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A COMPARATIVE STUDY ON SEISMIC PERFORMANCE EVALUATION OF IRREGULAR BUILDINGS WITH MOMENT RESISTING FRAMES AND DUAL SYSTEMS

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ABSTRACT

A structural system called Moment Resisting Frame is well known for resisting gravity loads (Live Load and Dead Load. But other than these loads such as wind loads and lateral loads coming from the Earthquakes are resisted by a structural system known as Dual systems. Our project is stressed on a Dual system combination of SMRF and shear wall systems and Flat slab with shear wall system. By using these lateral resisting systems the 3D models are generated and analysed with ETABs software. Equivalent static analysis and push over analysis are carried out to find natural period, lateral displacement, storey drift and base shear of the structure and hence to conclude the best lateral load resisting system pattern which is efficient to resist the lateral loads.

Key Words: Dual System, ETABS 9.7.4, Equivalent Static Analysis, Pushover Analysis, SMRF, Etc.

I. INTRODUCTION

Earthquakes are major geological phenomena. Man has been terrified of these phenomena for ages, as little has been known about the causes of earthquakes, but it leaves behind a trail of destruction. There are hundreds of small earthquakes around the world every day. Some of them are so minor that humans cannot feel them, but seismographs and other sensitive machines can record them. The science of Earthquake Engineering and Structural Design has improved tremendously and thus today we can analyse and design safe structures which can safely withstand earthquakes of reasonable magnitude by introducing suitable lateral resisting systems.

II. OBJECTIVES

The main objective of this study is (1).To construct the model of the irregular RC structure using ETABS 9.7.4 software and to analyze RC irregular high-rise structures and to observe the behaviour of structures by introducing SMRF, SMRF with Shear Wall and Flat Slab with Shear Wall system by equivalent static analysis and pushover analysis. (2).To study the various responses such as base shear, storey drift, lateral displacement for the structure.(3).To compare the results of SMRF, dual system and flat slab system for different patterns with same data and hence to conclude the best structural system.

III. METHODS OF ANALYSIS

3.1 Equivalent Static Analysis

The equivalent static method is the simplest method of analysis because the forces depend on the code based fundamental period of structures with some empirical modifiers. The design base shear is to be computed as whole, and then it is distributed along the height of the building based on some simple formulae appropriate for buildings with regular distribution of mass and stiffness. The design lateral force obtained at each floor shall then be distributed to individual lateral load resisting elements depending upon the floor diaphragm action.

3.2 Pushover Analysis

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. A two or three dimensional model which includes bilinear or tri linear load-deformation diagrams of all lateral force resisting elements 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 control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure is as shown in Fig 1.

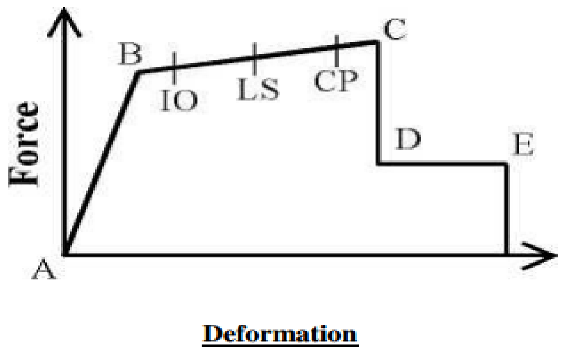


Fig 1: Load Deformation Curve

Estimating seismic demands at low performance levels, such as life safety and collapse prevention, requires explicit consideration of inelastic behaviour of the structure. The estimation of seismic performance of the structure depends on capacity curve generated by the ETABS software. The point at which the displacement and base shear meets, it is known as performance point. This value is found out by the following parameters.

IO - Immediate occupancy, LS - Life safety, CP - Collapse prevention, C – Collapse, A B - Performance point before immediate occupancy, DE - Performance point beyond collapse. Push over analysis as per ATC-40 guidelines is carried out for earthquake zone v in India using ETAB 9.7.4 software

IV. MODELLING AND ANALYSIS

4.1 Overview

It is very important to develop a computational model on which linear / non-linear, static/ dynamic analysis is performed. The summary of various parameters defining the computational models and the basic assumptions and the geometry of the selected building considered for this study. In the present study, frame elements were modelled with inelastic flexural hinges using point plastic model for Non linear Static analysis. A detailed description on the linear and nonlinear modelling of RC irregular structure is presented in this paper.

4.2 Building Description

The G+15 storey building is considered for the analysis by three Moment resisting frame buildings such as Special Moment Resisting Fame (SMRF), SMRF with Shear wall i.e. Dual System, and Flat Slab with shear wall were used in the analysis to know the realistic behaviour of building during earthquake using E-TABS version 9.7.4. The typical floor height is 3.0 m. The plan dimension of the building is L Shaped Structure with a typical bay is 5 m. Modal damping 5% is considered. Base Dimension of building is 50 m x 40 m, Number of bays along x-direction=10, Number of bays along Y-direction=8, Typical Storey height=3.0 meters, Bay width along x and y direction=5.0 meters, Base dimension of the building=50mx40m, Beams size=300 mm x450 mm, Column size=300mm x 900 mm, Depth of slab=200mm, Thickness of shear wall=300mm, Importance factor=1.00,zone factor=0.36.The loading for the structure includes dead load live load and earthquake load considered according to is 875 :1987 and IS 1893:2002(Part1) and the plan and elevation of structure is as shown in Fig 2 - 4.

Fig 2: Floor Plan Of Structure

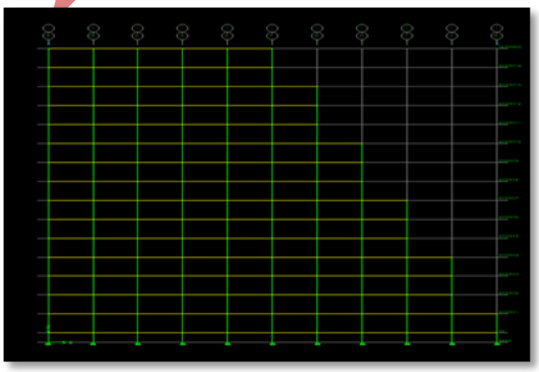
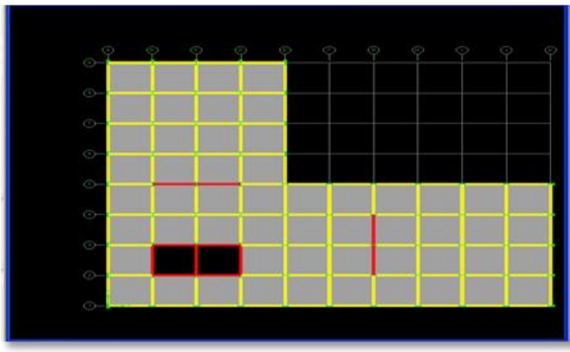


Fig 3: Elevation Of The Structure



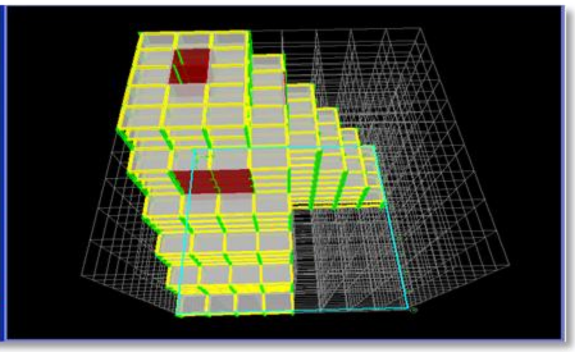


Fig 4: 3D View of Special Moment Resisting Frame with Shear Wall Building

V. RESULTS AND DISCUSSION

Basically, the frames are required to check with static equilibrium, resistance to horizontal forces, and sway stiffness to ensure the stability. The responses of the frames controlled by lateral resistance system are analyzed and the comparisons between different configurations are carried out.

5.1 Equivalent Static Analysis Results

Natural Period: The values of natural period for all the models are shown in the Table 1 & Fig 5. From the obtained results we can observe that the time period for SMRF is more when compared to other two models and hence can be stated that stiffness of SMRF building will be less than the remaining two models since stiffness of the buildings is directly proportional to its natural frequency and inversely proportional to the natural period.

Table 1: Time Period Values for SMRF, SMRF with Shear Wall, Flat Slab with Shear Wall

MODE NUMBERS	TIME PERIOD (seconds)			% Reduction of Model 2 in comparison with Model 1	% Reduction of Model 3 in comparison with Model 1
	Model 1	Model 2	Model 3		
1	2.12	1.0	0.96	52.83	54.72
2	2.1	0.8	0.73	61.90	65.24
3	1.7	0.67	0.6	60.58	64.71
4	0.85	0.27	0.24	68.23	71.76
5	0.8	0.24	0.20	70.00	75.00
6	0.7	0.20	0.18	71.43	74.29
7	0.5	0.14	0.12	72.00	76.00
8	0.47	0.13	0.11	72.34	76.60
9	0.44	0.12	0.10	72.73	77.27
10	0.37	0.11	0.09	70.27	75.68
11	0.32	0.1	0.089	68.75	72.19
12	0.30	0.096	0.085	68.00	71.67

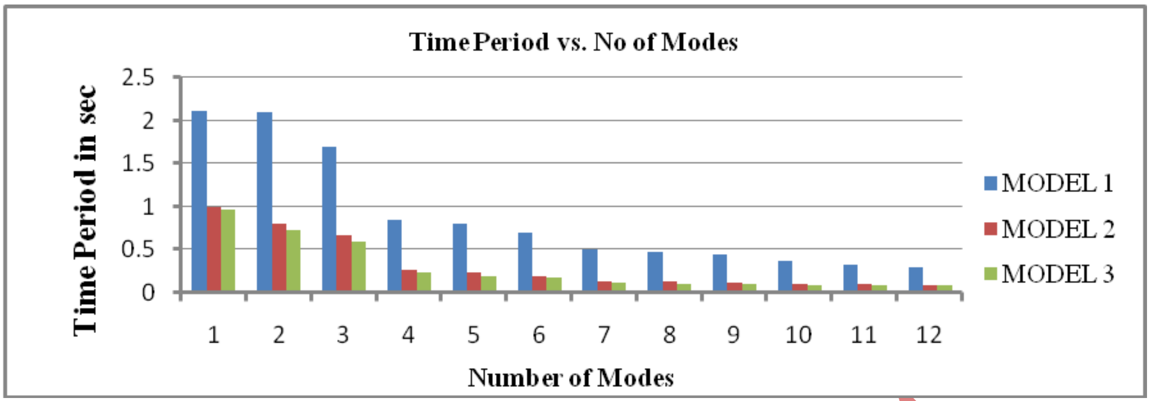


Fig 5: Time Period Vs. No of Modes for SMRF, SMRF with Shear Wall, Flat Slab with Shear Wall

Displacement: The displacement of all the three models is shown in the Table 2 & Fig 6. From the table we observed that displacement for SMRF is more when compared to dual system and flat slab with shear wall system.

Table 2: Displacement Values for SMRF, SMRF with Shear Wall, And Flat Slab with Shear Wall

STOREY LEVEL	DISPLACEMENT(MM)			%Reduction of Model 2 in comparison with Model 1	%Reduction of Model 3 in comparison with Model 1
	Model 1	Model 2	Model 3		
STOREY 1 (GF)	0.82	0.17	0.14	79.27	82.93
STOREY 2	5.34	1.11	0.91	79.21	82.96
STOREY 3	12.20	2.59	2.15	78.77	82.38
STOREY 4	19.99	4.42	3.69	77.89	81.54
STOREY 5	27.90	6.52	5.48	76.63	80.36
STOREY 6	36.50	9.02	7.59	75.29	79.21
STOREY 7	45.19	11.77	9.91	73.95	78.07
STOREY 8	53.60	14.63	12.36	72.71	76.94
STOREY 9	62.30	17.74	14.99	71.52	75.94
STOREY 10	70.73	20.96	17.72	70.37	74.95

STOREY 11	78.49	24.15	20.47	69.23	73.92
STOREY 12	85.95	27.45	23.28	68.02	72.91
STOREY 13	92.55	30.77	26.11	66.75	71.79
STOREY 14	97.99	33.97	28.88	65.33	70.53
STOREY 15	102.25	37.14	31.60	63.68	69.09
STOREY 16 (TERRACE)	105.30	40.12	34.24	61.90	67.48

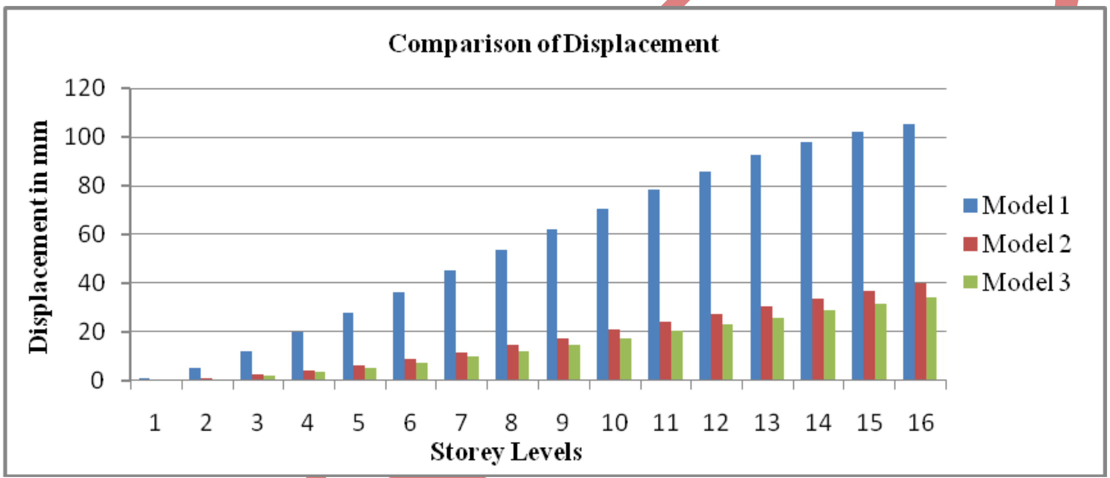


Fig 6: Displacement for SMRF, SMRF with Shear Wall, Flat Slab with Shear Wall.

Table 3: Base Shear Values for SMRF, SMRF with Shear Wall, And Flat Slab with Shear Wall.

STOREY LEVEL	BASE SHEAR(KN)			% Increase of of Model 2 in comparison with Model 1	% Increase of of Model 3 in comparison with Model 1
	Model 1	Model 2	Model 3		
STOREY 1 (GF)	4858.26	11720.02	9489.76	58.55	48.80
STOREY 2	4857.86	11718.87	9489.15	58.55	48.80
STOREY 3	4841.18	11679.05	9456.07	58.55	48.80
STOREY 4	4799.12	11578.08	9375.64	58.55	48.81
STOREY 5	4716.67	11380.18	9217.99	58.55	48.83

STOREY 6	4587.80	11069.84	8959.81	58.55	48.80
STOREY 7	4415.96	10653.04	8629.55	58.55	48.83
STOREY 8	4175.96	10070.89	8168.27	58.53	48.88
STOREY 9	3877.05	9342.51	7560.9	58.50	48.72
STOREY 10	3542.49	8518.68	6913.09	58.41	48.76
STOREY 11	3124.57	7489.6	6103.89	58.28	48.81
STOREY 12	2654.46	6323.95	5128.61	58.02	48.24
STOREY 13	2180.99	5181.77	4200.94	57.91	48.08
STOREY 14	1621.58	3832.31	3104.92	57.69	47.77
STOREY 15	1036.88	2417.75	1899.21	57.11	45.40
STOREY 16 (TERRACE)	527.14	1167.43	996.96	54.85	47.12

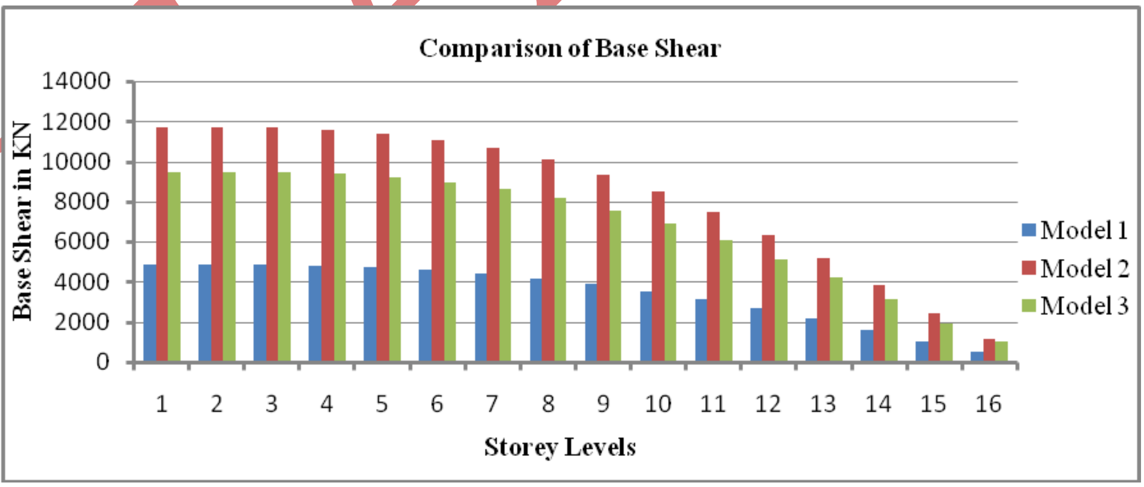


Fig 7: Base Shear Values for SMRF, SMRF with Shear Wall, Flat Slab with Shear Wall

The Base shear values at each storey for all the three models is shown in Table 3 & Fig 7. From the table we can state that base shear for SMRF is less when compared to dual system and flat slab with shear wall.

Table 4: Storey Drift Values for SMRF, SMRF with Shear Wall, And Flat Slab with Shear Wall

STOREY LEVEL	STOREY DRIFT			%Reduction of Model 2 in Comparison with Model 1	%Reduction of Model 3 in Comparison with Model 1
	Model 1	Model 2	Model 3		
STOREY 1 (GF)	0.00104	0.001035	0.000895	0.48	13.94
STOREY 2	0.001424	0.001075	0.000915	24.51	35.74
STOREY 3	0.001817	0.001081	0.000928	40.51	48.93
STOREY 4	0.002202	0.001105	0.000942	49.82	57.22
STOREY 5	0.002476	0.001099	0.000937	55.61	62.16
STOREY 6	0.002625	0.001085	0.000925	58.67	64.76
STOREY 7	0.002809	0.001073	0.00091	61.80	67.60
STOREY 8	0.002889	0.001033	0.000874	64.24	69.75
STOREY 9	0.002859	0.000974	0.000827	65.93	71.07
STOREY 10	0.002899	0.000918	0.000776	68.33	73.23
STOREY 11	0.002853	0.000831	0.000700	70.87	75.46
STOREY 12	0.002704	0.00072	0.000608	73.37	77.51
STOREY 13	0.002595	0.000612	0.000514	76.42	80.19
STOREY 14	0.002304	0.00049	0.000406	78.73	82.38
STOREY 15	0.001577	0.000341	0.000275	78.34	82.56
STOREY 16 (TERRACE)	0.000547	0.000215	0.000181	60.69	66.91

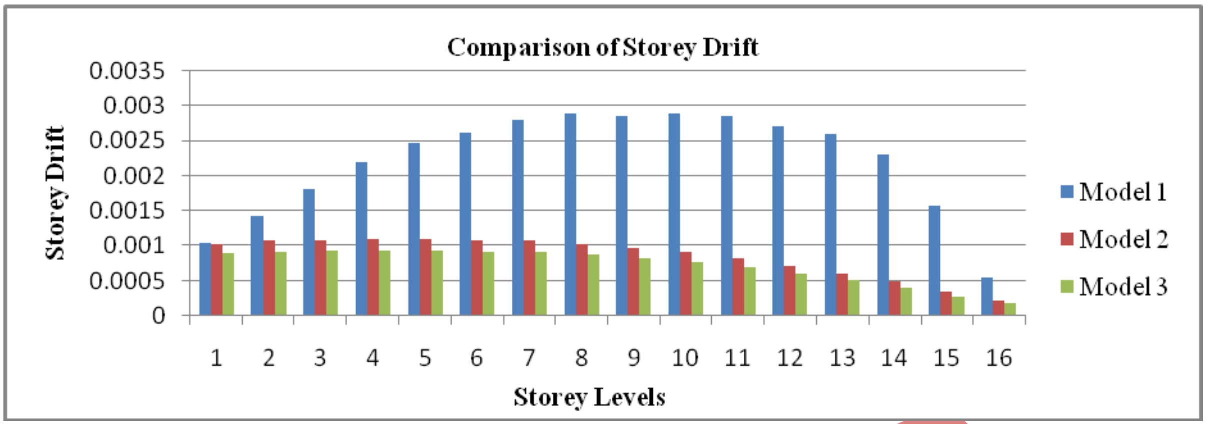


Fig 8: Storey drift for SMRF, SMRF with Shear wall, and Flat Slab with Shear wall

The storey drift for all the three models are shown in Table 4 & Fig 8. From the tabular values we can state that storey drift for SMRF is more when compared to dual system and flat slab with shear wall system.

5.2 Pushover Analysis Result

The details of non linear hinge assignments of beams and columns and the 3D view of dual system model in Push over analysis are as shown in Fig 9-10.

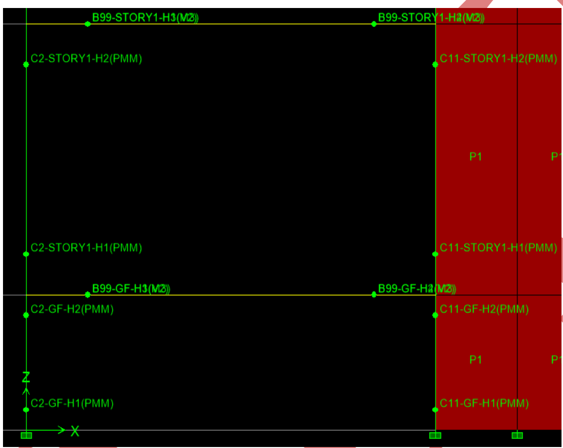


Fig 9: Non Linear Hinge Assignments

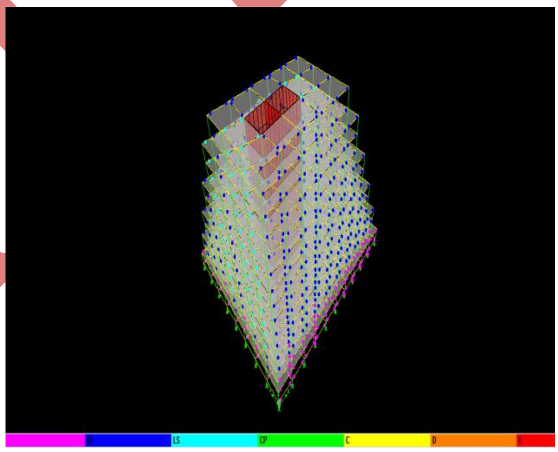


Fig 10: 3D View Of Dual Systems

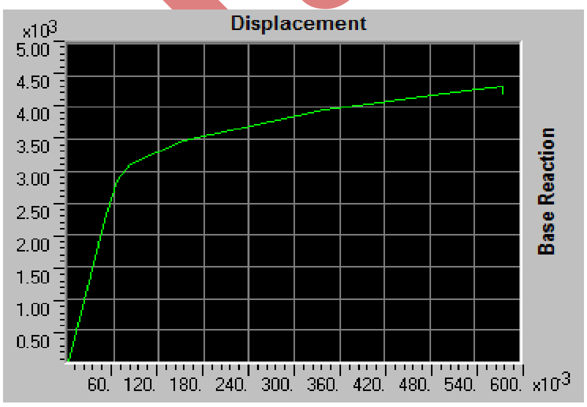


Fig 11: Base Reaction vs. Displacement Curve

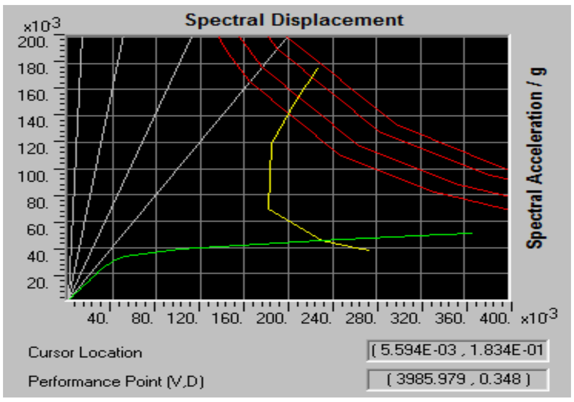


Fig 12: Capacity Spectrum Curve

The ultimate base shear is around 4335KN and the corresponding roof displacement is 575mm as shown in Fig 11. Red curve in the Fig 12 shows the response spectrum curve for various damping values. The base shear at performance point is 3986kN and corresponding displacement is 348mm. Green line indicates capacity spectrum, yellow line indicates single demand spectrum.

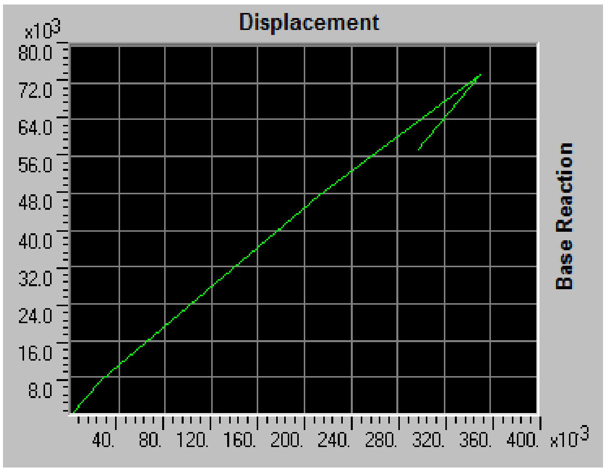


Fig 11: Base Reaction vs. Displacement Curve

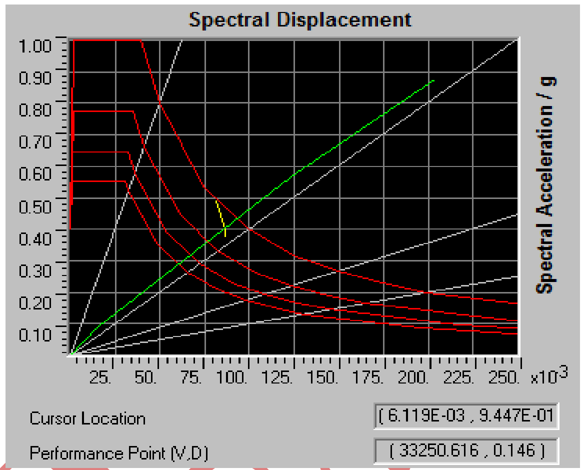


Fig 12: Capacity Spectrum Curve

The ultimate base shear is around 57288kN and the corresponding roof displacement is 296mm as shown in Fig 13. Red curve in the Fig.14 shows the response spectrum curve for various damping values. The base shear at performance point is 33250kN and corresponding displacement is 146 mm.

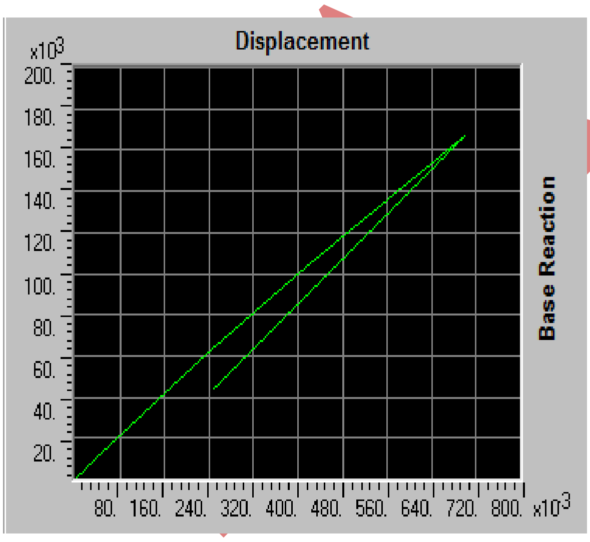


Fig 15: Base Reaction vs. Displacement Curve

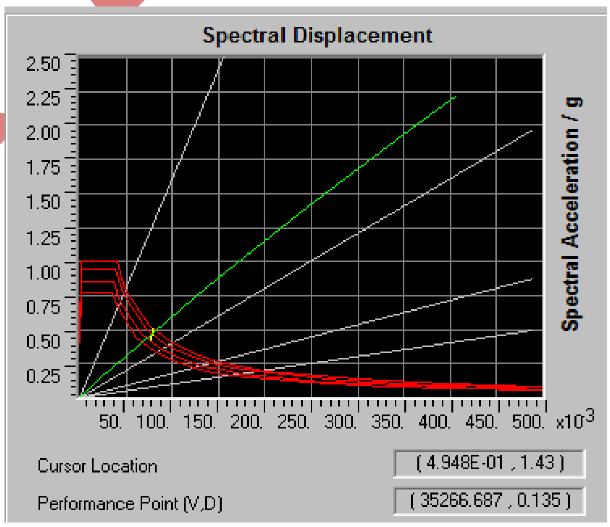


Fig 16: Capacity Spectrum Curve

The ultimate base shear is around 46000 KN and the corresponding roof displacement is 260 mm as shown in Fig 15. Red curve in the Fig.16 shows the response spectrum curve for various damping values. The base shear at performance point is 35266 KN and corresponding displacement is 135 mm.

Table 5: Comparison of Displacement at Performance Point for All the Models

Type of Building	**Displacement at performance point(mm)**	**% Reduction In comparison with SMRF**
SMRF(Model 1)	348	
Dual System(Model 2)	146	58
Flat Slab With Shear Wall System(Model 3)	135	61
Type of Building	**Base Shear at performance point(KN)**	**% Increase in comparison with SMRF**
SMRF(Model 1)	3986	
Dual System(Model 2)	33250	88.01
Flat Slab With Shear Wall System(Model 3)	35266	88.69

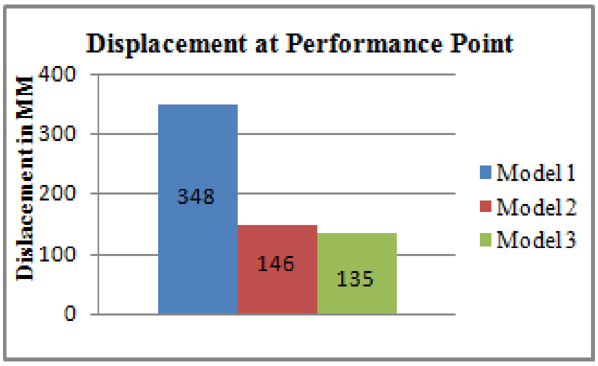


Fig 17: Displacement at Performance Point

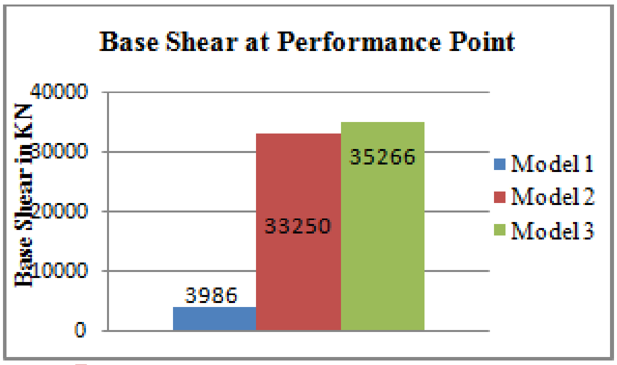


Fig 18: Base Shear at Performance Point

Displacement at performance point has reduced to 58% for dual system and 61% for flat slab with shear wall system when compared to SMRF as shown in Table 5 & Fig 17. Similarly Base Shear at performance point has increased up to 88.01% for dual system and 88.69% for flat slab with shear wall system when compared to SMRF as shown in Table5 & Fig18.

VI. CONCLUSION

Based on the results and discussions, following conclusion is drawn from the present study.

1. For irregular high rise buildings located in high seismic zones, provision of shear wall is more important in structural point of view and in particular serviceability point of view, since lateral displacement has reduced to 61.90% and 67.48% as compared to SMRF without shear walls. From the equivalent static analysis, it can be found that displacement of the each story will increase with the increase in story height for all the models. From the storey drift results, we can conclude that the provision of shear walls is effective in reducing the drift, and hence the overall stiffness of the structure will increase with the introduction of the shear walls.

2. From the study of Non-linear static or push over analysis it can be concluded that the performance level of all the systems is falling under the life safety to collapse prevention. The push over analysis is computed to know the seismic response of the structure. The performance of SMRF with shear walls and flat slab with shear walls is almost same and are more efficient and adaptable structural systems for the high seismic zones as compared to SMRF.

VII. ACKNOWLEDGMENT

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