Retrofitting of Soft Storey Building by using Different Bracing System due to Seismic Load

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Abstract— *In the present study an attempt has been made to evaluate an existing building located in seismic zone V using equivalent static analysis. Indian Standard IS-1893:2002 (Part-1) is followed for the equivalent static analysis procedure. Building is modeled in commercial software STAAD Pro. Seismic force demand for each individual member is calculated for the design base shear as required by IS-1893:2002. Corresponding member capacity is calculated as per Indian Standard IS456:2000. Deficient members are identified through demand-to-capacity ratio. A number of beams and column elements in the first floor of the present building are found to be deficient that needs retrofitting. A local retrofitting strategy is adopted to upgrade the capacity of the deficient members. This study shows that steel jacketing is an efficient way to retrofit RC members to improve flexure as well as shear capacity.*

Keywords— RETROFITT, Earthquake, Composite, Conventional, Frame, Steel, Reinforced Concrete, Structure, Multi-storey, SMRF, Framed structures, Maximum Axial Force, STAAD PRO.(V8i) series 4.

I. INTRODUCTION

The increase in urbanization for the past few years has made the vehicle parking a major concern. In order to overcome this usually we provide the first storey of the building for parking. The open ground storied structure is a structure in which the infill wall is absent at the ground storey for the purpose of parking or social gathering. According to earthquake reports the structure having open ground storey leads to complete collapse due to absence of infill wall. Distribution of strength, mass, stiffness should be consistent throughout the building both vertically and horizontally as per design philosophy of structures. Improper orientation of walls results in soft storey, weak storey and torsion effect. The severe damage can be seen on the structure due to irregularity of structures. Due to modern era of construction the buildings without open ground storey is unavoidable because there is shortage of area for parking so we have to provide some special measures on the structure to mitigate the effect of soft storey on the structure . It is very necessary to conduct an in-depth study on the nonlinear behavior of the structure so that it gives the proper response of the structure during earthquakes.

II. LITERATURE REVIEW

1. N.A. Ghate and S.P. Siddh (2018) studied various building models such as soft storey structure with shear wall, and soft storey with steel bracings at the first storey. The study includes the analysis of soft storey building with ETABS software by pushover analysis method and the results and conclusion of the analysis is to be included. There are three models- first is Infill frame with soft storey (IFSS), second one is Infill frame with .shear wall in soft storey (IFSW) and third one is Infill frame with cross bracing (IFCB). From the pushover analysis of the structural models the results for maximum base shear, maximum displacement, maximum inter-storey drift, maximum storey force, etc are analyzed. When considered base shear capacity IFSW exhibit higher base shear than other systems irrespective of number of stories. Base shear of G+9 IFSW is higher than the base shear of IFSS, IFCB. Building with shear wall at the bottom storey had higher moment when compared to other systems irrespective of the number of stories. Response reduction factor of these frames is higher than the IS code recommendations. Time period of these systems is more when comparing to IS code time period from IS 1893.

2. R. Ismail, et.al (2018) analyzed 4 models with various bracings system like V bracing, X bracing, eccentric bracing and without bracing. An investigation had been conducted to determine the lateral displacement by using SAP2000. The objectives of this paper are to determine the maximum displacement and base shear on each sort of bracing system. The outcomes were analyzed from time history analysis by various type of bracing system. The result for both maximum displacement and base shear is based on 0.05 second of peak ground acceleration. It can conclude that

model which has V bracing type is the best and effective method of bracing system for soft storey building. From the outcome acquired, it demonstrated that V bracing had the lowest value for maximum displacement compared with other models. In addition, V bracing type also showed the lowest value of base shear. Thus, it proved that V bracing type reduces the maximum displacement and base shear of the soft storey building. X-bracing can reduce lateral storey displacement, storey drift as well as axial force and bending moment in columns effectually.

3. B. Patel, et.al (2017) observed different braced buildings were studied and the seismic parameters in terms of base shear and storey displacement are compared. Also these parameters were analyzed using different types of bracing and to choose appropriate bracing configuration to resist seismic load efficiently. The STADD Pro and ETABs software's were used for modeling and to carry out the analysis. The lateral loads subjected to the buildings were considered as per Indian standard codes. Three models were prepared in which first is Moment Resisting Frame (MRF) second is RCC building with V-bracing system and third is RCC building with X- bracing system. The equivalent static load analysis was carried out using STADD ProV8i and the response spectrum analysis was carried out using ETABS. Finally the conclusions are drawn as the base shear of braced buildings increased as compared to building without bracing which indicates that the stiffness of building increases. The performance of X- bracing system has more margin of safety when compared to V-bracing system.

4. A Dharanya, et.al (2017) analyzed a G+4storey residential RC building with soft storey retrofitted with cross bracings and shear wall. This analysis was made as per IS 1893:2002 codal provision by using ETABS software. The cross bracings such as X bracing were to be provided at the outer periphery of the column and the shear walls were provided at the corners of the buildings. The building models were analyzed by equivalent stiffness method using ETABS software. That building was considered to be located at Bhuj, which is one of the high seismic area (Zone V) located in India. To improve the building's stability against lateral loading an additional structural member such as shear wall and bracings were placed in the structure and analyzed. Finally the conclusions was drawn that the natural time period of the structure has highly reduced after placing shear wall than the bracings, which will improve the stability against earthquake and make the structure more stable. The structure has a minimum lateral displacement with shear wall and bracings compared with bare frame. Structure with shear wall system has a least lateral displacement.

5. S. Kiran, et.al (2017) studied the effects of soft storey in the buildings and remedying it by using different structural arrangements, like shear walls, diagonal steel bracing and cross steel bracings. The linear dynamic analysis (response spectrum analysis) had been adopted for various symmetrical buildings such as low rise (G+6), medium rise (G+14) and high rise (G+24). The response of the models, in terms of storey drift, lateral displacement, storey shear and storey stiffness was compared for different configurations resulting that 95% decrease in term of lateral displacement for low rise 95% for medium rise and 95% for medium rise building. It was concluded that the provision of shear walls can reduce the effects of soft storey to a much greater extend. Cross steel bracings can also play an inevitable role in reducing the soft storey effect in the buildings.

III. RESULTS AND DISCUSSIONS

From above literature review it is summarized that the structure with soft storey losses greater initial stiffness and maximum strength when compared to the structure without soft storey. It was also observed that the load path from the point of application of load was not distributed properly in the structure with soft storey. The placement of shear walls can be modified to enhance the performance of building in seismic prone areas. The analysis was done for Zone III and IV, to analyze in higher seismic prone areas it can be done for Zone V.

Also it can be seen that in that shear wall could improve the lateral stability of the structure more than the bracings in a simple framed structures. The different kind of bracings are used in a model and analyzed to determine the best type of bracings which can be effectively used in structure to reduce storey drift, storey displacement etc. From above review X bracings are more effective for minimum storey displacement and also give more margin safety. As the height of the building increases, stability of the building becomes a major factor that can be achieved by using structural configurations. Also we get that the displacement reduces when the soft storey is provided in higher levels.

TABLE 1
SPECIFICATIONS OF BUILDING

S.No.	Description	Specifications
1.	Building Frame System	OMRF
2.	Ground Storey height	3.5m
3.	Typical Storey height	3.0m
4.	Type of soil	Medium (II)
5.	Support Condition	Fixed
6.	Grade of concrete	M30
7.	Grade of steel	Fe 415
8.	Live Load	3.5 kN/m2
9.	Floor Finish	1 kN/m2
10.	Infill Panel	Brick Masonry
11.	Importance factor	1
12.	Response Reduction Factor	3
13.	Column Size	600mm x 300mm
14.	Beam size	500mm x 350mm
15.	Slab Thickness	120mm
16.	Stair Slab Thickness	100mm
17.	Thickness of brick wall	230mm

TABLE 2
CONSIDERED EARTHQUAKES FOR NTHA

S.No.	Earthquake	Country	Date	Station	Hypocenter
1	Chi Chi	Taiwan	25 Sept, 1999	Tcu080	10.2 Km
2	Kobe	Japan	16 Jan, 1995	KJMA	1.0 Km
3	El Centro	USA	19 May, 1940	USGS Stn. 0117	12.2 km
4	Loma Prieta	USA	18 Oct, 1989	CSMIP Stn. 1667	65.2 Km
5	North Ridge	USA	17 Jan, 1994	CSMIP Stn. 24514	9.9 Km

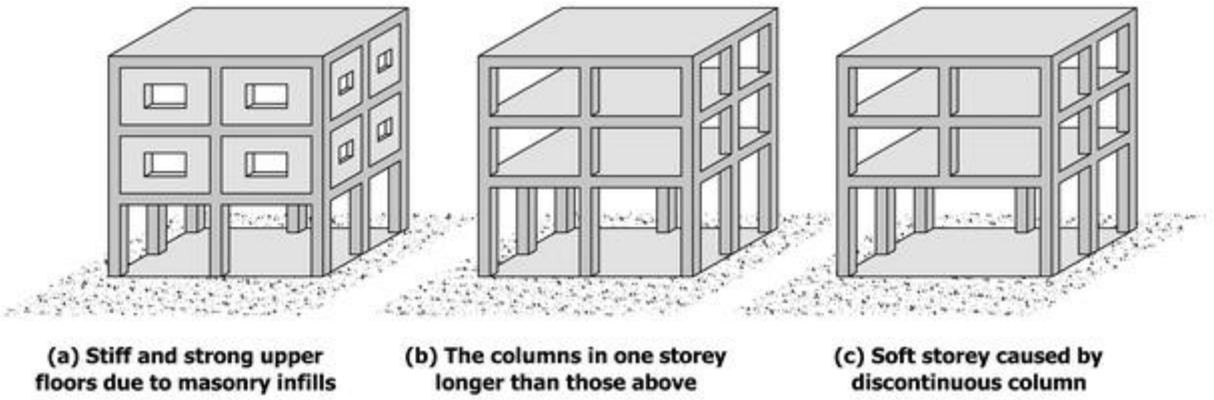

FIGURE 1: Examples of soft storey configurations

TABLE 3
SCALING OF GROUND MOTIONS (Target PGA of Zone V = 0.36 g)

S.No.	Earthquake	PGA (cm/s2)	Target PGA (cm/s2)	Scale Factor
1.	Chi Chi	527.23	353.16	0.669
2.	Kobe	805.45	353.16	0.438
3.	El Centro	341.61	353.16	1.033
4.	Loma Prieta	281.40	353.16	1.255
5.	North Ridge	826.80	353.16	0.427

TABLE 4
SPECTRAL MATCHING DETAILS AS PER 'SEISMO MATCH 2016

S No.	Earthquake	Average Misfit	Maximum Misfit	Maximum Acceleration
1.	Chi Chi	5.1 %	23.9 %	0.973 g
2.	El Centro	4.3 %	29.2 %	1.128 g
3.	Kobe	4.4 %	28.1 %	0.963 g
4.	Loma Prieta	6.5 %	21.0 %	1.084 g
5.	Northridge	3.0 %	22.8 %	1.110 g

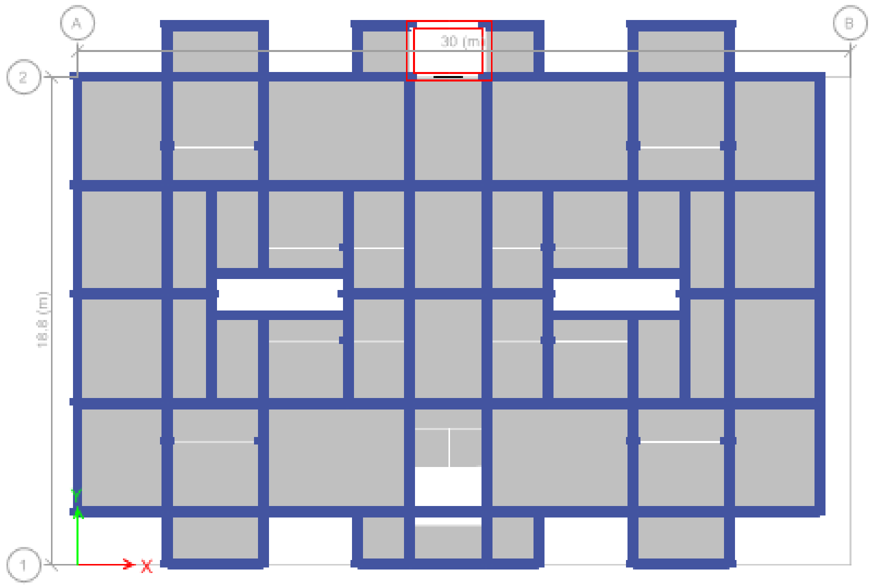

FIGURE 2: Plan of Building (ETABS)

FIGURE 3: Plan of Building (AutoCAD)

TABLE 6
OBSERVED BASE SHEAR FOR DIFFERENT MODELS.

EARTHQUAKES	BASE MODEL (KN)	CROSS BRACED MODEL (KN)	SHEAR WALL MODEL (KN)
Chi Chi	33679.8723	34043.7666	53318.8695
Kobe	40733.5333	41976.6685	56428.338
Loma Prieta	40416.8928	45461.8157	54986.9339
North Ridge	40386.7033	39459.3208	41646.0861
El Centro	40684.9721	44008.9444	54986.9339

3.1 Performance Points:

TABLE 7
PERFORMANCE POINTS OF DIFFERENT MODELS

Model	A – IO	IO- LS	LS-CP	CP-C	C - D	D - E	>E	TOTAL
Base Model	5204	12	5	15	0	0	0	5236
Cross Braced Model	5215	2	19	0	0	0	0	5236
Shear Wall Model	4564	0	0	0	0	0	0	4564

3.2 Storey Drift

A graph is plotted taking floor levels as ordinate and story drifts as abscissa for different models to compare storey drifts.

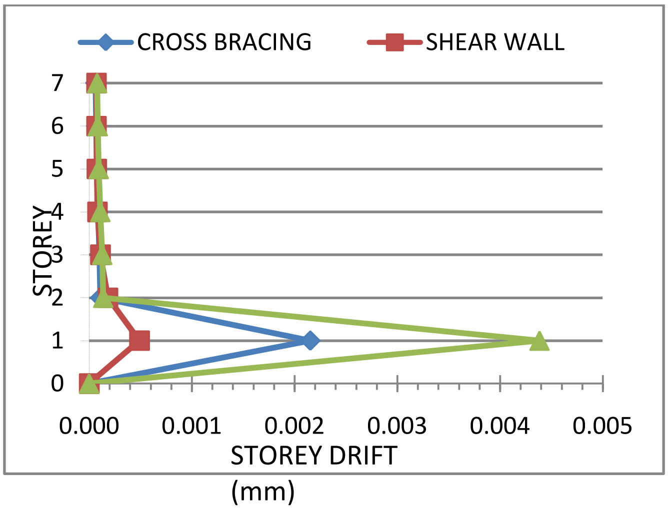

FIGURE 6.1- Observed values of Storey Drifts for Chi Chi

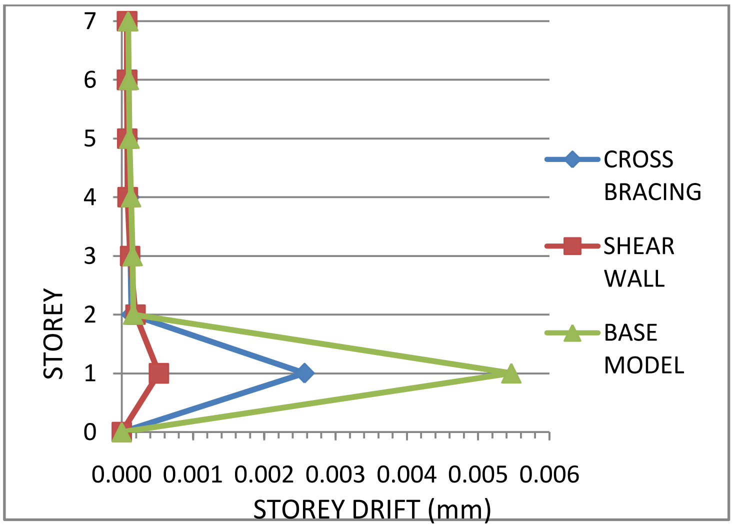

FIGURE 6.2- Observed values of Storey Drifts forkobe

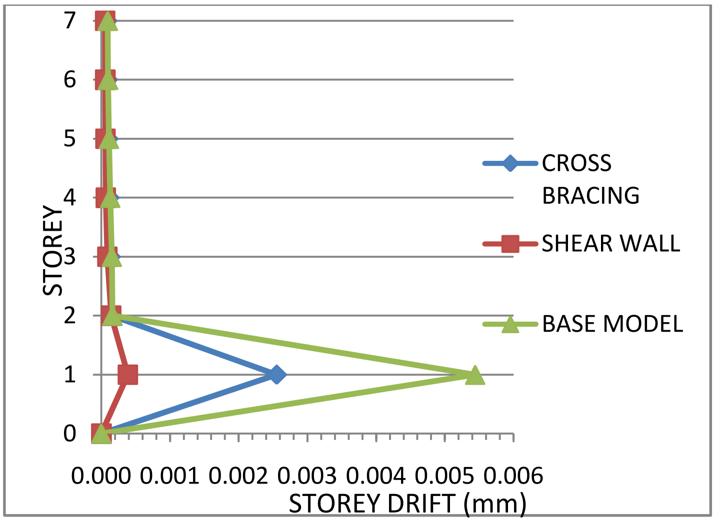

FIGURE 6.3- Observed values of Storey Drifts for El Centro

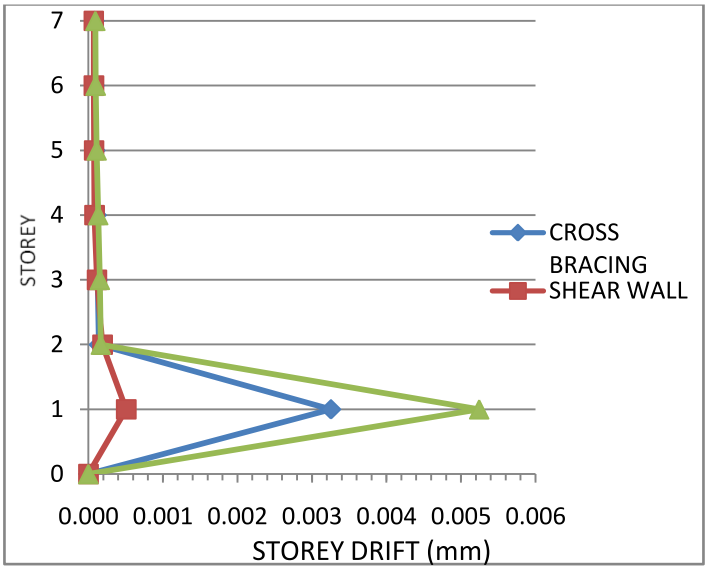

FIGURE 6.4- Observed values of Storey Drifts for Loma Prieta

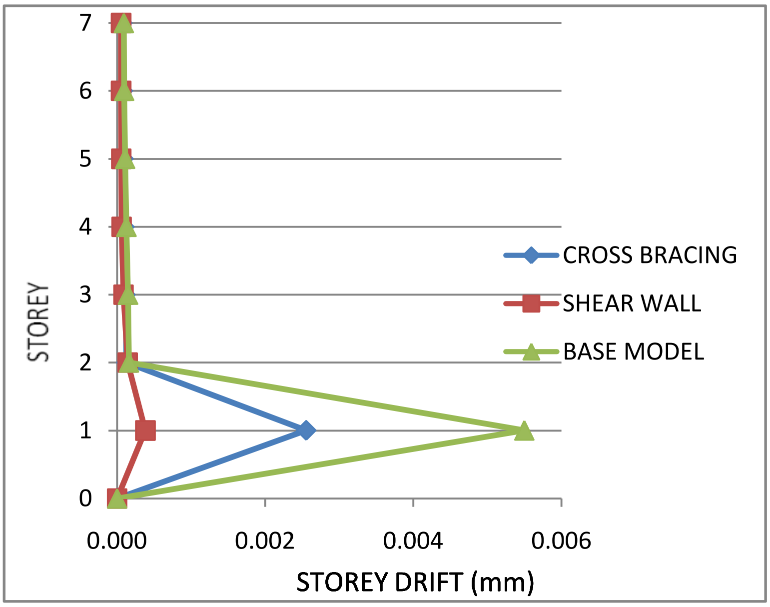

FIGURE 6.5- Observed values of Storey Drifts for North Ridge

From the above profiles it is observed that storey drift in Model I is higher than other two models and it is lesser in Model II. The abrupt change of slope of drift in first storey can be seen in graphs. That means the ductility demand for Model I is largest (27). However the storey drift curve become smoother in Model II that means large stiffness and less ductility demand(27).

3.3 Storey Displacements

A graph is plotted taking floor levels as ordinate and story displacements as abscissa for different models to compare storey displacements.

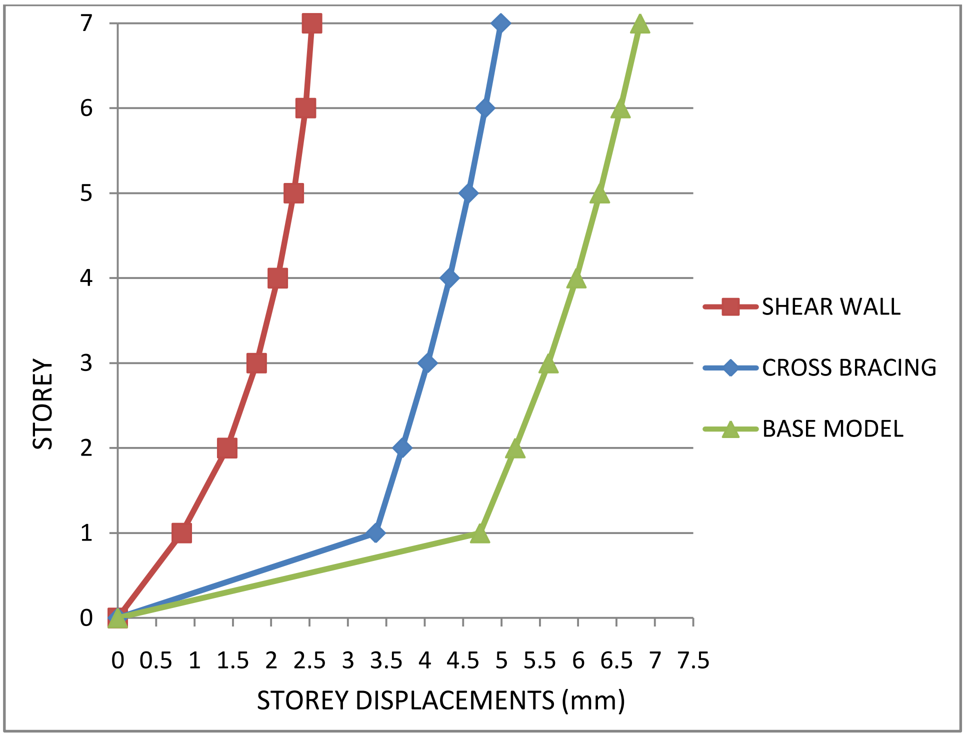

FIGURE 6.6: Observed values of Storey Displacements for Chi Chi

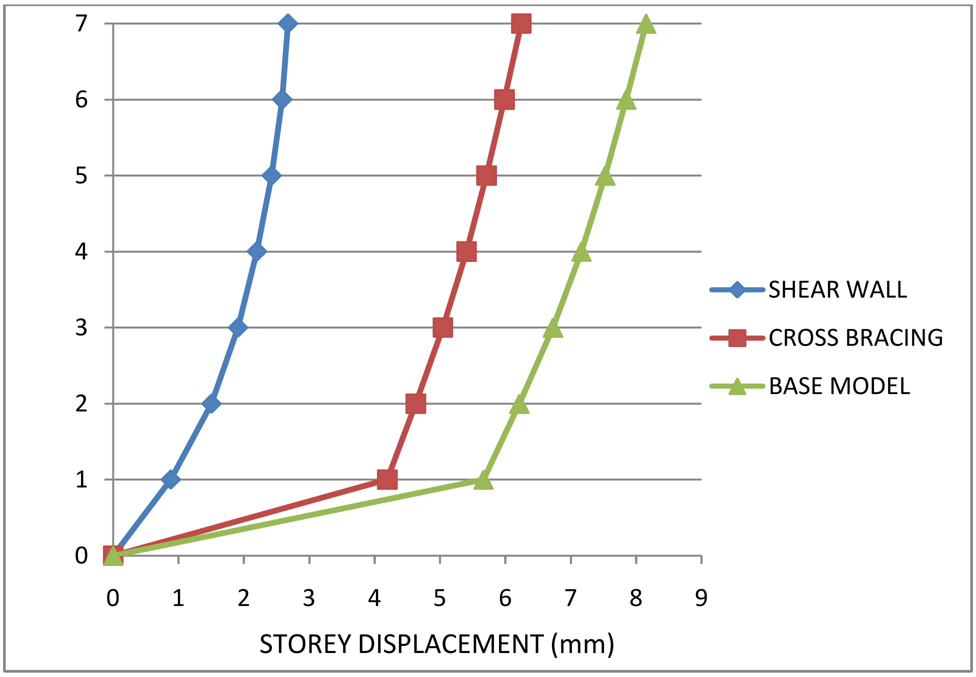

FIGURE 6.7- Observed values of Storey Displacements for Kobe

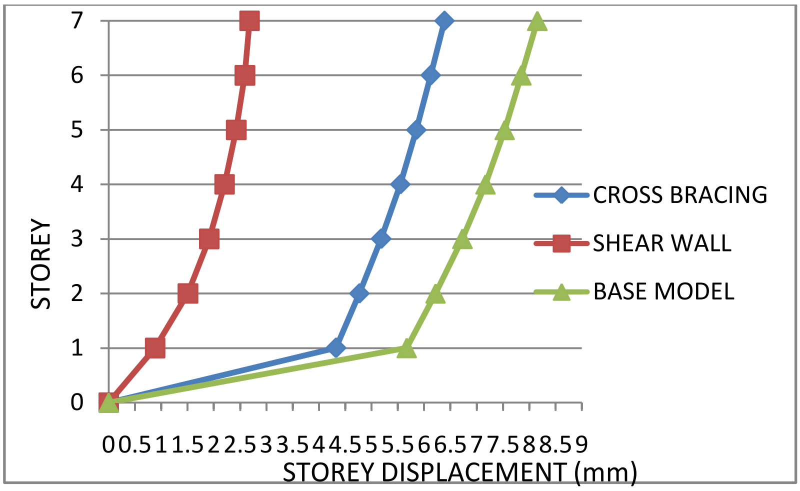

FIGURE 6.8- Observed values of Storey Displacements for El Centro

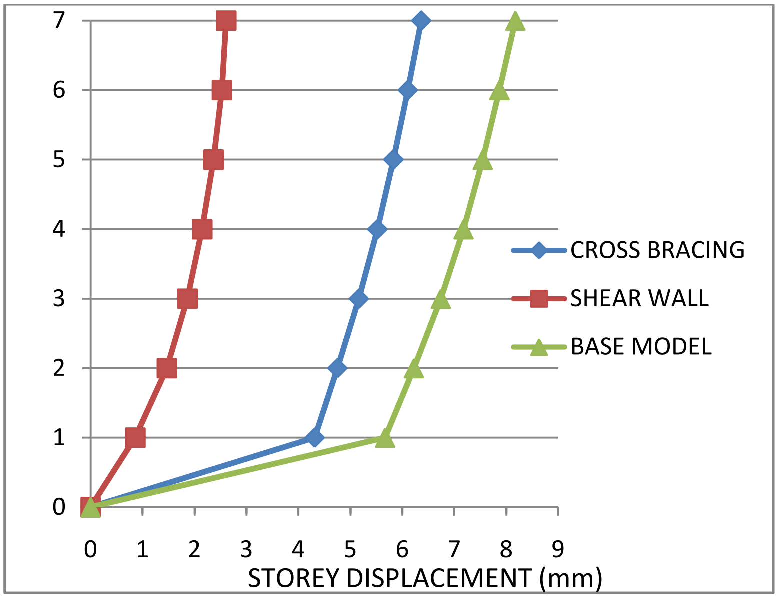

FIGURE 6.9- Observed values of Storey Displacements for Loma Preita

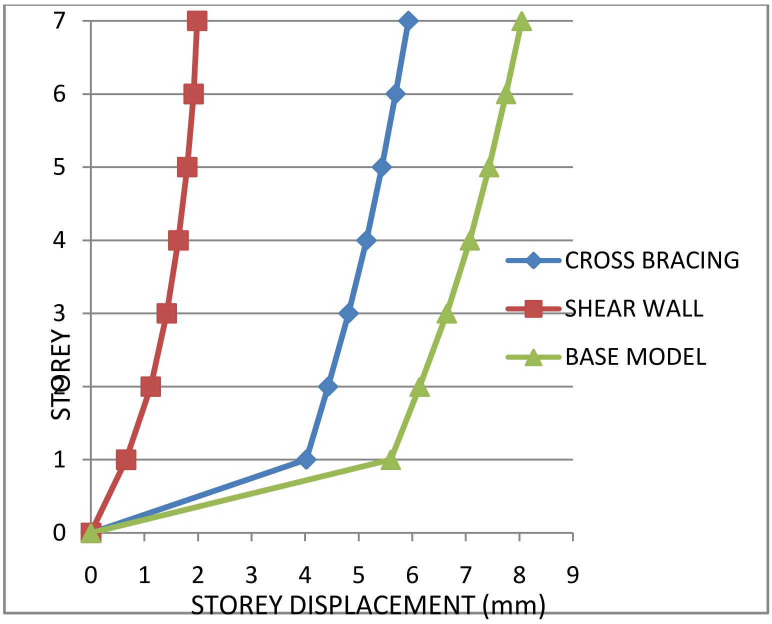

FIGURE 6.10: Observed values of Storey Displacements for North Ridge

From the above graphs it is clearly shown that the large storey displacement in case of soft storey in Model I. On the other hand if shear walls are used in the entire storey (Model II) the displacement is very small as compare to other two models. If we use shear wall in the structure then it reduces 75% displacement whereas if the cross bracings are used in the soft storey of base model then it will reduce 26% displacement.

3.4 Time Period

A graph is plotted taking modes as Yaxis and time period in X axis for all the models shown in figure below-

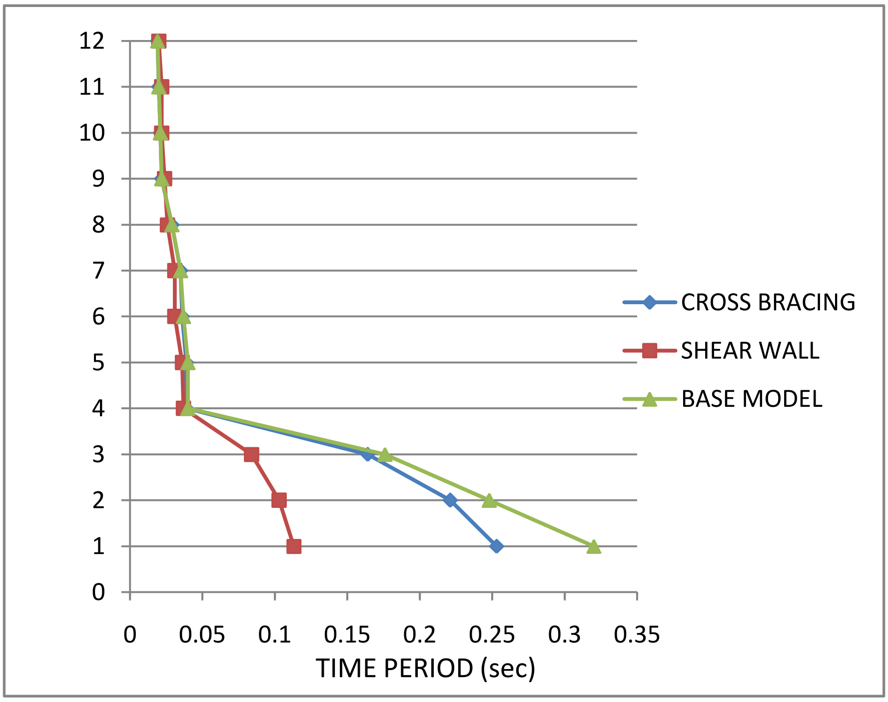

FIGURE 6.11: Comparison of time period for different modes in zone V

It is observed that the time period of vibrations for all the three models it is considerably reduced for models II and III as compared to model I. The model II having shear wall reduces time period in large extent as compare to model I and III which is base model and retrofitted with cross bracing respectively.

3.5 Base Shear

The base shear of different models are mentioned below-

TABLE 6
OBSERVED BASE SHEAR FOR DIFFERENT MODELS.

EARTHQUAKES	BASE MODEL (KN)	CROSS BRACED MODEL (KN)	SHEAR WALL MODEL (KN)
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Shear induced at the base of building during earthquake is called base shear which depends on the seismic mass and stiffness of building. Variation in base shear is as shown in table 3(a) and 3(b). It is observed that due to consideration of infill base shear has increased. Among all the different models, the building having shear wall i.e. model II has maximum base shear. Higher the base shear higher is the rigidity of the frame and more is the rigidity lesser is the displacement which can be seen in displacement graphs.(1)

3.6 Performance Points

TABLE 7
PERFORMANCE POINTS OF DIFFERENT MODELS

Model	A – IO	IO- LS	LS-CP	CP-C	C - D	D - E	>E	TOTAL
Base Model	5204	12	5	15	0	0	0	5236
Cross Braced Model	5215	2	19	0	0	0	0	5236
Shear Wall Model	4564	0	0	0	0	0	0	4564

The plastic hinges may be applied to the beams, columns and bracings to study the nonlinear behavior as they show the structural conditions at different stages. Hinges will attain a collapsible condition after passing through some intermediate stages i.e. immediate occupancy (IO) and life safety (LS) levels. The formation of maximum number of hinges in the early stage is not good for the structure as it signifies the early reaching of collapse of the structure. From Table , it is clear that the number of hinge formation in retrofitted building by shear wall is less compared to the base model and retrofitted bycross bracing, thereby making it safer.

3.7 Capacity Spectrum Curve

In the graph shown below the retrofitted model with shear wall will have a higher performance level owing to the lower spectral displacement. This performance level can be found by overlapping the capacity spectrum with the Sa vs. Sd curve of target spectrum where Sa stands for spectral acceleration and Sd stands for spectral displacement.

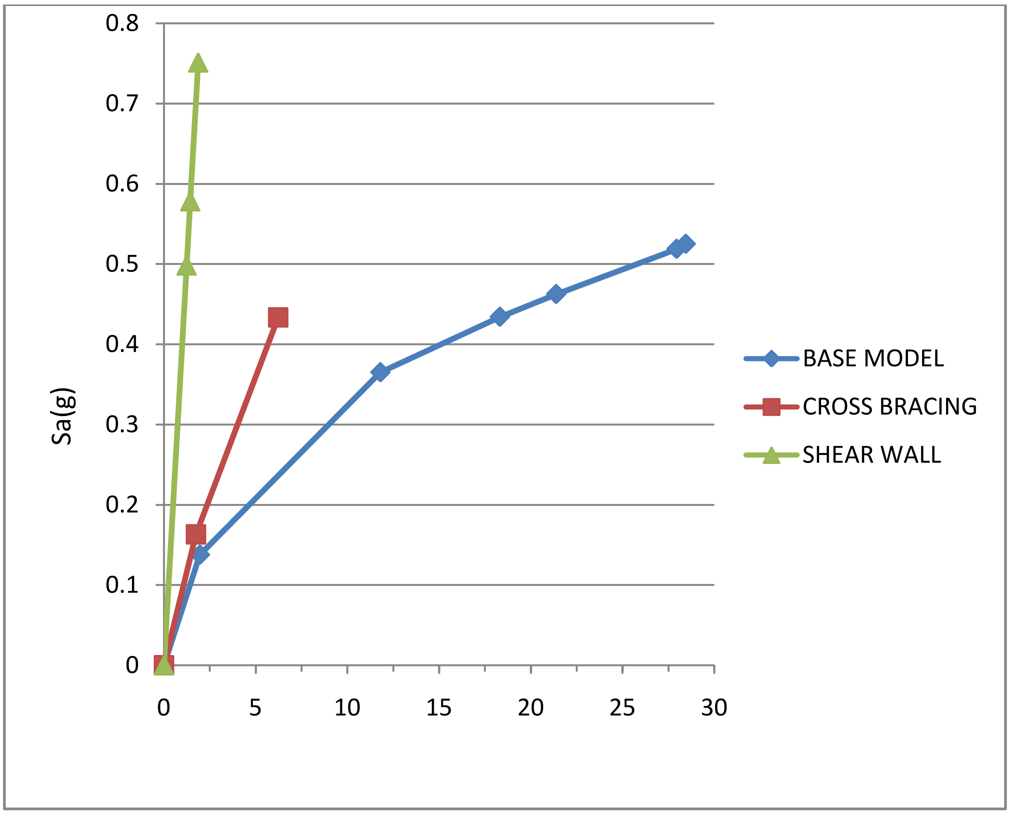

FIGURE 6.12: Capacity Spectrum

The ability of a structure to undergo inelastic deformation beyond the initial yield deformation is termed as ductility displacement. The ductility displacement demand of a given earthquake load is obtained from the pushover curve. The more the ductility displacement the more ductile is the structure. It can be clearly seen that the retrofitted building with shear wall has lesser ductility displacement.

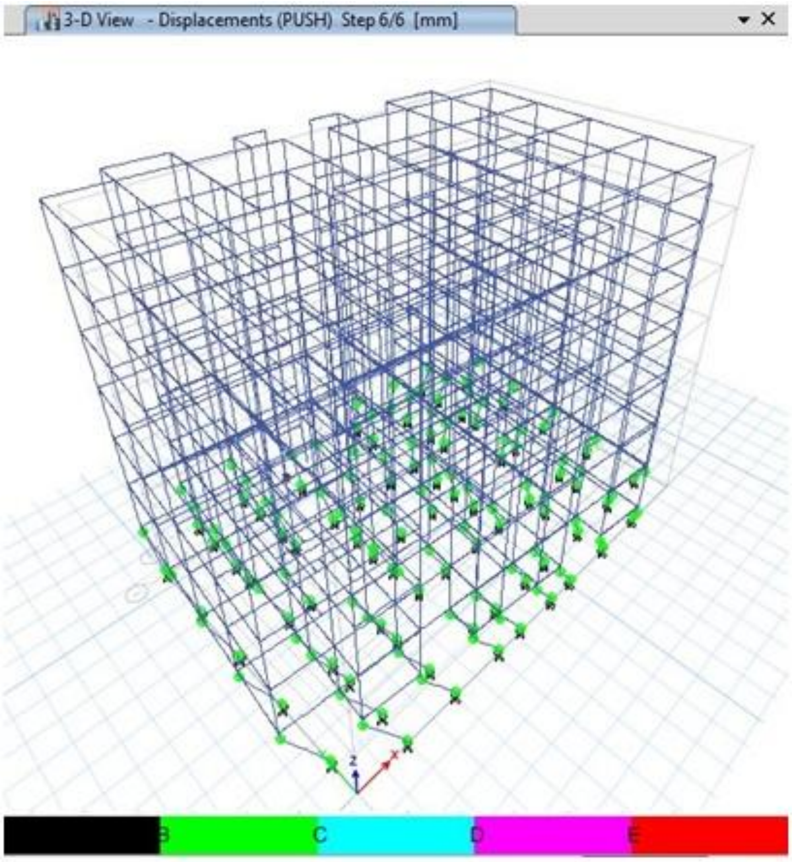

FIGURE 6.13: Hinge failure pattern for base model

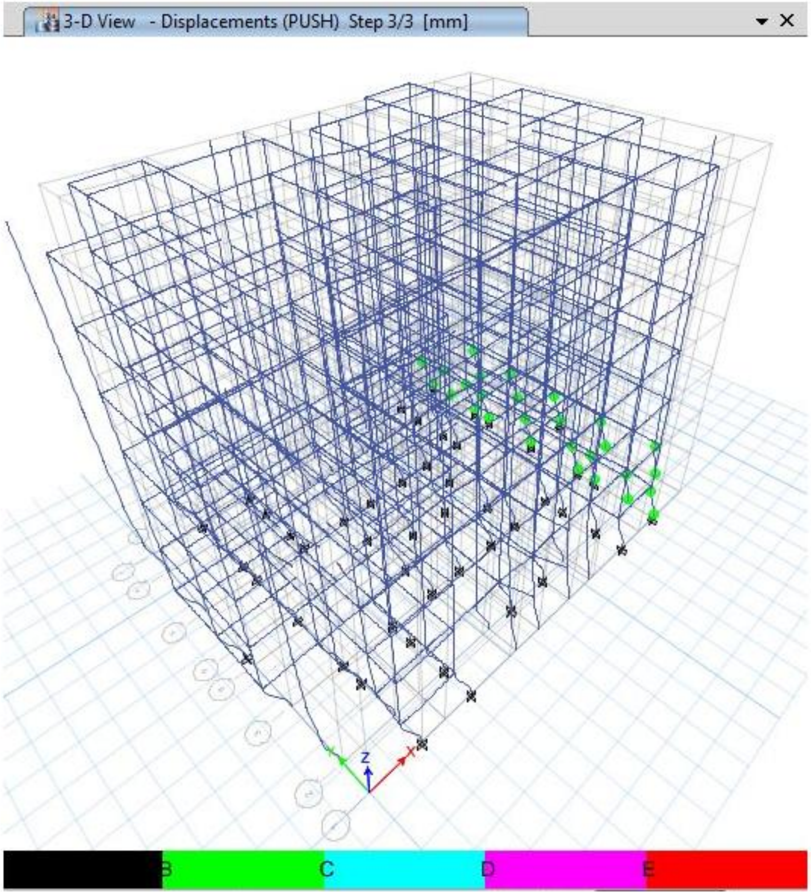

FIGURE 6.14: Hinge failure pattern for model retrofitted by shear wall

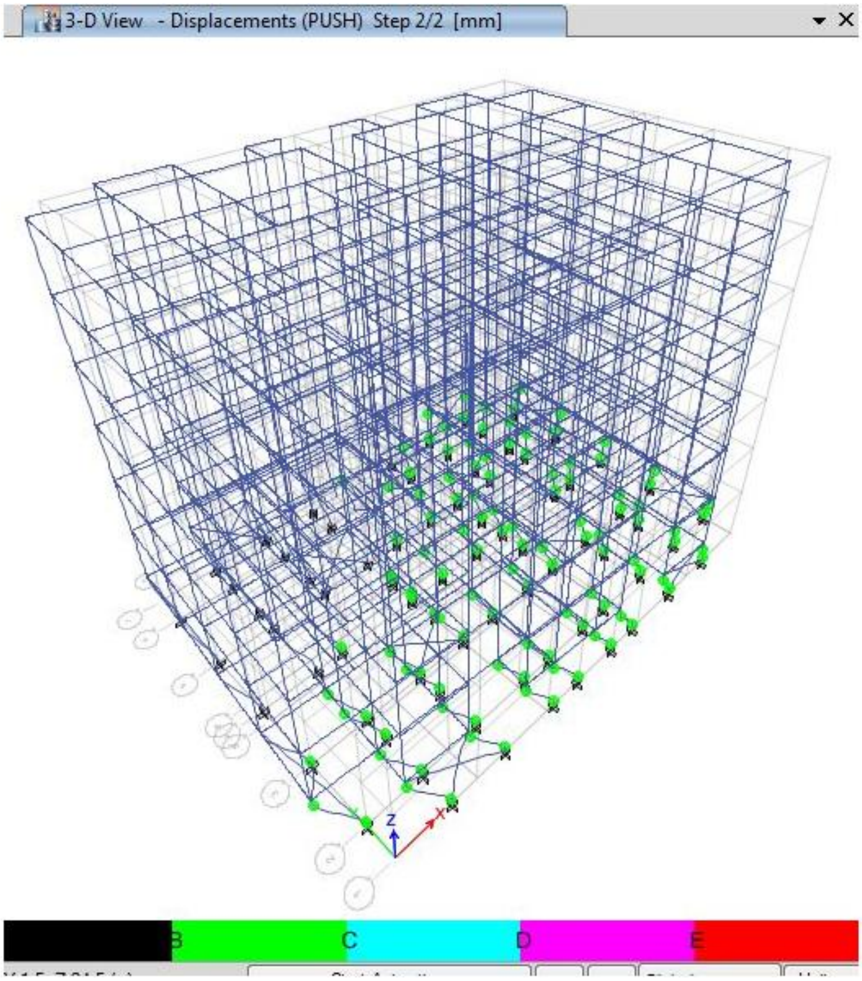

FIGURE 6.15: Hinge failure pattern for model retrofitted by cross bracing

IV. CONCLUSION

The nonlinear behavior of the structure taken as case study of Zone V (Guwahati) had been analyzed for Time History as well as Pushover Analysis. It was subjected to a suite of six different earthquakes which were scaled as per the target spectrum of Zone-V and the performance of the structure was evaluated. The storey drift, storey displacement, base shear, time period, performance points and capacity spectrum have been observed and evaluated for base model and retrofitted with shear wall and cross bracings (both in different models). The behavior of retrofitted structure with shear wall may be significantly different from what has been observed for base model and cross bracing retrofitted structure. Synthesis of the observed seismic response has led down to the following conclusions-

1. Storey drift is reduced in base model due to introduction of shear wall as compared to cross bracing in great extent.
2. Storey displacement is reduced by 75 to 80% in model II and 23 to 26% in model III as compared to model I.
3. The time period of vibrations for all the three models was analyzed. It is considerably reduced for models II and model III as compared to model I.
4. Base Shear of models were analyzed and it is clearly shown that the base shear of the structure heavily increases and makes the structure more stable against seismic action by using shear wall for retrofitting of the structure.
5. The pushover analysis highlights the performance points in different models. It is shown that the performance of base model is poor as compare to other two models. After retrofitting the base model with shear wall the hinges are not formed beyond immediate occupancy level which makes structure safer.
6. In capacity spectrum curve model II shows less ductility demand under higher acceleration.

A financial feasibility study was also carried out, taking in to consideration the cost-benefit ratio, and it can be concluded that shear wall is an effective technique of retrofitting the structure against lateral loadings.

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