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SEISMIC RESPONSE OF INFILL FRAME STRUCTURES WITH SHEAR WALL FOR LIFT USING PUSHOVER ANALYSIS BY SAP2000 SOFTWARE

Dinesh M. Pandit
Student of ME Structure, Civil Engineering Department,
PES College of Engineering, BAMU University
Aurangabad, India
dineshpandit719@gmail.com

Rahul D. Pandit
Assistant Professor, Civil Engineering Department,
PES College of Engineering, BAMU University
Aurangabad, India
rahul_pandit22@rediffmail.com

Dr. Abhijeet P. Wadekar
Professor, Civil Engineering Department, and
Principle, PES College of Engineering, BAMU University
Aurangabad, India
apwadekar@gmail.com

Abstract
This paper presents an analysis on performance-based seismic evaluation of G+14 RC frame building with masonry infill (MI) and shear wall (SW) for lift using Non-linear Static Pushover analysis with SAP2000v14 software for three different models i.e., Model-1: RC bare frame, Model-2: RC frame with MI wall (Soft storey) and Model-3: RC frame with MI wall and SW for lift (Soft storey). Result indicates, maximum displacement for Model-1 i.e., 0.3346m, Model-2 & 3 gave displacement of 0.0904m and 0.0718m respectively. These results clearly show, the stiffening in Model-2 is increased to 72.98% and for Model-3 is 78.54% compared to bare frame.

***Index Terms*— Masonry Infill, Shear Wall, Pushover analysis, displacement, drift, stiffness, Hinge formations.**

I. Introduction
Recently, there has been a considerable increase in the tall buildings for both residential and commercial and the modern trend is towards more tall and slender structures. Thus the effects of lateral loads like wind loads, earthquake load and blast force are attaining increasing importance.
Reinforced concrete (RC) frame buildings with masonry infill walls and shear wall for lift have been widely constructed for commercial, industrial and multi-storeyed residential apartments appears to be in seismic regions worldwide. Masonry infill (MI) walls and shear walls for lift plays

a vital role in resisting the lateral seismic loads on building. Thus introduction of MI and shear walls for lift in RC frames changes the lateral-load transfer mechanism, which is responsible for reduction in bending moments and increase in axial forces. The Non-linear static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The purpose of pushover analysis is to evaluate the expected performance of structural systems, by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis. Comparing these demands to available capacities at the performance levels of interest, the design can be carried out. The evaluation is based on an assessment of important performance parameters including inter-storey drift, base shear, hinge formation and inelastic element deformation.

II. Need of Present Work

The brick masonry infilled (MI) walls and Shear walls are considered as a non-structural elements in analysis and design. Though they are considered to be a non-structural element, they have their own strength and stiffness. Hence if the effect of brick masonry and shear wall are considered in analysis and design procedure, considerable increase in strength and stiffness of overall structure may be observed. This attracts part of the lateral seismic shear forces on buildings, thereby reducing the loads on the RC members.

From the effect of previous significant earthquakes, it is concluded that the seismic risk in urban areas are increasing. Hence there is a need to revise this situation and it is believed that one of the most effective ways of doing this is through, the improvement of current seismic standards.

III. Objectives Of Analysis

The present study aims at following objectives,

1) To carry out Non-Linear Static Pushover Analysis of frames with following Models,
   a) RC Bare frame.
   b) RC frame with masonry infill.
   c) RC frame with masonry infill and shear wall for lift.
2) To compare the following results between the above mentioned frames,
   a) Base shear verses Displacement i.e. Pushover Curve,
   b) Storey Displacements,
   c) Maximum plastic rotations (hinge formation)
   d) Performance Point
   e) Storey Drift and their checks according IS1893 (Part1):2002.

The analysis of frames is carried out using SAP2000v14 Software.

IV. Modelling

Earthquake response analysis is an art to simulate the behaviour of a structure subjected to an earthquake ground motion based on a mathematical model of the structure. The correct analysis will depend upon the proper modelling of the behaviour of materials, elements and connections of structure. For the proposed work, three-dimensional G+14 storey RC building is modelled in SAP2000 software as shown in Fig.1.The plan of building is shown in fig.2. This model is analysed for three different models as mentioned in objectives by providing brick walls and shear walls.

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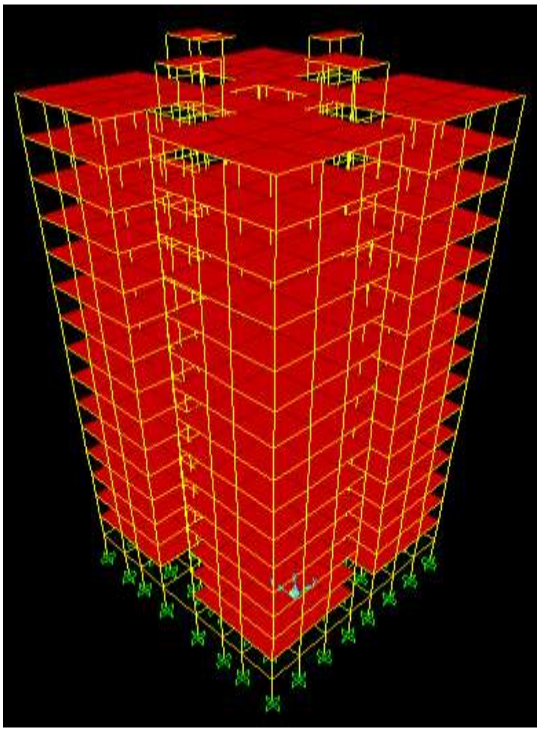
Fig.1 Three-dimensional model of frame

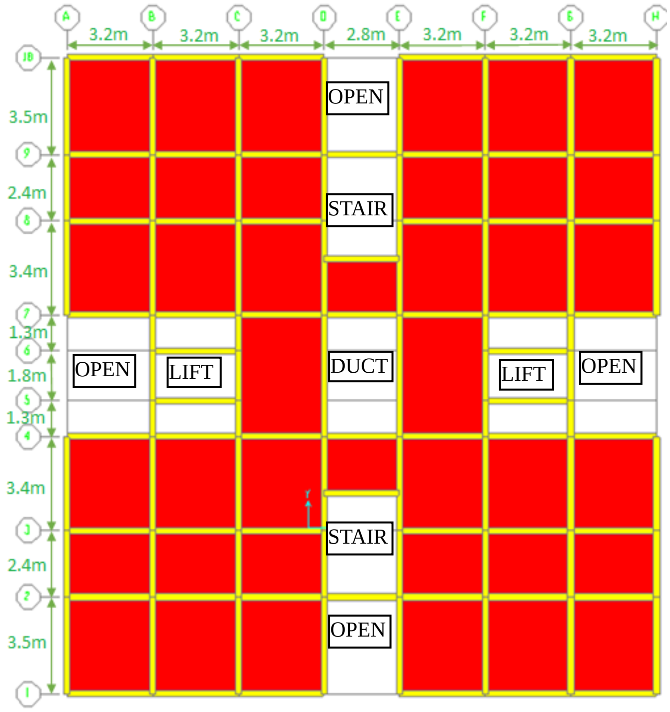

Fig. 2 Plan of frame

V. Analysis Procedure

A two or three dimensional model is first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a controlled displacement at the top of building reaches a certain level of deformation or structure becomes unstable. Finally all results are obtained.

VI. Performance Analysis

The results obtained from the Non-linear Static Pushover Analysis regarding base shear and displacement in case of Model 1 to Model 3 are presented by graphs in Figure 3 to 5.
The maximum values of displacement for Model 1 to 3 are shown in Table 1.

TABLE I. Maximum displacement values.

Model No.	Displacement (m)
1	0.3346
2	0.0904
3	0.0718

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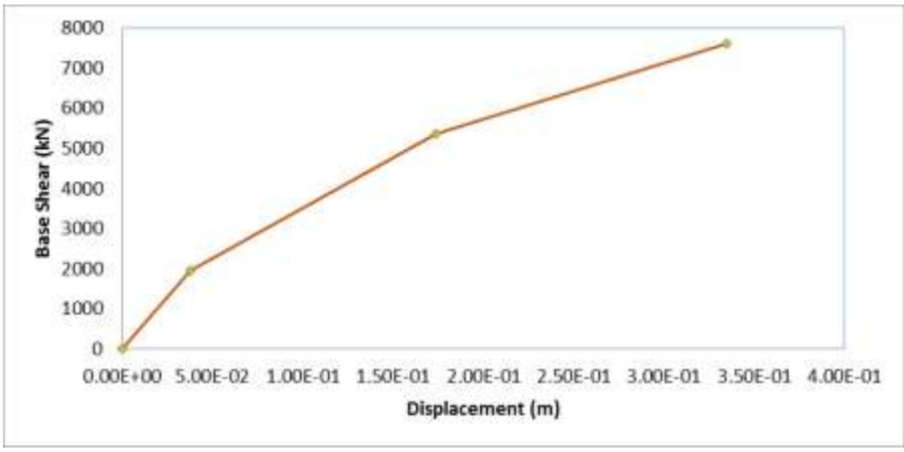

Fig. 3 Base Shear verses Displacement for Model 1 (Pushover Curve)

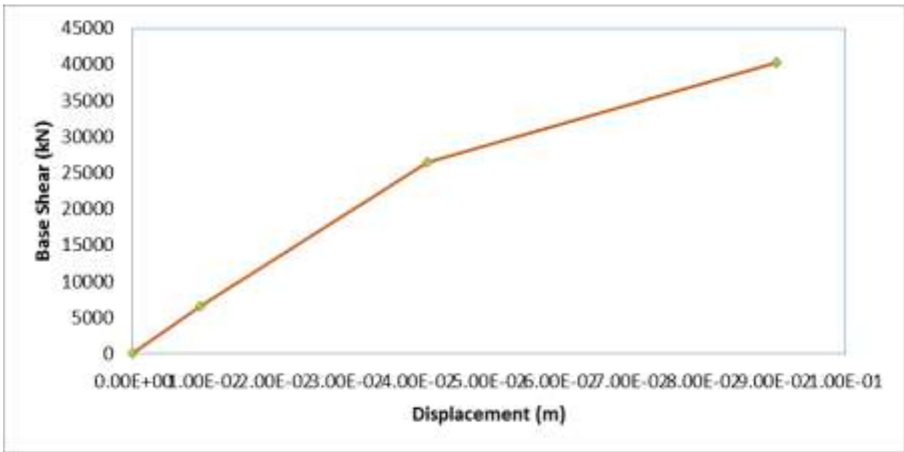

Fig. 4 Base Shear verses Displacement for Model 2 (Pushover Curve)

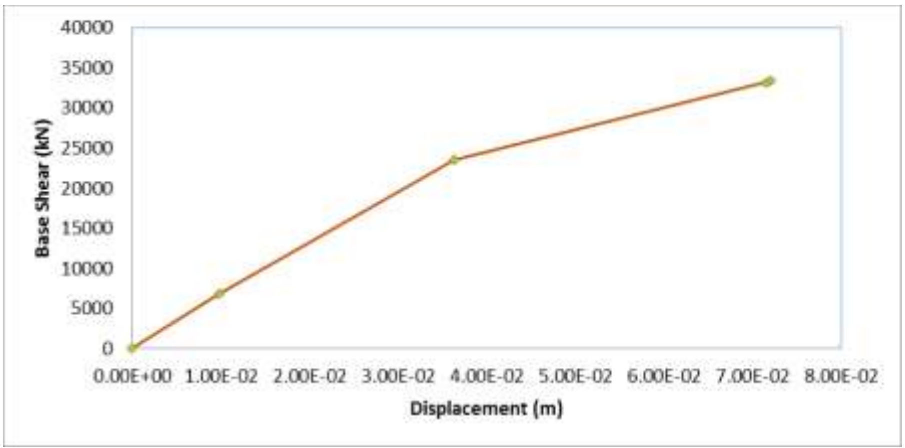

Fig. 5 Base Shear verses Displacement for Model 3 (Pushover Curve)

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The above results state that the displacement for model-1 is more than the other models. The value for Model-3 gives less displacement which tells that it is having higher strength and stiffness compared to other. This indicates the influence of masonry infill and shear wall for lift on the structure.

TABLE II. Stiffening Factor

MODEL No.	1	2	3
Displacement at top floor (m) Δ max	0.3346	0.0904	0.0718
Stiffening Factor w.r.t Δ max of Model1	-	72.98%	78.54%

These results clearly show, the stiffening in Model-2 is increased to 72.98% and for Model-3 is 78.54% compared to bare frame.

A. Storey wise displacement

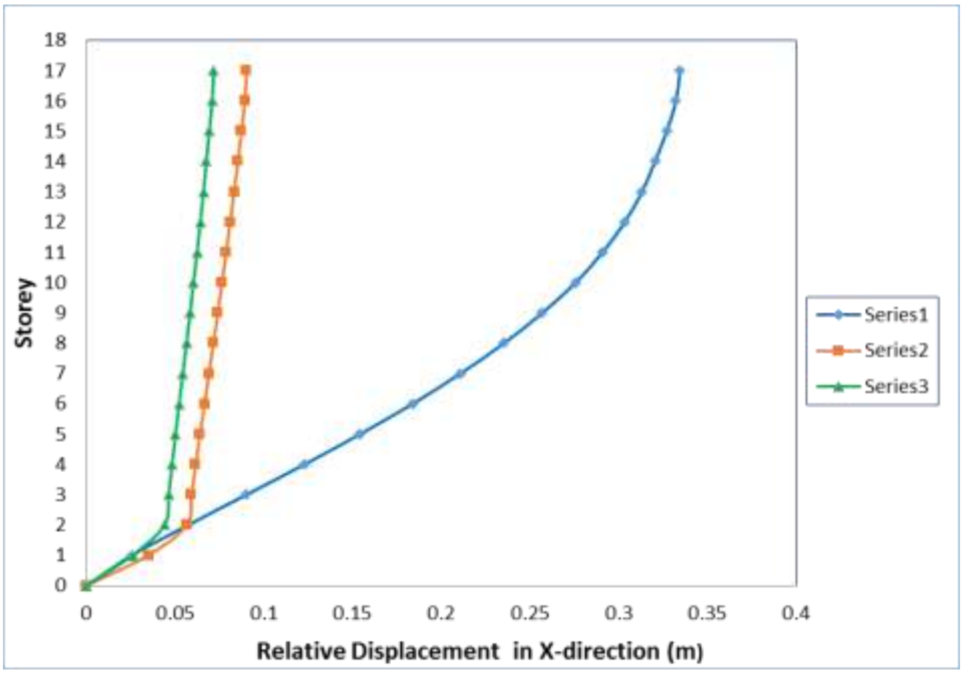

Fig 6. Storey verses Displacement for all models

Where, Series 1 = Model 1 (blue line)
Series 2 = Model 2 (orange line)
Series 3 = Model 3 (green line)

Figure 6. Indicates the displacement of all frame models at each floor level. Model-1 is having large displacement at each floor than that of Model-2 and 3. Model-3 clearly shows the minimum displacement at each floor level than the other frames.

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B. Relative Storey Drift

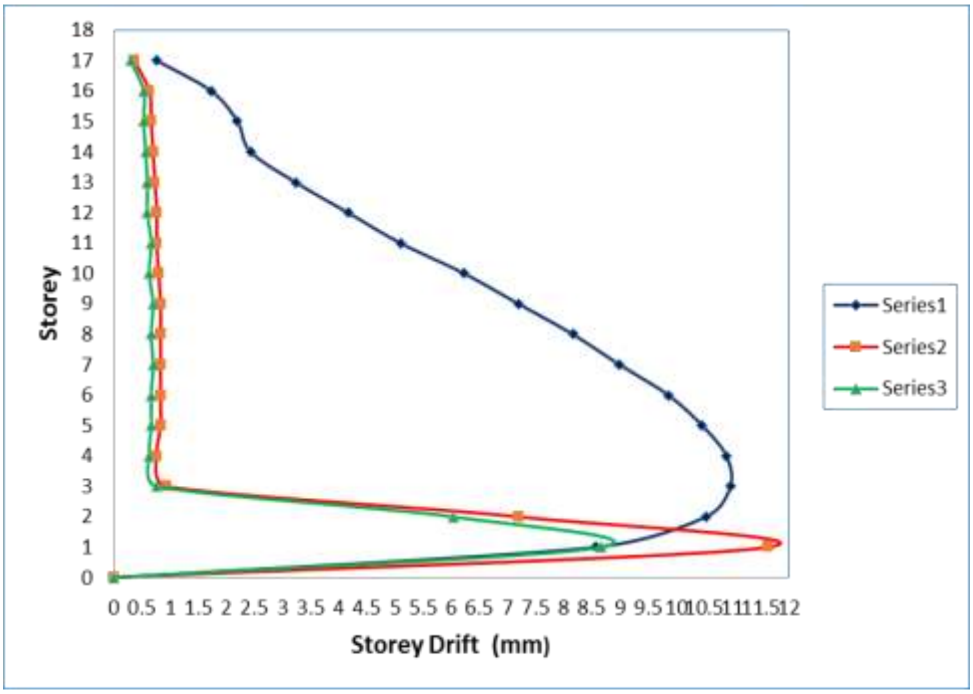

Fig. No. 7. Storey Drift for all models

Where, Series 1 = Model 1 (blue line)
Series 2 = Model 2 (orange line)
Series 3 = Model 3 (green line)

The above Graph represented clearly, the relative storey drift is more for Model-1 and is minimum for Model-3 at each floor, which shows the importance of presence of masonry infill and shear wall for lift in the structure.The storey drift obtained from SAP2000v14 for all Models are within the permissible drift, compared to IS 1893 (Part-I): 2002, clause no. 7.11.1, Page No.27.

C. Demand - Capacity Pushover result (Performance Point)

For determining the performance point of building frame, SAP2000v14 gives value of Teff, Beff, Sd capacity and Sd demand and Sa capacity and Sa demand.
Where,

Teff = effective period
Beff = effective damping
Sd = Spectral displacement and
Sa = Spectral acceleration

The base shear is converted into spectral accelaration and displacment is converted into spectral displacment in SAP2000v14 Software for finding the performance point. The curve obtained by Sa demand vs Sd demand, intersects the curve obtained by Sa capacity vs Sd capacity, the intersection point of these curves is called as Performance point.

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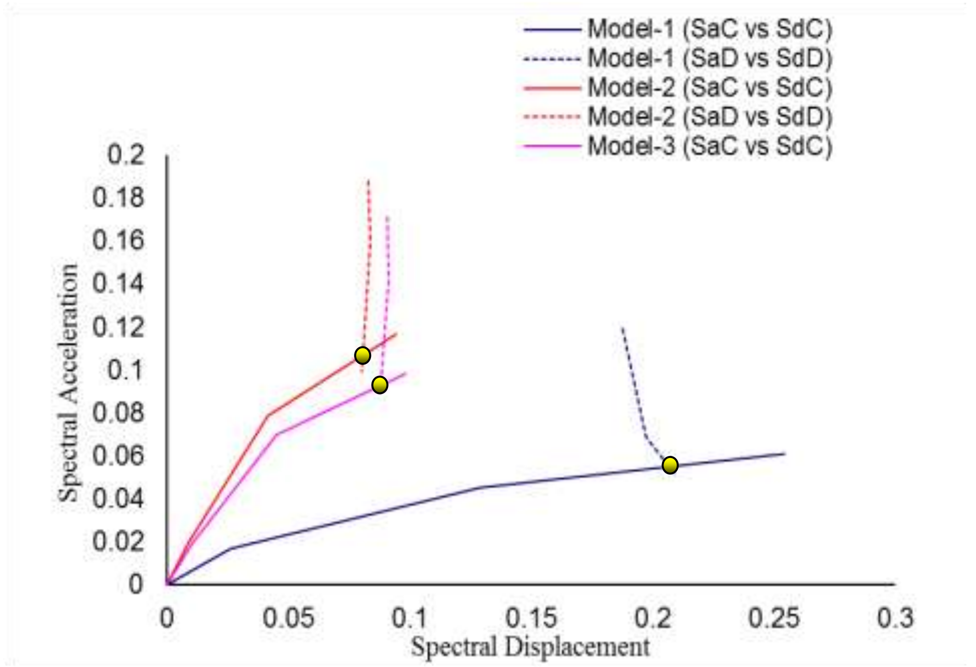

Fig.8 Performance point for all Models

Fig. 8 indicates that the demand is more important for Model 1 since it intersects the capacity curve near the event point between IO and LS (Immediate Occupancy and Life Safety). For Model-2 and 3, the demand curve intersect the capacity curve near the event point between B and IO, which means an elastic response and the security margin is greatly enhanced. Thus addition of masonry infill wall and shear- wall for lift increases the level of safety. Therefore, it can be concluded that the margin of safety against collapse for Model-1 is small, whereas providing by the masonry infill walls and shear wall in R.C. frame, sufficient strength and displacement is obtained.

D. Hinge Formation

Formations of Hinges in case of Model 1 to 3 are compiled in Table 3 to 5. It gives clearly the number of hinges formed in various steps.

TABLE III. Hinge formations for Model 1

Step	Base Force (KN)	Displacement (m)	A to B	B - IO	IO - LS	LS-CP	CP-C	C-D	D-E	Beyond E	Total
0	0	0	6232	0	0	0	0	0	0	0	6232
1	1964.468	0.0377	6229	3	0	0	0	0	0	0	6232
2	5372.921	0.1738	3401	2831	0	0	0	0	0	0	6232
3	7607.044	0.3346	3005	3009	218	0	0	0	0	0	6232

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TABLE IV. Hinge formations for Model 2

Step	Base Force (KN)	Displacement (m)	A to B	B - IO	IO - LS	LS-CP	CP-C	C-D	D-E	Beyond E	Total
0	0	0	6232	0	0	0	0	0	0	0	6232
1	6650.787	0.0095	6230	2	0	0	0	0	0	0	6232
2	26491.92	0.0414	5589	641	2	0	0	0	0	0	6232
3	40287.42	0.0903	5349	614	240	28	0	1	0	0	6232
4	40281.43	0.0903	5349	614	240	29	0	0	0	0	6232

TABLE V. Hinge formations for Model 3

Step	Base Force (KN)	Displacement (m)	A to B	B - IO	IO - LS	LS-CP	CP-C	C-D	D-E	Beyond E	Total
0	0	0	6232	0	0	0	0	0	0	0	6232
1	6887.18	0.0099	6227	5	0	0	0	0	0	0	6232
2	23546.14	0.0363	5606	625	1	0	0	0	0	0	6232
3	33443.092	0.0720	5385	634	207	5	0	1	0	0	6232
4	33090.09	0.0715	5385	634	202	9	0	1	1	0	6232

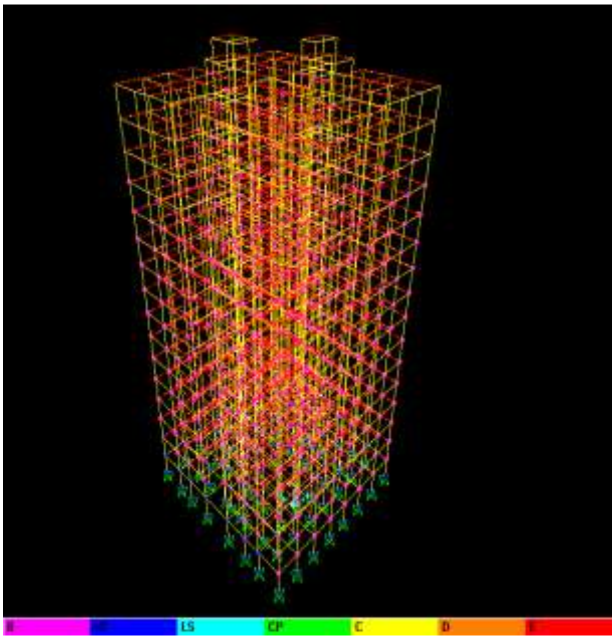

Fig. 9. Position of hinge for pushover analysis (Model 1)

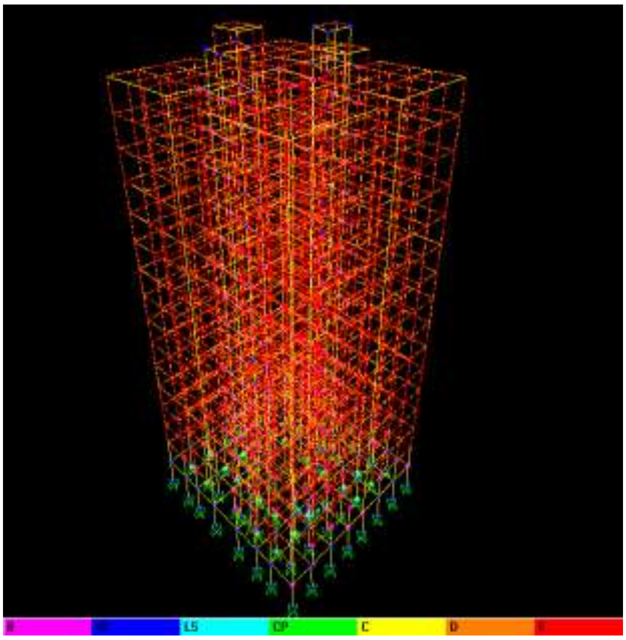

Fig. 10. Position of hinge for pushover analysis (Model 2)

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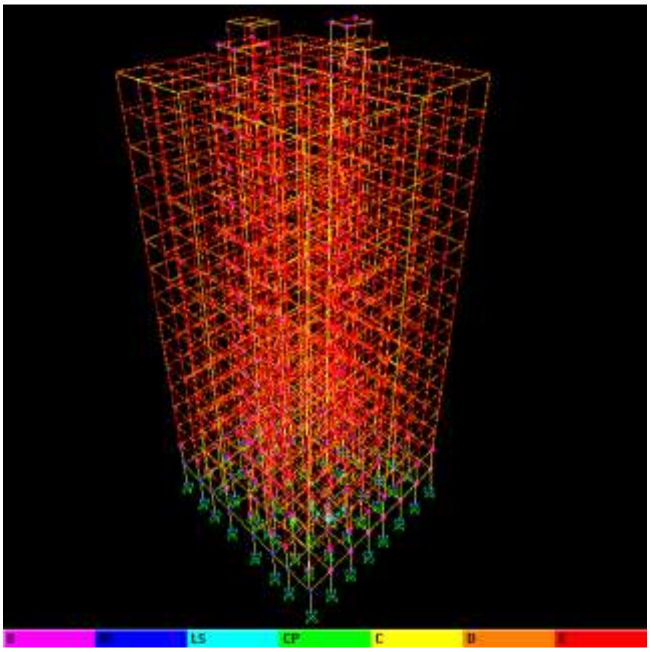

Fig. 11. Position of hinge for pushover analysis (Model 3)

From Table 3 to 5 and Fig. 9 to 11, the formation of hinges in Model-1 takes place at all floors and are thousands in number and is between IO and LS (Immediate Occupancy and Life Safety), so the overall risk of life-threatening injury as a result of structural damage is expected to be low., but significant damage to the structure may occurred. In Model-2, the hinge formation takes place hundreds in numbers at all the floors but only for lift columns, and for the other columns the hinges are formed at the ground level and below between B and IO. For Model-3, the hinges are formed hundreds in number at ground floor and below and hinges are formed between B and IO. Hence for model-2 and Model-3, the risk of life-threatening injury as a result of structural damage is very low, and some minor structural repairs may be done. So the design of Model-2 and Model-3 is safer comparative to model-1.

VII. Conclusion

The conclusion based on, the results of Nonlinear Static Pushover Analysis of Model-1 to Model-3 are presented here.

1. Model-1 has very large displacement than Model-2 and Model-3.
2. Stiffness of Model-3 increased up to 78.54%.
3. In Model-1, the demand curve intersects the capacity curve near the event point between IO & LS (Immediate Occupancy & Life Safety). Which means that for Model-1, some structural elements and components are severely damaged, but this has not resulted in large falling debris hazards, either within or outside the building. Injuries may occur during the earthquake; however, the overall risk of life-threatening injury as a result of structural damage is expected to be low.
4. In Model-2 and Model-3, the demand curve intersects the capacity curve near the event point between B & IO. It indicates that the elastic response and security margin is greatly

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achieved than bare frame, by providing masonry wall and shear wall for lift for high rise structure. The risk of life-threatening injury as a result of structural damage is very low, and some minor structural repairs may be done.

5. The drift for Model-1 is very large compared to Model-2 and Model-3 and hence Model-2 and Model-3 are safer.
6. The seismic analysis of RC frame for high rise building should be done by considering the infill walls and shear wall for lift in the analysis.
7. The IS Code describes very insufficient guideline about infill wall with shear wall for lift design procedures

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