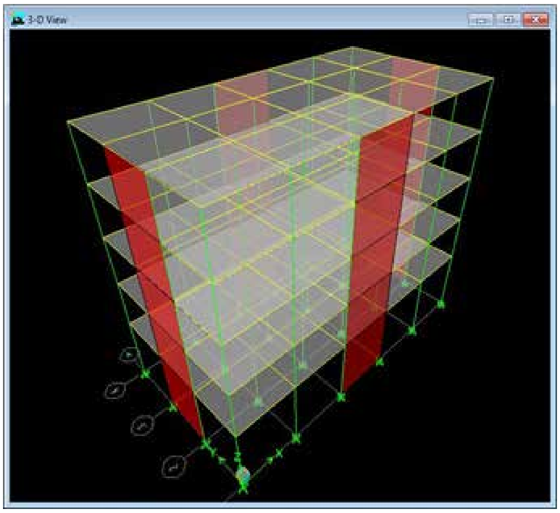


Model 4 Shear wall at the Centre

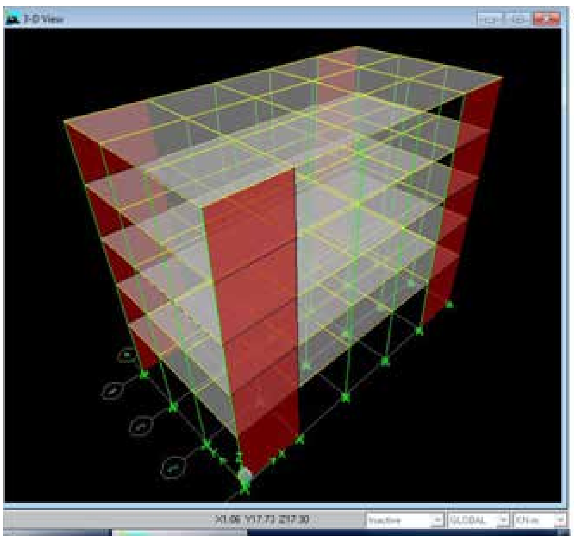


3D View of the Bareframe

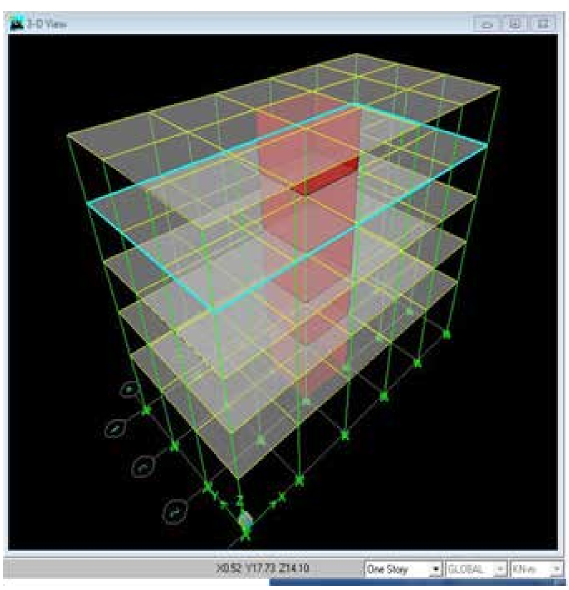
Volume : 3 | Issue : 9 | September 2014 • ISSN No 2277 - 8179



3D View of the Shearwall at the Periphery



3D View of the Shearwall at the Corner.

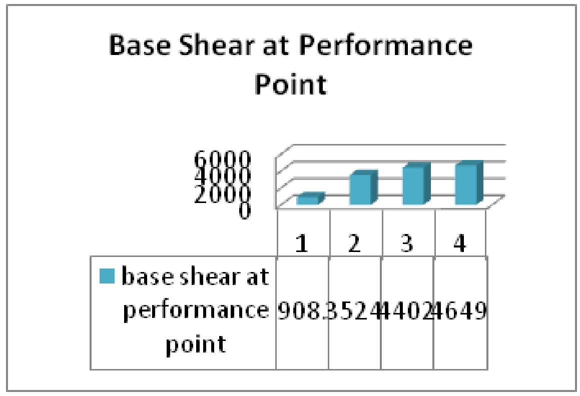


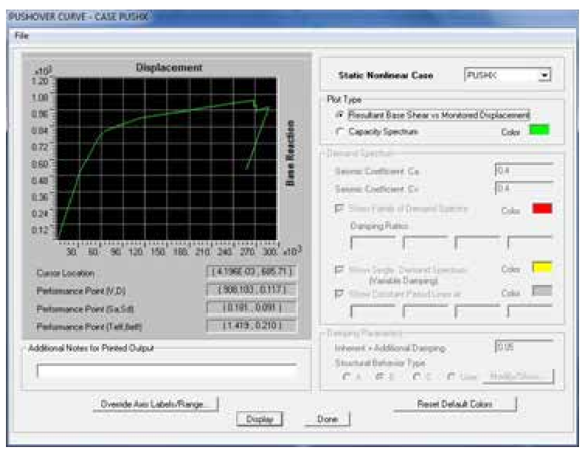
3D View of the Shearwall at the Centre.

RESULTS AND DISCUSSIONS

Table No 1 - BASE SHEAR AT PERFORMANCE POINT

Base shear	ZONE III 5 Storey	Displacement in mts
MODEL 1 (BAREFRAME)	908.135	0.117
MODEL 2(PERIPHERY SHEAR WALL)	3524.136	0.063
MODEL 3 (CORNER SHEAR WALL)	4402.085	0.042
MODEL 4 (CENTRE SHEAR WALL)	4648.81	0.041





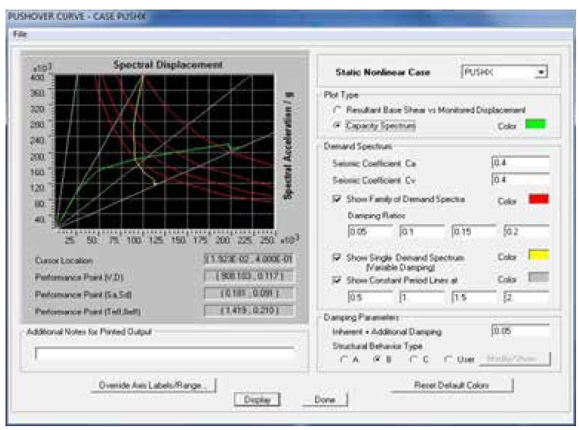
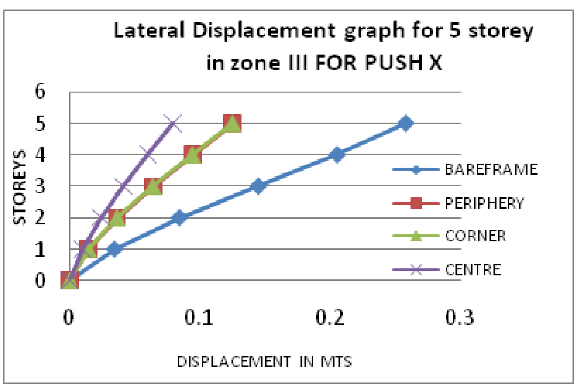


Table No 2-LATERAL DISPLACEMENTS tables FOR 5 STOREY ZONE III and ZONE V FOR PUSH X

For Zone 3								
storeys	model1		model2		model3		model4	
	eqx	pushx	eqx	pushx	eqx	pushx	eqx	pushx
5	0.0241	0.2581	0.0059	0.1255	0.0037	0.125	0.0035	0.079
4	0.0218	0.2054	0.0045	0.0947	0.0028	0.094	0.0027	0.06
3	0.0179	0.1448	0.0061	0.0644	0.0019	0.064	0.0019	0.041
2	0.013	0.0842	0.0018	0.0367	0.0011	0.036	0.011	0.024
1	0.0075	0.0343	0.0007	0.0145	0.0004	0.014	0.0005	0.01
0	0	0	0	0	0	0	0	0

For Zone 5								
storeys	model1		model2		model3		model4	
	eqx	pushx	eqx	pushx	eqx	pushx	eqx	pushx
5	0.0543	0.2717	0.0132	0.1809	0.0082	0.136	0.0079	0.010
4	0.049	0.2475	0.0101	0.1376	0.0062	0.103	0.0061	0.007
3	0.0403	0.2119	0.007	0.0942	0.0042	0.070	0.0043	0.005
2	0.0293	0.165	0.0041	0.0541	0.0024	0.040	0.0025	0.003
1	0.0169	0.1013	0.0017	0.0216	0.001	0.015	0.0011	0.001
0	0	0	0	0	0	0	0	0



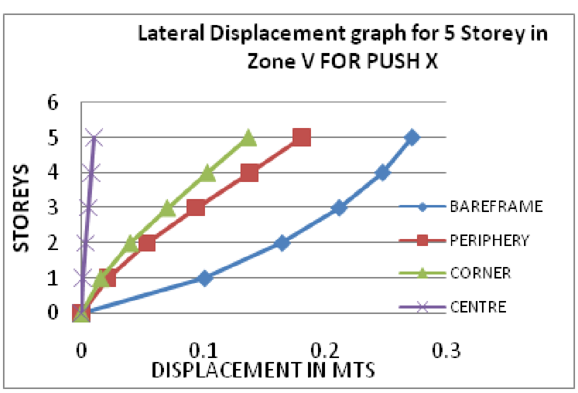
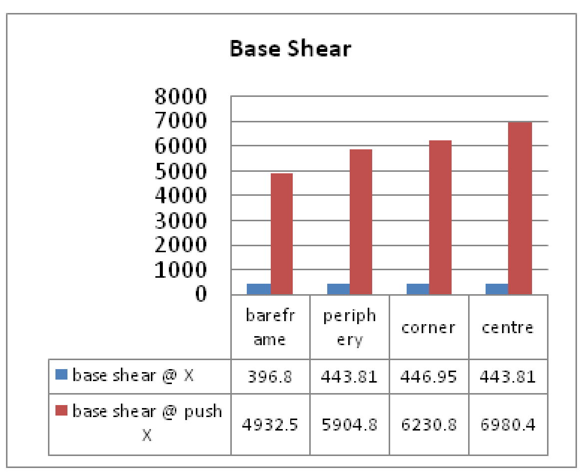


Table No 3-BASE SHEAR COMPARISION BETWEEN LINEAR AND NON LINEAR STATIC ANALYSIS (PUSH OVER ANALYSIS)

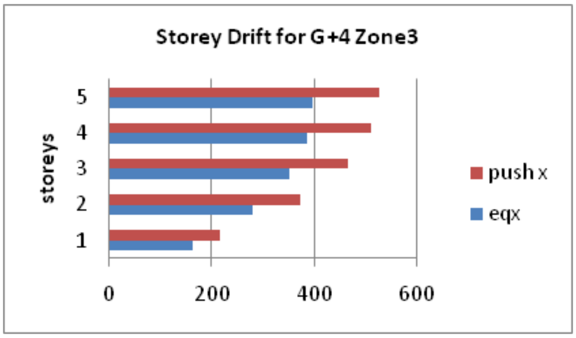
MODELS	EQX	PUSH X
BAREFRAME	396.81	4932.5
PERIPHERY	443.81	5904.8
CORNER	446.95	6230.2
CENTRE	443.81	6980.4



Volume : 3 | Issue : 9 | September 2014 • ISSN No 2277 - 8179

Table No 4-Storey Shear

storey Shear		
storey	eqx	push x
5	162.99	216.06
4	279.85	370.97
3	349.69	463.55
2	384.54	509.75
1	396.8	526



CONCLUSION

- The Lateral load resisting capacity is least in model1(bareframe) and its value gradually increases in model2 (shearwall at periphery), model 3 (shearwall at the corner),model4 (shearwall at the centre).and it has maximum value in model4
- Lateral displacements is found to be maximum for model 1 (Bareframe) least in model 4 (Shearwall at the centre. It shows thatmodel 4 is better in resisting lateral displacements compared to other models.
- The base shear resisting capacity of the building with central shear wall system is high.
- The number of plastic hinges are less in case of central shear wall system and almost equal to the plastic hinges of bareframe.
- Lateral displacements for various models are more in zoneV compared to those in zone III.
- Base shear obtained from pushover analysis is more than the base shear obtained from equivalent static analysis.

Table No 5-Performance level for G+4 building models

Model	Displacement	Baseforce	A-B	B-IO	IO-LC	LC-CP	CP-C	C-D	D-E	>E	TOTAL
Bareframe	0.1140	905.6129	800	0	108	92	0	0	0	0	1000
Periphery shear wall	0.0740	4062.80	943	69	136	42	0	0	0	0	1192
Corner shear wall	0.0607	6314.28	913	117	96	64	0	0	0	0	1190
Centre shear wall	0.0583	6365.07	954	52	122	62	0	0	0	0	1190

The data presented in the above table shows the elastic hinges for bareframe are 800 and plastic hinges between IO-LS are 108, and between LS-CP are 92.

For shear wall at the corner region the elastic hinges are 913 and plastis hinges between between IO-LS are 96 and between LS-CP are 64.

For shear wall at the centre the elastic hinges are 954 and plastis hinges between between IO-LS are 122 and between LS-CP are 62

The LS-CP column in the above Table indicates the range of overall performance level of G+4 storey building model in PUSHX direction.

The displacement and baseforce represents the ultimate capacity of G+4 storey building model in PUSH X direction

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