PUSHOVER ANALYSIS OF HIGH RISE RC BUILDING WITH VARIOUS ASPECT RATIOS OF SHEAR WALL

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Abstract - *All the existing old Rcc building in the India had been design as per the clauses and conditions given in old Indian Standard codes which are not as per the standard in the current codal provision. Hence it is a need of time to check whether this previously design old buildings are capable of fulfilling the seismic demands or not otherwise it can cause hazardous to life. Pushover analysis is the method which is adapted to check whether this old structure is fulfilling the current demands of seismic provisions or if not fulfilling the demand it can be modified with the help of results obtained by Pushover analysis. Pushover analysis is also called as nonlinear static analysis used by designers to check and analyses this structure because of its suitability and simplicity. In the current study the two buildings with and without share wall have been analyzed with the help of pushover analysis for seismic conditions and a parametric study of the result obtained shown. The aspect ratio of shear wall that is the ratio of height to length has also the effect on the seismic parameters of the structure. For different aspect ratios the building has been analyzed and the comparative study for different aspect ratio from 1 to 3 has been done. The result obtained shows that with the help of Pushover analysis that, the shear wall increases the lateral strength and overall strength of building during the seismic conditions. It can be seen that for different aspect ratio of the behavior of the structure changes for pushover analysis.*

***Key Words*: Aspect ratio, Pushover analysis, Rcc building, Shear wall, Seismic condition**

1.INTRODUCTION

The pushover analysis is a performance-based design approach for evaluation of the seismic performance of new designed and also existing structures. Pushover analysis can also be termed as nonlinear static analysis and gives a significant information of the seismic force resisting capacity of the structure vis-a-vis the seismic demand imposed by the earthquake on the structure.

The purpose of nonlinear static analysis is to evaluate the seismic performance of structural systems by computing its strength and deformation capacity in design earthquakes by use of inelastic analysis, and comparing these capacities to the imposed demands at the performance levels. The assessment is based on the evaluation of important performance parameters, including overall drift, inter-storey drift, inelastic element deformations, deformations between elements, and element connection forces especially for elements and connections that cannot sustain inelastic deformations. In case of major alterations to be done in an existing building, the seismic performance of structurally modified building can be easily evaluated by pushover analysis.

1.2. LITERATURE REVIEW

Zhibin Su and Tao Han [2] have performed nonlinear static analysis on a single RCC shear wall model in SAP2000 software, which is modelled by a nonlinear multi-layer shell element. Nonlinear static pushover analysis of the model is performed by imposing uniform acceleration lateral load pattern and inverted triangle lateral load pattern. The stress contours of the rebar layer and concrete layer and the curve between roof top displacement and base shear of shear wall are obtained. It may be ascertained that the yielding of rebar layer and cracking of the concrete layer may be seen by stress contours and program of the SAP2000 proves to be good for nonlinear modelling of shear wall under earthquakes.

Cavdar and Cavdar [3] authors have examined the seismic behavior of a buildings that collapsed during the Bingol earthquake of 2003 and was investigated by non-linear static analysis along with non-linear dynamic analysis. The selected construction of the reinforced concrete retaining walls is located in Bingol, Turkey. A local code was taken in account to evaluate the seismic performance of the shear wall buildings. The performance of the reinforced concrete shear wall design was evaluated by the use of equivalent methods and procedures for seismic load transmission and nonlinear analysis.

Rana and Limin [7] in this paper authors have performed static nonlinear analysis on a 19 storey, high rise RC building located in San Francisco, USA. Building consists of RC shear walls as a primary lateral load resisting element. The building is designed in compliance to 1997 Uniform Building Code, and nonlinear static analysis was performed to validate code's performance objective of Life Safety under design earthquake. Procedure which are followed for analysis and results were presented in this paper.

Kurma and Vignan [8] in this paper pushover analysis has been done on two multistorey R.C. building. Plan of 2 buildings was taken symmetrical 10 storeys and it had 5 bays in the horizontal & 5 bays in vertical and second building structure had 15 stories. The shear wall had been provided for studying their resisting lateral forces. The effect of the reinforced shear wall on Rcc frame building with shear wall on the longer and shorter sides has been studied in this paper. The base shear and displacement decreased with the shear wall. The comparative study had been done for base shear, storey drift, spectral acceleration and displacement, storey displacement.

Fahjan and Doran [9] authors have evaluated the consistency of different methods for nonlinear shear wall modeling. They had studied 3, 5, 7 storey RCC building with shear walls and are analyzed with the help of nonlinear 2D FE method acted by incrementally increasing lateral loads with gravity loads. In this paper, mainly nonlinear modeling of shear walls for mid-rise buildings is focused. In current practice, plastic hinges are expected along the critical height of the shear walls.

1.3. OBJECTIVES

- To assess the performance of the RC building in its inelastic behavior.
- To perform pushover analysis of structure without shear wall.
- To modify same structure with shear wall and perform pushover analysis.
- Compare the results obtained by both types of structures.
- To study the failure in shear wall for varying aspect ratio (L/H) of shear wall.

1.4. BASIS OF NONLINEAR ANALYSIS PROCEDURE

The target displacement is set to a model at a control point which corresponds to the maximum displacement which structure is expected to resist during the earthquake. Since, analytical model considers the material inelastic response, the computed internal member forces during the design earthquake are reasonably accounted.

1.5. PROCEDURE OF NONLINEAR STATIC ANALYSIS

• For performing pushover analysis, a model of a building is produced in FE analysis software such as ETABS, SAP2000, etc.

• Elastic Analysis is performed on the model and the designing for reinforcement is done. Subsequently, nonlinear analysis is initiated by initially defining the plastic hinge properties to the structural elements based on its loading response. Plastic hinge property considerations are referred from FEMA 356 and FEMA 273. Generally, for columns and tall slender shear walls PMM interaction hinges are provided and for beams flexural hinges are provided.

• A lateral loading pattern is selected for the building. For the analyses, preferably two vertical distributions of lateral loads should be imposed on the building to consider the range of design actions that are expected to occur during the earthquake response of the structure.

• Further, either of the following two approaches is followed to evaluate the nonlinear performance of the building, 1. Force-controlled 2. Displacement-controlled. For RC structures, generally displacement-controlled approach is more reliable.

• A target displacement is set to the structure. Target displacement can be computed either by coefficient method or capacity spectrum method. In this research, capacity spectrum method will be adopted as it produces more realistic evaluation of the analysis.

• Base shear vs roof top displacement relation is plotted for the structure. Structure is displaced till it attains 150% of target displacement.

• Spectral acceleration vs spectral displacement plot (capacity curve) is obtained by transforming base shear vs roof top displacement curve using empirical relations suggested by ATC 40.

• Spectral acceleration response spectrum plot is reduced to acceleration displacement response spectrum (ADRS) plot (demand curve) using empirical relations.

• Further, demand and capacity curve are merged to obtain there intersection point known as "Performance Point". Performance point forms the basis of the Acceptance level criteria of seismic performance of the structure. These levels are Immediate Occupancy (IO), Life Safety (LS) and Collapse Prevention (CP), as suggested by FEMA.

2. METHODOLOGY

- To prepare Rcc building floor plan.
- To analyse the structure with the help of pushover analysis.
- Again, to modify the same structure by introducing shear wall.

- To perform the non linear static analysis on that modified structure.
- To carry out pushover analysis for different models of with and without shear wall for various aspect ratios.

3. PROBLEM STATEMENT AND SYSTEM MODELLING

To investigate the effect of seismic forces on the building structures, analytical models are considered in this study.

Modelling and analysis of 2 models is done whereas the plan and elevation of building models is kept same for purpose of comparison of results. These 2 models are as follows-

1) First model is RCC frame model.

2) Second model is Rcc frame with shear walls.

To Find out the behavior of various model with and without shear wall for various aspect ratios i.e., ratio of height to length of shear wall under the seismic forces various analytical models are considered in this study work. The aspect ratio starting from 1 to 3 is considered.

For each aspect ratio the model with shear wall and without share wall is considered. In total 12 different models are made in the software ETABS for this study. Some parameters of the models are kept same for purpose of comparison of results.

All models are subjected to static nonlinear analysis with the help of structural analysis program ETABS. The dimension of all the beams and columns are designed according to Indian standard codal specifications. The proposed building is designed to resist dead load, and live load & seismic load.

Firstly, the plan and elevation of building was decided. Then this building was modelled in ETABS. This building was analyzed as RCC building. The nonlinear static analysis is done on the building model with the help of software ETABS. Then the same model is modified by introducing shear wall and the new modified model is again analyse by performing nonlinear static analysis on it. Results obtained by the both analyses are compared. Changes in the parameters such as fundamental time period, storey displacement, storey drift, pushover curves, Hinge responses were recorded and presented in the study.

The details of proposed building are as follows.

Building Model details: -

No of storey – 10
Outer Dimensions – 15m * 24m
Height – 30m
Concrete – M30
Steel – Fe 500
Beam size – 300 * 350 mm
Column size – 500 * 500 mm
Slab thickness – 200 mm
Shear wall thickness – 250 mm
Seismic Zone – III
Zone factor: Z – 0.16
Damping – 5%
Response Reduction Factor (R) – 4

Details of model for aspect ratio study: -
Outer Dimensions – 9m * 9m
Concrete – M30
Steel – Fe 500
Beam size – 300 * 350 mm
Column size – 400 * 400 mm
Slab thickness – 200 mm
Shear wall length – 3m
Shear wall thickness – 250 mm
Seismic Zone – III
Zone factor: Z – 0.16
Damping – 5%
Response Reduction Factor (R) – 4

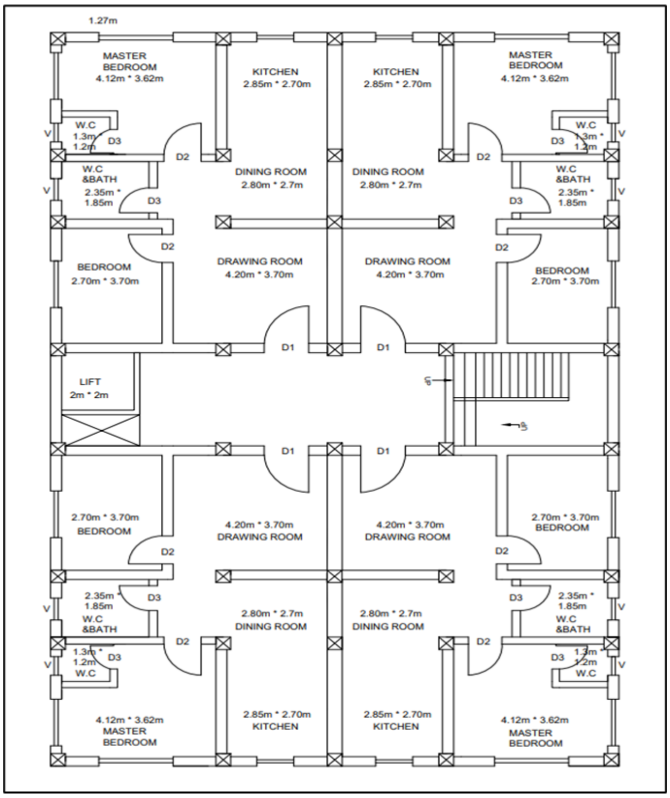

Fig -1: Typical floor plan of building

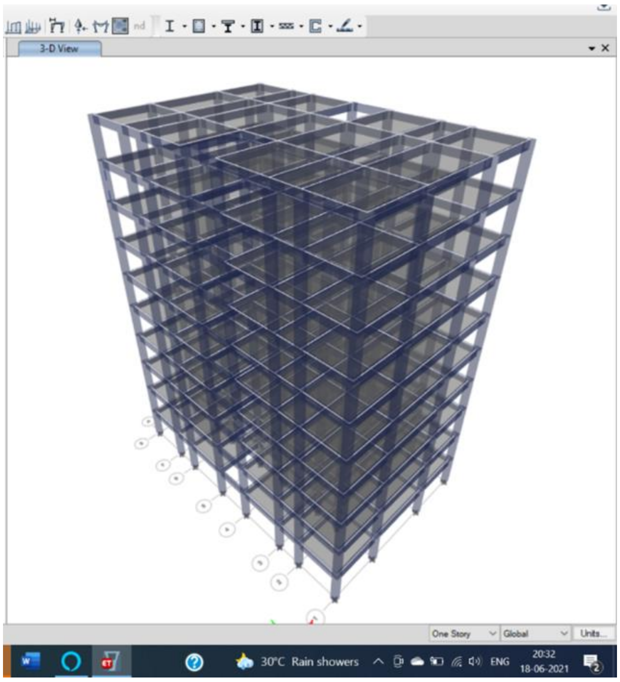

Fig -2: 3D view of building model without shear wall

4. Results

The Non linear analysis that is pushover analysis is carried out on the model with the help of finite element analysis software ETABS. The analysis was carried out for maximum number of 100 steps. The hinge properties were assigned to the structural elements such as beams, columns etc. as per the standard provisions. The pushover curve, hinge responses and other parameters were recorded. The linear and nonlinear analysis results obtained are shown in the following tables and figures.

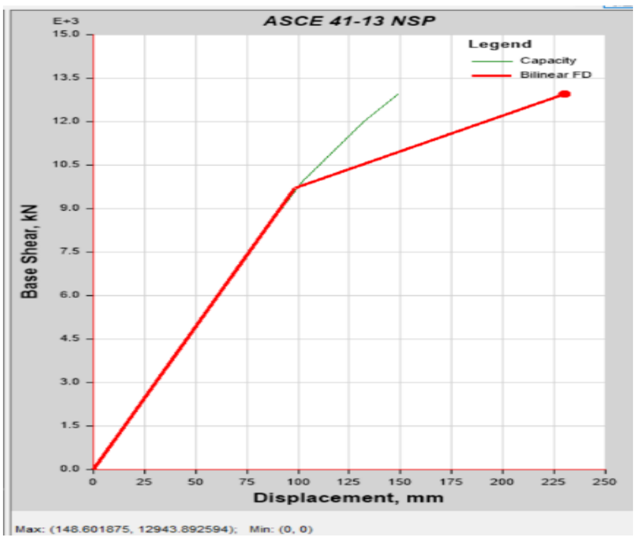

Fig -3: Pushover curve

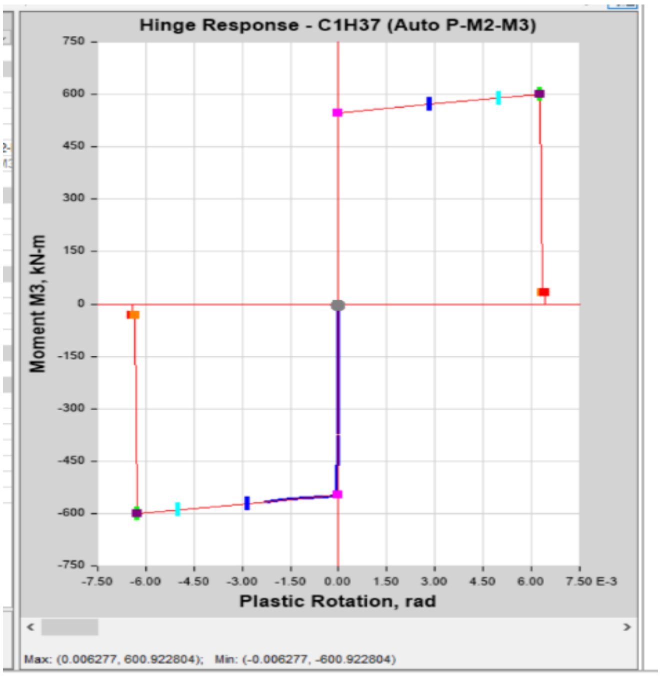

Fig -4: Hine response

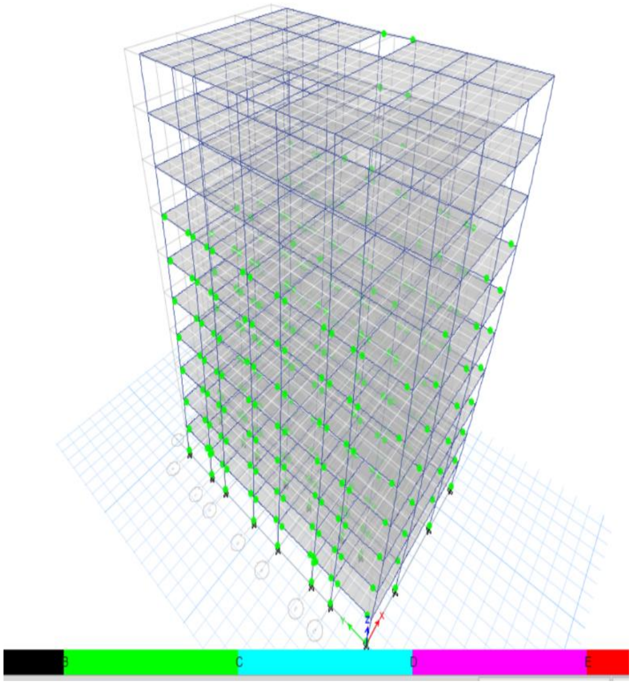

Fig -5: Hinges form on structure during pushover analysis

The same model is modified with shear wall. Results for same building model modified with shear wall are as follows.

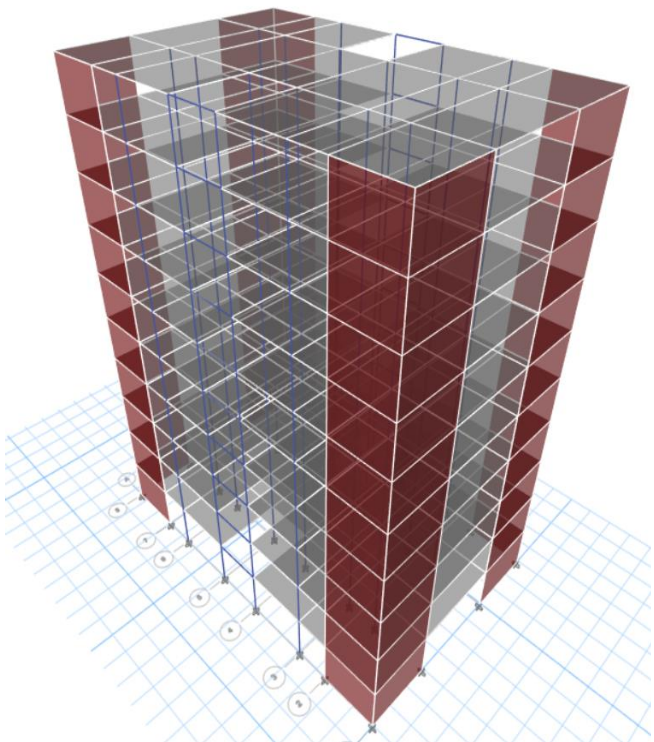

Fig -6: 3D view of building model with shear wall

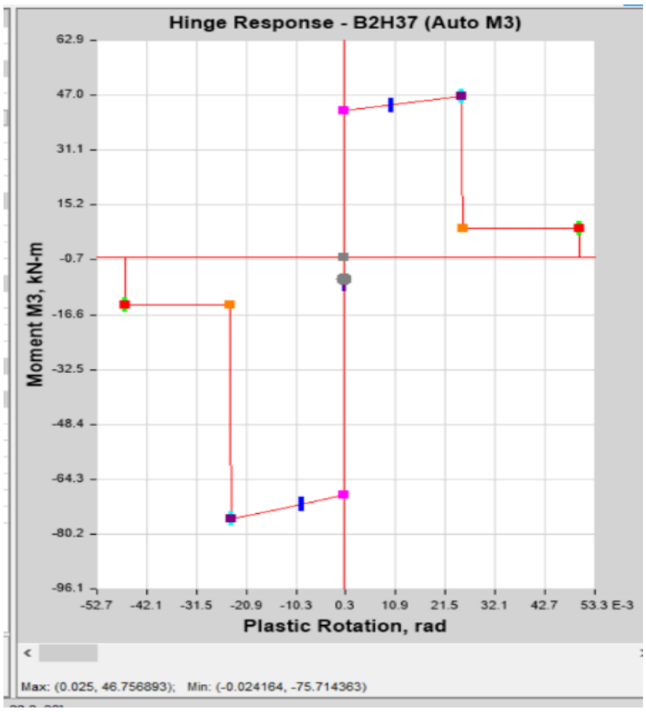

Fig -8: Hinge response

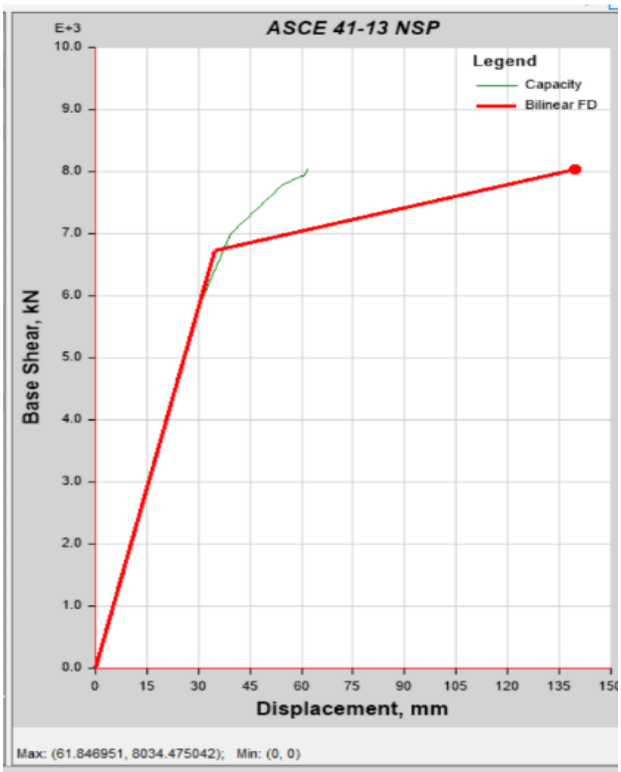

Fig -7: Pushover curve

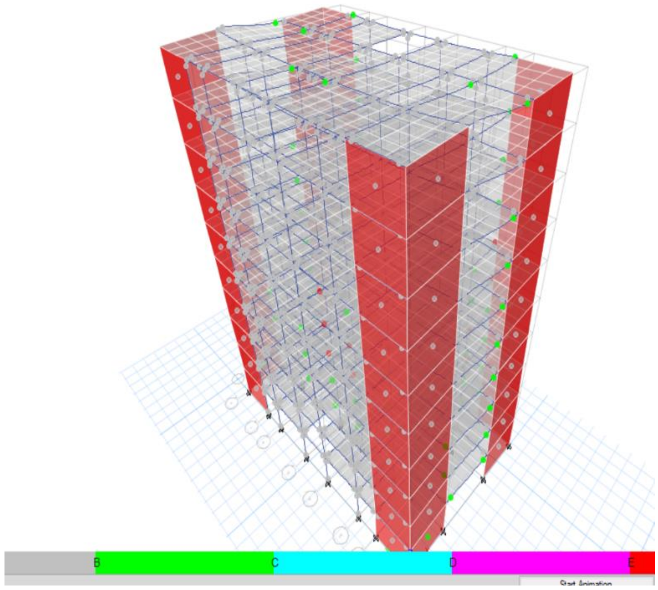

Fig -9: Hinges form on structure during pushover analysis

Table -1: Comparison of results of building models

Sr. No.	Description	Basic model	Model with Shear wall
1	Fundamental Time period (sec)	0.959	0.617
2	Maximum Displacement (mm)	17.38	14.52
3	Maximum Lateral Force (KN)	218.24	327.6
4	Maximum story drift	737	621

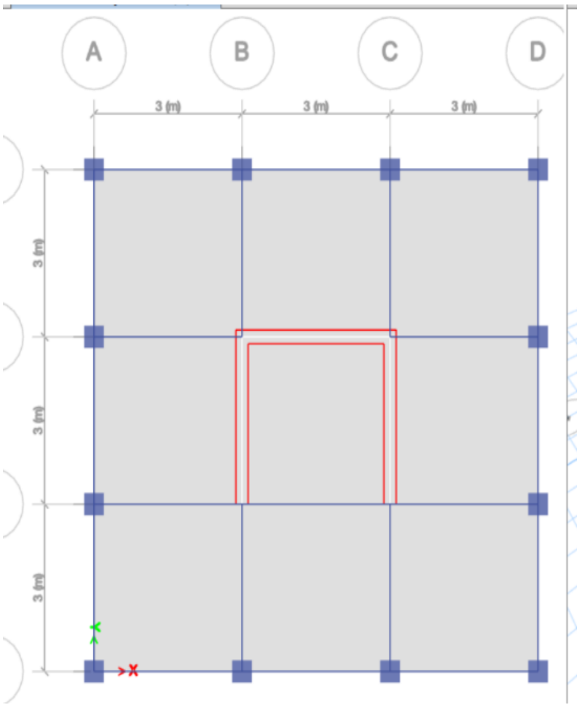

Fig -10: Plan view of model of shear wall for aspect ratio study.

The seismic analysis was carried out for shear wall model with height to length ratio from 1 to 3. The results obtained for linear and non linear analysis has been compared in the tables below.

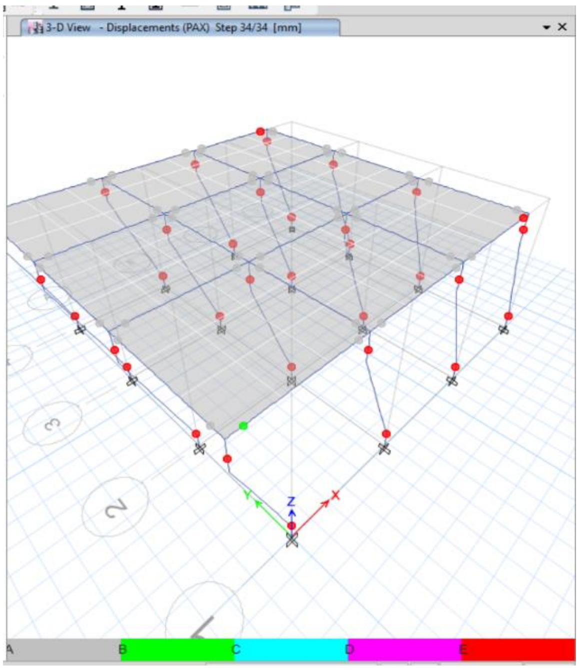

Fig -11: Hinges form on structure without shear wall for Ratio 1.5

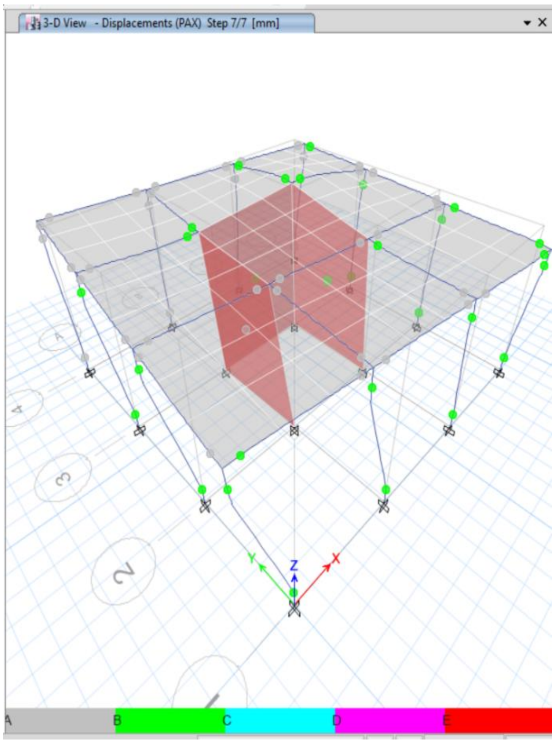

Fig -12: Hinges form on structure with shear wall for Ratio 1.5

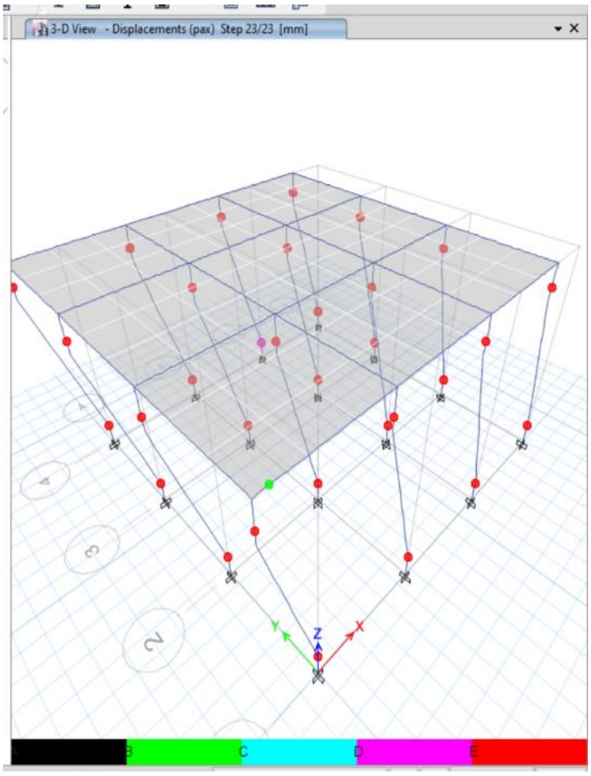

Fig -13: Hinges form on structure without shear wall for Ratio 2

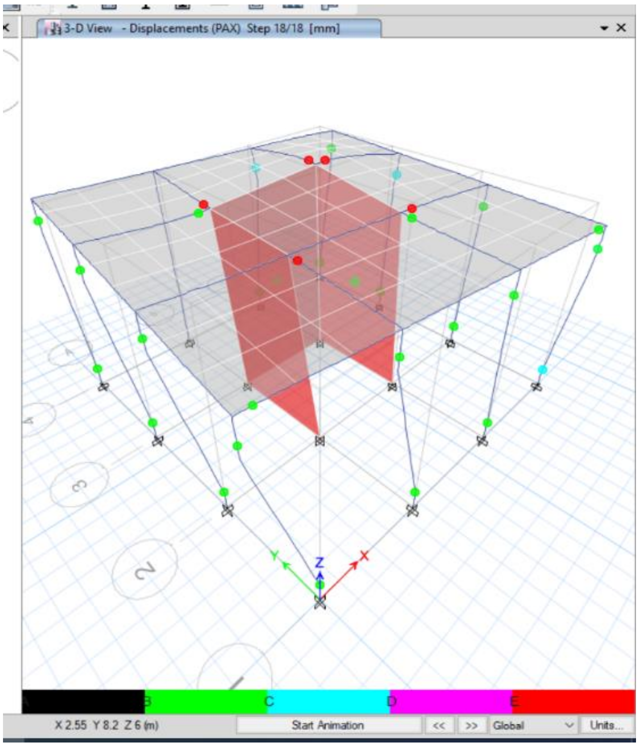

Fig 14: Hinges form on structure with shear wall for Ratio 2

Table -2: Comparison of results for models of shear wall aspect ratio 1- 2

	Ratio 1		Ratio 1.5		Ratio 2	
Description	Basic model	With Shear wall	Basic model	Model with Shear wall	Basic model	Model with Shear wall
Shear wall length	-	3 m	-	3 m	-	3 m
Shear wall height	-	3 m	-	4.5 m	-	6 m
Fundamental Time period (sec)	0.096	0.065	0.174	0.107	0.269	0.159
Maximum Displacement (mm)	0.184	0.07	0.376	0.205	0.90	0.45
Maximum Lateral Force (KN)	53.16	56.7	35.62	63.66	38.0	69.28
Maximum story drift	62	25	84	46	15	13

Table -3: Comparison of results for models of shear wall aspect ratio 2.5 - 3

	Ratio 2.5		Ratio 2.75		Ratio 3	
Description	Basic model	With Shear wall	Basic model	Model with Shear wall	Basic model	Model with Shear wall
Shear wall length	-	3 m	-	3 m	-	2.5 m
Shear wall height	-	7.5 m	-	8.25 m	-	7.5 m
Fundamental Time period (sec)	0.381	0.32	0.889	0.251	0.34	0.271
Maximum Displacement (mm)	1.806	0.86	2.44	1.138	3.22	1.46
Maximum Lateral Force (KN)	40.42	75.5	41.6	78.66	42.48	81.79
Maximum story drift	241	115	296	138	350	163

5. CONCLUSIONS

The fundamental time period for the model with the shear wall is highly reduced as compared to the basic model without shear wall.

Due to increase in the stiffness of the structure because of insertion of shear wall, the strength and capacity has been increased and hence it has attracted the more forces.

From the results obtained from the analysis it has been seen the model with shear wall, the, maximum story displacement is slightly decreased. Thus, the overall performance gets enhanced by introducing shear wall.

From the results obtained from the analysis it has been seen the model with shear wall, the, maximum load on the structure and story drift is also slightly decreased. Thus, the overall performance gets enhanced by introducing shear wall.

The shear wall placed on the corners of the building models and place at the center in the aspect ratio study both have shown the good results in terms of better resistance to seismic forces.

For each aspect ratio of the shear wall, it is seen that from the hinge form on structure that, the model with shear wall has performed better as compared to model without shear wall.

For each aspect ratio of the shear wall, it is seen that models that were at collapse level were converted to immediate occupancy level based on their hinge responses.

From the parametric study of shear wall it can be said that shear wall with ratio between 1.5 and 2 have shown better results. Hence shear wall with this ratio can be preferred as compared to small and large aspect ratio of shear walls.

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