Seismic Performance Evaluation of Mivan Structural System v/s Conventional Structural System with Effect of SSI by Pushover Analysis

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Abstract - *The progress of any country can be judged by the progress of the construction industry of the country. Cost and time are the two important entities which plays vital role in any construction activity. Hence it has become necessary to estimate cost and time required to complete the construction. At same time progressive rise in stock of construction industry in India and rapid growth of population and urbanization has led to shortage of accommodation. One of such fastest method of construction technology is Mivan Technology. In existing study an attempt is made to study the nonlinear performance and behaviour of Mivan Structures compared with Conventional Structures. Both type of structure is modelled with same material and loading configuration with identical plan and elevation.*

Both type of Structure is modelled for G+3, G+6, G+9 and analysed and designed as per IS codes. Linear and nonlinear results where compared for gravity loading, and inelastic seismic loading with soil flexible support. From the results it is observed that Mivan structures gives better seismic performance than Conventional structures when subjected to gravity as well as seismic loading.

***Key Words*: Mivan System, Conventional System, Soil Structure Interaction, Pushover Analysis, ETABS,**

1. INTRODUCTION

The progress of any country can be only judged by the progress of the construction industry of the country. Cost and time are the two important entities which plays vital role in any construction activity. Hence it has become necessary to estimate cost and time required to complete the construction. Indian construction industry has started using a number of the arena elegance technology. At same time, progressive rise in stock of construction industry in India and rapid growth of population and urbanization has led to shortage of accommodation and situation has become critical in urban and metropolitan areas. For construction of mass building works, it's far important to have progressive technology that are capable of fast construction and are able to construct best quality and durable construction in cost intended manner. One of such technology is Mivan Construction system.

1.1 Mivan Technology

One of such fastest method of construction technology is Mivan Technology; The Mivan Technology became advanced by means of Mivan organization Ltd from Malaysia overdue 1990s as a technology for construct of mass housing mission in developing nations. The members were to be cast in situ, using aluminium as formwork and walls as load bearing walls. Same formwork is repeated throughout the construction providing economical and rapid construction method. In this system column and beams are replaced by shear walls.

Fig. 1.1 Mivan Technology.

1.2 Pushover Analysis

The static pushover evaluation is becoming a popular method for seismic performance evaluation of present and new structures. The pushover evaluation of a structure is a static non-linear analysis under the permanent vertical load and gradually increasing lateral loads. The equivalent lateral static load represents earthquake produced forces and plots a graph representing base shear vs top displacement in a structure is obtained via this evaluation that could imply any premature failure or weak point. The evaluation is achieved up to failure, thus it allows determining disintegrate load and ductility ability. Pushover is a static-nonlinear evaluation approach where structure is subjected to gravity loading and a monotonic displacement-controlled lateral load which constantly increases via elastic and inelastic manner until ultimate condition is obtained.

1.3 Soil Structure Interaction

The technique where in the response of the soil influences motion of the structure and motion of the structure impacts the reaction of the soil is named as SSI. In this case neither the structural displacements nor the ground displacements are independent from each other. From last 3 decades, the impact of SSI on earthquake response of structures has attracted an intensive interest among researchers and engineers. Computation of the soil stiffness is done from **FEMA 356.**

2. METHODOLOGY

In the present study, two different structural systems viz, Mivan structural system and Conventional structural system G+3, G+6, G+9 structures are modeled with soil flexible support and analysed using ETABS which have identical plan and elevation and results are compared.

Table 2.1 Structural Configuration

Building Configuration	
PLAN	20m x 20m
No. of Bays	4 Bays
Slab Panel	5m x 5m
Floor Height	3m
Zone	V
Type of Soil	Soft Soil
Material Properties.	
Grade of Concrete	M 25
Grade of Steel	Fe 415
Density of Concrete	25 kN/m^3
Density of Brick Wall	20 kN/m3
Member Dimensions.	
Column	450 x 450 mm
Beam	300 x 380 mm
Wall Thickness	150 mm
Slab Thickness	150 mm
DEAD LOAD	
Type of Load	**Load Calculation**
Wall Load on Beam	12 kN/m.
LIVE LOAD	
Floor Live Load	5 kN/m^2
SEISMIC PARAMETERS as per IS1893:2000 (Part -I)	
Seismic Zone	V
Type of Structure	SMRF(Special Moment Resisting Frame)
Damping Ratio	5% (RC Structure) (Table 2)
Importance Factor (I)	1 (Table 6)
Response Reduction Factor(R)	5 (Table 7)

2.1 Model Considered for the Analysis

The plan and 3D view of the structure with soft soil flexible support are considered. Fig 2.1 & 2.2 shows the plan and 3D view of conventional & Mivan system.

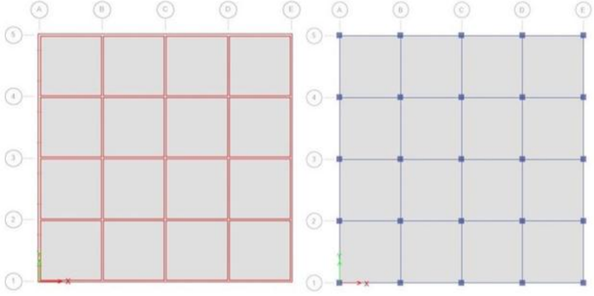


Fig No. 2.1 Mivan & Conventional Structural Plan.

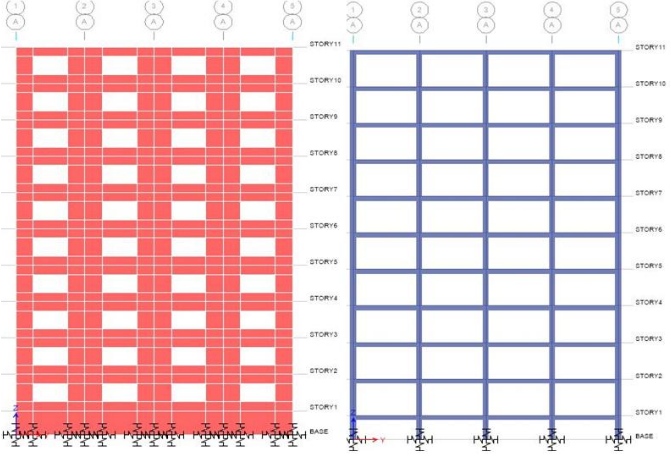


Fig No. 2.2 Mivan & Conventional Structural Elevation.

2.2 Pushover Analysis

Pushover analysis is a static, nonlinear technique in which the significance of the lateral force is incrementally expanded, maintaining the predefined distribution sample along the peak of the building. i.e. 2% of total height of structure. The Ultimate load & maximum inelastic behavior, stiffness of the structure, critical links & failure modes of structure is determined. The base shear vs peak displacement graph is obtained which is pushover curve which gives the details of the maximum base shear that the structure can resist during earthquake. The hinges are described as according to the criteria given in **ASCE 41.** Shear hinges (V2) & flexural hinge (M3) is assigned to beam element at distance ratio of 0.05 and 0.95 interacting (P-M2-M3) hinge for column at distance ratio 0.05 & 0.95.

2.3 Performance Degree of Structure

Performance based design is a technique to the layout of any complexity of structure. A Structure constructed in this manner is needed to meet sure measurable or predictable overall performance necessities, such as strength efficiency and seismic load, without a selected prescribed method by using which to reap the ones requirements. The non-structural and structural additives of the buildings together contribute to the building performance. The structural overall performance ranges based at the roof drifts are as shown below, the force deflection behavior of the hinge and these points classified as.

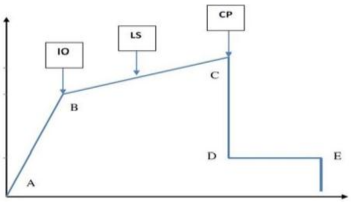


Fig No. 2.3 Force v/s Deformation curve.

A-B: Elastic state, A: Unloaded condition. B: Onset of yielding, B-IO: Below immediate occupancy. IO-LS: Between immediate occupancy and life safety. LS-CP: Between life safety to collapse prevention. CP-C: Between collapse prevention and ultimate capacity. C: Ultimate strength 6) C-D: Between Ultimate strength and residual strength. D: Residual strength, D-E: Between residual strength and collapse E: Collapse.

2.4 Soil Structure Interaction

The technique where in the response of the soil influences motion of the structure and motion of the structure impacts the reaction of the soil is named as SSI. In this case neither the structural displacements nor the ground displacements are independent from each other. From last 3 decades, the impact of SSI on earthquake response of structures has attracted an intensive interest among researchers and engineers. Computation of the soft soil stiffness is done from **FEMA 356,** from the equation given in Table No 2.2.

Table 2.2 Computation of Soil Stiffness from FEMA 356

DOF	Stiffness of foundation at surface
Translation along x-axis	Kx=$\frac{GB}{2-v}\left[3.4\left(\frac{L}{B}\right)^{0.65}+1.2\right]$
Translation along y-axis	Ky=$\frac{GB}{2-v}\left[3.4\left(\frac{L}{B}\right)^{0.65}+0.4\frac{L}{B}+0.8\right]$
Translation along z-axis	Kz=$\frac{GB}{1-v}\left[1.55\left(\frac{L}{B}\right)^{0.75}+0.8\right]$
Rocking about x-axis	Kxx=$\frac{GB^3}{1-v}\left[0.4\left(\frac{L}{B}\right)+0.1\right]$
Rocking about y-axis	Kyy=$\frac{GB^3}{1-v}\left[0.47\left(\frac{L}{B}\right)^{0.24}+0.034\right]$
Torsion about z-axis	Kzz=$GB^3\left[0.53\left(\frac{L}{B}\right)^{2.45}+0.51\right]$

3. RESULTS AND DISCUSSIONS

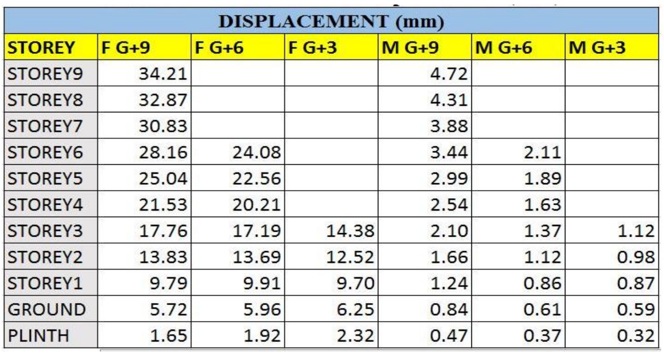
3.1 General

In present chapter, the results acquired for distinct building models with specific zones and soft soil type are considered for specific types of analysis executed particularly equivalent Static and response Spectrum and Nonlinear static pushover analysis. The evaluation is carried out in ETABS software. After performing the linear and Nonlinear analysis of structure is taken into consideration, their behaviour is analysed and compared in phrases of following parameters.

3.2 Displacement (mm)

The details of maximum displacement of the all the structure for the applied load pattern and analysis are noted down in the Table 3.1 and graph showing the graphical variation of displacement at each storey level Is shown in the Fig No. 3.1.

Table 3.1 Maximum Displacement (mm)



DISPLACEMENT (mm)						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
STOREY9	34.21			4.72		
STOREY8	32.87			4.31		
STOREY7	30.83			3.88		
STOREY6	28.16	24.08		3.44	2.11	
STOREY5	25.04	22.56		2.99	1.89	
STOREY4	21.53	20.21		2.54	1.63	
STOREY3	17.76	17.19	14.38	2.10	1.37	1.12
STOREY2	13.83	13.69	12.52	1.66	1.12	0.98
STOREY1	9.79	9.91	9.70	1.24	0.86	0.87
GROUND	5.72	5.96	6.25	0.84	0.61	0.59
PLINTH	1.65	1.92	2.32	0.47	0.37	0.32

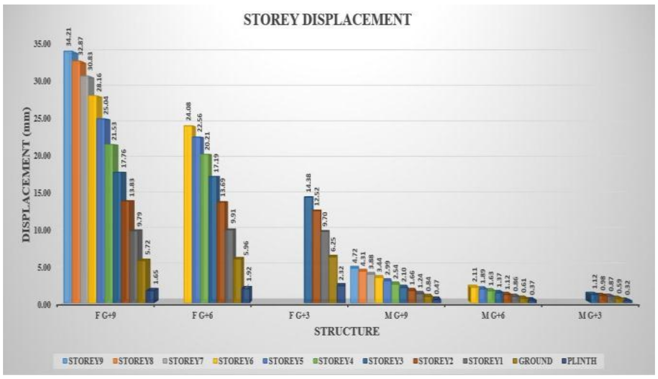


Fig No. 3.1 Storey Displacement (mm)

From the above Table No 3.1 and Fig No.3.1, it can be noticed that the maximum deflection for frame structure for G+9 is 34.21mm and that for Mivan structural System of G+9 is 4.72 mm similarly it is observed that Mivan structures have less displacement as compared to the Conventional structural system. Mivan structural system is rigid and have better resistance to lateral loads hence the displacement is less in mivan Structural system.

3.3 BASE SHEAR (kN)

Base shear is an estimate of the most predicted lateral force in an effort to arise because of seismic ground motion at the bottom of the structure. Base shear of both type of structure is noted down in Table 3.2 and plotted in graph Fig No. 3.2.

Table 3.2 Base Shear (kN)

BASE SHEAR (kN)						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
LINEAR	904	895	850	3323	2346	1069
NONLINEAR	15550	14952	12664	450484	711393	921354

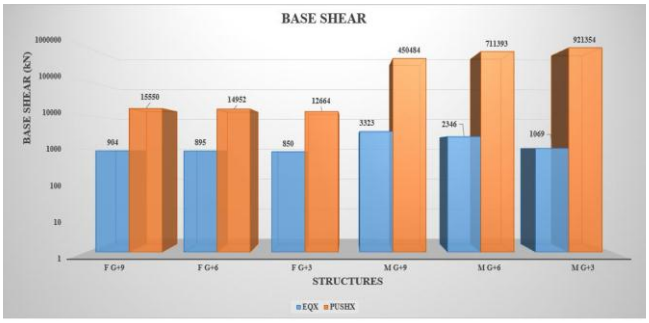


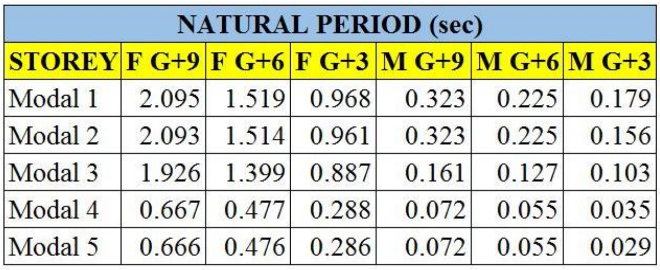
Fig No. 3.2 Base Shear (kN)

From the above results from the Fig No. 3.2 and the Table No. 3.2 it is observed that the base shear of the Mivan structural system is very much high as that of conventional structural system. Mivan structural system base shear for all the three model is on an avg. 40% more than that of conventional structural system. This is due to increase in structural stiffness of shear wall as the shear wall increases the rigidity of structure leading to higher base shear values.

3.4 Natural Period (Sec)

Natural frequency and period characteristics plays tremendous role in evaluating the seismic behaviour of a structure. The design codes of various nations provide some estimate of the natural period by using empirical formulas. RCC structure are normally used for high-rise buildings in earthquake regions. Natural period obtained from the analysis of the structure is noted down in Table No. 3.3.

Table 3.3 Natural Period (Sec)



NATURAL PERIOD (sec)						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
Modal 1	2.095	1.519	0.968	0.323	0.225	0.179
Modal 2	2.093	1.514	0.961	0.323	0.225	0.156
Modal 3	1.926	1.399	0.887	0.161	0.127	0.103
Modal 4	0.667	0.477	0.288	0.072	0.055	0.035
Modal 5	0.666	0.476	0.286	0.072	0.055	0.029

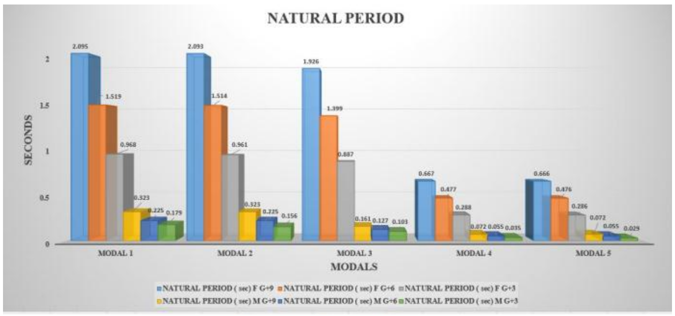


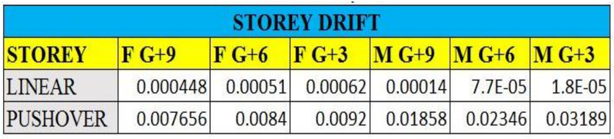
Fig No. 3.3 Natural Period (Sec)

From the Table No.3.3 and Fig No.3.3 of natural period it is clearly visible that natural period is decreasing from conventional structural system to mivan structural system it shows that the mivan structural system is very stiff as compared to conventional structural system and conventional structural system is flexible as compared to mivan structural system. The detailed comparison of natural period of all the structure is plotted in Fig No.3.3.

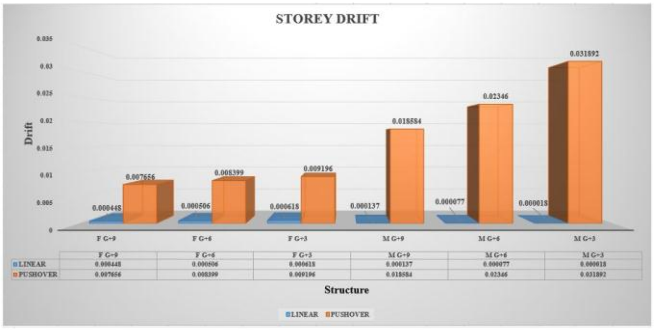
3.5 Storey Drift

Storey drift of a multi-storey building is relative lateral displacement to storey below. The drift of building is the ratio of maximum lateral drift of peak of the structure to the total height of structure. The maximum permissible inter storey drift as per IS1893 is 0.004h the detail of storey drift obtained from analysis of the respective model is tabulate in Table No.3.4.

Table 3.4 Storey Drift



STOREY DRIFT						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
LINEAR	0.000448	0.00051	0.00062	0.00014	7.7E-05	1.8E-05
PUSHOVER	0.007656	0.0084	0.0092	0.01858	0.02346	0.03189



	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
LINEAR	0.000448	0.000506	0.000618	0.000137	0.000077	0.000018
PUSHOVER	0.007656	0.008399	0.009196	0.018584	0.02346	0.031892

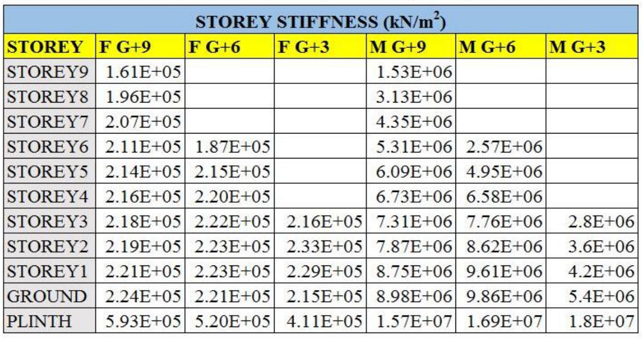
Fig No. 3.4 Storey Drift

The storey drift of the respective models are shown in graph above Fig No. 3.4 from the graph it is observed that the storey drift of mivan structure is very less as that of conventional structure both for linear and nonlinear cases. This is due to Mivan structural system provides better resistance to lateral loads.

3.6 Stiffness (kN/m²)

The extent to which it resists deformation in response to applied load is known as stiffness. The stiffness result of all the Structures are noted down in the Table 3.5 below.

Table 3.5 Storey Stiffness (kN/m²)



STOREY STIFFNESS (kN/m²)						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
STOREY9	1.61E+05			1.53E+06		
STOREY8	1.96E+05			3.13E+06		
STOREY7	2.07E+05			4.35E+06		
STOREY6	2.11E+05	1.87E+05		5.31E+06	2.57E+06	
STOREY5	2.14E+05	2.15E+05		6.09E+06	4.95E+06	
STOREY4	2.16E+05	2.20E+05		6.73E+06	6.58E+06	
STOREY3	2.18E+05	2.22E+05	2.16E+05	7.31E+06	7.76E+06	2.8E+06
STOREY2	2.19E+05	2.23E+05	2.33E+05	7.87E+06	8.62E+06	3.6E+06
STOREY1	2.21E+05	2.23E+05	2.29E+05	8.75E+06	9.61E+06	4.2E+06
GROUND	2.24E+05	2.21E+05	2.15E+05	8.98E+06	9.86E+06	5.4E+06
PLINTH	5.93E+05	5.20E+05	4.11E+05	1.57E+07	1.69E+07	1.8E+07

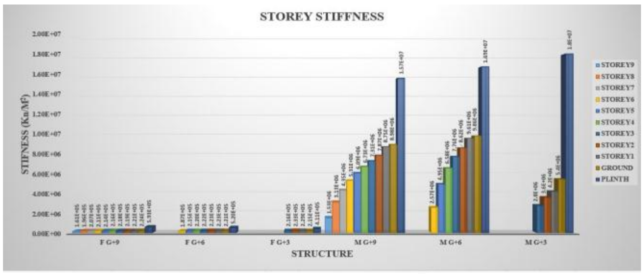


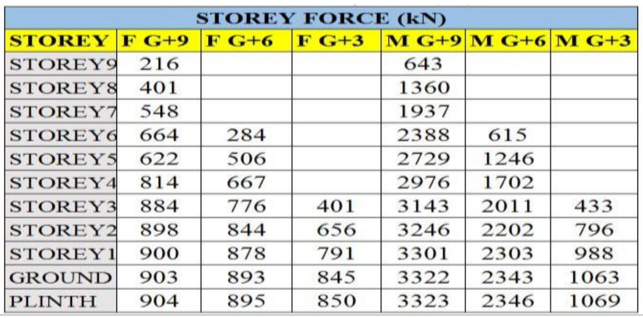
Fig No. 3.5 Storey Stiffness (kN/m²)

The Fig No.3.5 and Table No.3.5 above shows the stiffness of the different structure for same loading patterns. Fig No.3.5 shows that mivan structure is stiffer compared to conventional structure. As mivan structure is stiffer gives better resistance to the lateral loads. Since Mivan system is having large rigidity, the deformation is also less in such system.

3.7 Storey Shear Force (kN)

Storey force is an estimate of the most predicted lateral force in an effort to arise because of seismic ground motion at each storey level of the structure. The details of storey force acting on the structures are tabulated below in Table 3.6

Table 3.6 Storey Shear Force (kN)



STOREY FORCE (kN)						
STOREY	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
STOREY9	216			643		
STOREY8	401			1360		
STOREY7	548			1937		
STOREY6	664	284		2388	615	
STOREY5	622	506		2729	1246	
STOREY4	814	667		2976	1702	
STOREY3	884	776	401	3143	2011	433
STOREY2	898	844	656	3246	2202	796
STOREY1	900	878	791	3301	2303	988
GROUND	903	893	845	3322	2343	1063
PLINTH	904	895	850	3323	2346	1069

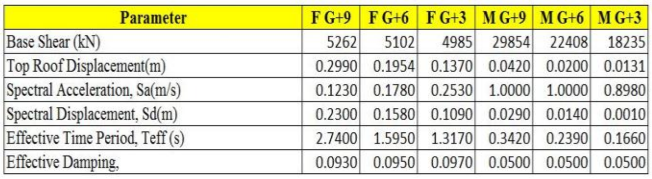
Fig No. 3.6 Storey Shear Force (kN)

The above table No.3.6 and Fig No.3.6 it is noticed that conventional structure has lesser storey force as that of mivan structure. This is due to conventional structural system is more flexible as that of mivan structural system.

3.8 Pushover Analysis Results

Pushover analysis is contemplated as an effective tool to assess the capability of structure for seismic forces and for this reason it is expected the actual behavior of the structure during earthquake.

Table 3.7 Capacity Spectrum Parameters



Parameter	F G+9	F G+6	F G+3	M G+9	M G+6	M G+3
Base Shear (kN)	5262	5102	4985	29854	22408	18235
Top Roof Displacement(m)	0.2990	0.1954	0.1370	0.0420	0.0200	0.0131
Spectral Acceleration, Sa(m/s)	0.1230	0.1780	0.2530	1.0000	1.0000	0.8980
Spectral Displacement, Sd(m)	0.2300	0.1580	0.1090	0.0290	0.0140	0.0010
Effective Time Period, Teff (s)	2.7400	1.5950	1.3170	0.3420	0.2390	0.1660
Effective Damping,	0.0930	0.0950	0.0970	0.0500	0.0500	0.0500

The Table No.3.7 above shows the value from capacity spectrum obtained from the structures analysed from the value it can be observed that in mivan system base shear is much higher than that conventional structure system. Displacement at performance point of mivan model is very less which shows that mivan structures provides better resistance to seismic forces then conventional system. Spectral acceleration is high for mivan structure but spectral displacement is less. Natural period of the conventional system is more than mivan, which mean conventional structure are more flexible then mivan therefore conventional system attract less seismic forces.

3.9 Plastic Hinge Formation

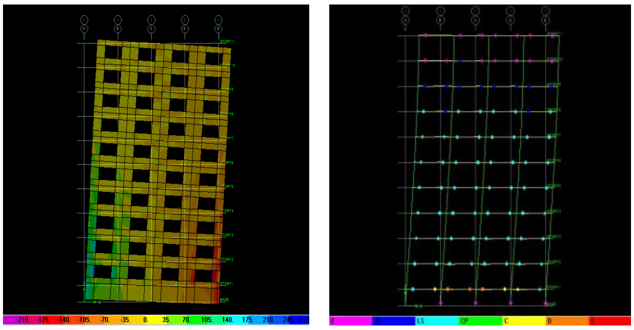


Fig No. 3.7 Stress level and Hinge formations

The above figure shows the plastic hinge formation and stress levels in the structures is noticed that the hinge formation starts in beam which means the structures follows weak beams and strong column theory and later on incremental lateral loads hinges started forming in columns to keep the structure safe it should be noted that the hinges formed should be within life safely point. In figure, it clearly shows the hinges formed in beam are almost within life safe point except the bottom beams which are at residual strength. The columns are all within immediate occupancy. From the fig No.3.7 of mivan structure the blue colure indicate the tensile stresses and red indicates the compression stresses. the bottom members of the structure are in high stresses and rest members are almost have no effect which means mivan structures perform well during seismic ground motions.

4 CONCLUSIONS

4.1 Summary

The present study makes an effort to evaluate the seismic performance of Mivan structural system v/s Conventional structural system, using the codes specified design spectrum in the elastic and inelastic demine, using ETABS software. The results of the study lead to the following conclusions.

4.2 CONCLUSIONS

1. Mivan structural system provides better lateral resistance to overall displacement. Displacement of the conventional structural system is 86% more than that of Mivan structural system.
2. Conventional structural system has lower base shear as compared with mivan structural system. The base shear of mivan structural system is 40% more than conventional structural system. The structural stiffness of mivan structural system is very high and hence attracts larger base shear.
3. Mivan structural system in general decreases the natural period (increases the base shear), while the conventional structural system decreases the base shear. (increases the natural period), however mivan structural system is very predominant.
4. Mivan structural system have an average of 82% less storey drift as compared to conventional structural system.
5. From the results of non-linear analysis, which gives the realistic behaviour of the structure to the ground motions. It can be observed that Mivan structural system perform better than the conventional structural system as the hinges are within life safety performance level, and none of the hinges corresponds to the collapse performance level.

REFERENCES

[1] Mr.N.B. Baraskar, Prof.U.R. Kawade, "Structural Performance of RC Structural wall system over conventional Beam Column System in G+15 storey Building", International Journal of Engineering Research and General Science, Volume 3, Issue 4, July-August, 2015.

[2] Rajesh M N, S K Prasad, "Seismic Performance Study on RCC Wall Buildings from Pushover Analysis", International Journal of Research in Engineering and Technology.

[3] M.K. Rahman, M. Ajmal, M.H. Baluch, "Nonlinear Static Pushover Analysis of an Eight Storey RC Frame-Shear Wall Building in Saudi Arabia", king fahd university of petroleum and mineral, Dhahran, Saudi arabia,2012.

[4] Dr. M.N. Bajad, Rohan P. Shah, Harshkumar C. Ughareja, "A State of Art Review on Aluminium Formwork Systems" International Journal of Engineering Research-Online, vol-4, issue-2,2016

[5] FEMA 356 (2000). Pre-standard and commentary for the seismic rehabilitation of buildings, American society of Civil Engineers, Reston, Virginia.

[6] Federal Emergency Management Agency, FEMA-440: Improvement of Nolinear Static Seismic Analysis Procedures. June 2005: Washington DC.

[7] Dr. Vinod Hosur, "Earthquake – Resistant Design of Building Structures", Wiley Precise Textbook.

[8] IS 1893 (Part 1)-2002, "Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi, India.

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