

# Seismic Evaluation of Retrofitted RC Frame Building Using Shear Wall and Steel Braces

Ajeet N. Nikam<sup>1</sup>, Prof. Mayur M. More<sup>2</sup>, Prof. Satish S. Kotwal<sup>3</sup>, Prof. Manoj M More<sup>4</sup>

Assistance Executive Engineer, Central Public Work Department, Mumbai, Maharashtra, India<sup>1</sup>

Assistance Professor, Department of Civil Engineering, Bharati Vidyapeeth's College of Engineering, Kolhapur, Maharashtra, India<sup>2</sup>

Assistance Professor, Department of Civil Engineering, Bharati Vidyapeeth's College of Engineering, Kolhapur, Maharashtra, India<sup>3</sup>

Assistance Professor, Department of Civil Engineering, KIT's College of Engineering, Kolhapur, Maharashtra, India<sup>4</sup>

**ABSTRACT:** Many existing buildings lack the seismic strength and detailing requirements of IS1893:2002 and IS 13920:1993, because they are designed for only gravity loads or built prior to the implementation of these codes. In present, study two buildings 8 and 12 storied are considered. Which are designed for only gravity loads according to IS 456:2000 without ductile detailing as well as same buildings are designed as per seismic loading according to IS 1893:2002 and ductile detailing. Seismic evaluation of these buildings is carried out with nonlinear static pushover analysis using SAP 2000 software. Moreover, the performance points and performance levels of existing and retrofitting cases are determined by capacity spectrum methods from SAP 2000. Gravity designed buildings are found in LS-CP range for DBE condition whereas buildings designed for seismic loading according to IS 1893:2002 and ductile detailing are at operational (B) to immediate occupancy (IO) level. Then various retrofitting schemes viz. Steel X braces, inverted V braces, shear wall are employed only for gravity designed buildings. For retrofit of the buildings, requirement of immediate occupancy (IO) under design basis earthquake (DBE) is aimed at. The evaluation of structural over strength, the global ductility, behavior factor of retrofitted buildings is extracted from pushover curve. Idealized force-displacement capacity curve is evaluated based on the method recommended by FEMA-356 provisions. The results are compared based on performance point, yield strength, lateral stiffness, and overstrength and ductility parameters. The results show that there is no unique solution and several different schemes can be provided to give adequate performance. Most increase in the lateral strength and stiffness is related to using steel X braces and shear wall respectively.

**KEYWORDS:** seismic evaluation, performance levels, pushover, steel X bracing, shear wall.

## I. INTRODUCTION

The existing structures which are designed for gravity loading or designed as per earlier codes are seismically deficient. In traditional engineering design, the safety of a building is established on the margin of its structural capacity over the code-specified design load. In such an approach, designers usually have limited knowledge on the actual behavior of structures under extreme (i.e., failure or near failure) conditions; seldom they could determine an accurate prediction of the level of structural damage in post-yield stage. For designs governed by gravity loads, the above issue is not a major concern; but for buildings subjected to high seismic loads, however, the deformability of a structure at which it gets to keep its primary function becomes highly significant since engineers often rely on the ductility of the structure to reduce the seismic load. Thus the structural engineering community has developed a new method of analysis and design, seismic procedures that incorporate performance based structures, which is moving away from simplified linear elastic methods towards a more nonlinear technique. Recent interests in the development of performance based codes for the design or rehabilitation of buildings in seismic active areas show that an inelastic procedure commonly referred to as the pushover analysis is a viable method to assess damage vulnerability of buildings.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

The present study includes the seismic evaluation of reinforced concrete buildings which are 8 and 12 storied, and are first designed for gravity loading according to IS 456:2000 without ductile detailing. Same buildings are designed with seismic loading according to IS 1893:2002 and ductile detailing has been done in accordance with IS 13920:1993. The analysis and design is carried in SAP 2000 software. Designed buildings are evaluated using nonlinear static pushover analysis in Y direction only. For pushover analysis FEMA 356 and ATC-40 guidelines are followed. Performance point is found by using capacity spectrum method from the SAP2000 software. Since above all buildings failed to give desired target performance level that is operational (B) to immediate occupancy (IO) and they lies in life safety (LS) to collapse prevention level (CP), hence buildings need to be retrofitted. Steel X, inverted V braces and shear wall are employed as the retrofitting strategies. Shear walls are placed in exterior bay as well as interior bay and Steel X, inverted V braces are placed exterior bay only. Modeling of shear wall is confined to wide column analogy. All these retrofitting schemes are applied to both the 8 and 12 storied building. Then from push over curve idealized curve is drawn as per FEMA 356 recommendations. The various seismic parameters are extracted from pushover curves for various retrofit schemes. The results of analysis are compared in terms of seismic parameters such as performance levels, hinge formation pattern, yield strength and lateral stiffness and effectiveness of retrofitting schemes on above parameters is studied.

## II. DESCRIPTION OF BUILDINGS

The structures representing medium and high rise reinforced concrete framed buildings are considered in this study. Floor to floor height is 3.1 m and Plinth level is 1.2 m above base of footing. The Site is located in Seismic Zone IV. Buildings are resting on Type II (medium soil). Slab thickness is 150 mm. Outer and inner wall thicknesses are 230 mm and 150 mm respectively. Grade of concrete and steel are M20 and Fe 415 respectively. The Imposed load on floor is  $3\text{ kN/m}^2$  and imposed load on roof is  $1.5\text{ kN/m}^2$ . Floor finishes is  $1\text{ kN/m}^2$  and roof treatment load is  $1.5\text{ kN/m}^2$ . All buildings have similar plan dimension  $25\text{ m} \times 39\text{ m}$  as shown in figure 1.

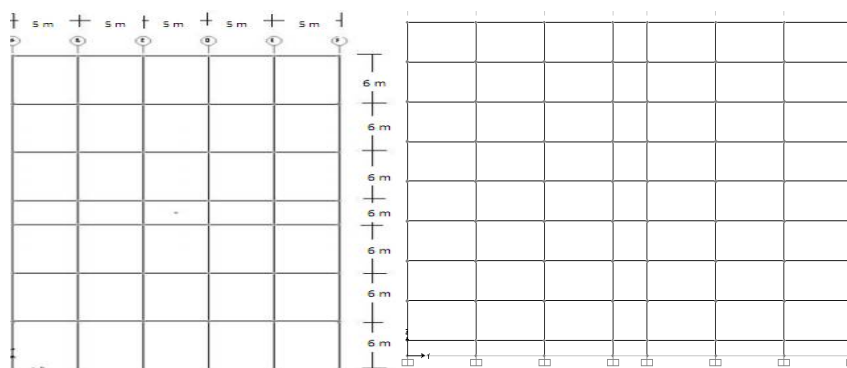


Figure 1 Plan and elevation of building

Buildings are first designed for gravity loads only as per IS 456:2002 and load combination considered is  $1.5(DL+LL)$ . For seismic design load combinations are taken from IS 1893: 2002 part 1 and ductile detailing is done by guidelines laid by IS:13920. Following load combinations are used for seismic design.

- $1.5 (DL + LL)$
- $1.2 (DL+LL \pm EQX)$
- $1.2 (DL+LL \pm EQY)$
- $1.5 (DL \pm EQX)$
- $1.5 (DL \pm EQY)$
- $0.9 DL \pm 1.5 EQX$
- $0.9 DL \pm 1.5 EQY$

The member size resulting from analysis are shown in Table 1

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Table 1. Cross section of members as per gravity load design and seismic design

Type of building	No. of Storey	Member	Sectional dimensions in mm	Description
Building designed for Gravity	8	Beams	300 x 300	Plinth beams
			300 x 400	All other beams
		Columns	450 x 450	Top four floors all columns
			500 x 500	Exterior bay columns bottom 4 floor
			600 x 600	Interior bay columns bottom 4 floor
Building designed for Earthquake loading	8	Beams	300 x 450	Plinth beams and beam spanning 3 m
			300 x 600	All other beams
		Columns	450 x 450	Top four floors all columns
			650 x 650	All other columns
Building designed for Gravity	12	Beams	300 x 300	Plinth beams
			300 x 400	All other beams
		Columns	600 x 600	Interior bay columns bottom 4 floor
			500 x 500	All exterior bay columns and top 4 floor columns <sup>2</sup>
Building designed for Earthquake loading	12	Beams	300 x 450	Plinth beams and beam spanning 3 m
			300 x 600	All other beams
		Columns	700 x 700	All bottom 4 storied columns
			600 x 600	All other columns

### III. MODELING OF BUILDINGS

The buildings are modeled in SAP 2000 software, line elements having 6 DOF per node is used for modeling beams and columns. The infill walls and the slabs are not modeled. The weight due to infill walls is uniformly distributed over beam. And the weight of the slab is considered acting on adjacent beams as per yield line pattern. The bottom of each column is assumed to be fixed so there is no soil structure interaction. The stiffness of columns and beams are shown in table no 2.

Table 2 Effective stiffness value [2]

Component	Flexure Rigidity	Shear rigidity	Axial rigidity
Beams	$0.5E_cI_g$	$0.4E_cA_w$	-
Columns with compression due design gravity loads $\leq 0.3A_gf^c$	$0.5E_cI_g$	$0.4E_cA_w$	$E_sA_s$
Columns with compression due design gravity loads $\geq 0.5A_gf^c$	$0.7 E_cI_g$	$0.4E_cA_w$	$E_cA_g$

### IV. PUSHOVER ANALYSIS OF BUILDINGS

To perform nonlinear pushover analysis a constant gravity load is first applied. As per the Indian earthquake code IS1893:2002 the constant gravity load is taken as  $DL+0.25LL$ . At the end of the gravity load analysis lateral load is applied. Lateral loads can be taken as inverted triangle, uniformly distributed load, inverted parabolic load etc. In present study lateral load is considered as inverted parabolic load.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

To incorporate nonlinear behavior of buildings nonlinear hinges are assigned at faces of column and beams. Beams are assigned with moment hinges (M3), and columns are assigned with axial load and biaxial moment (PMM) hinges. Auto hinges are provided from SAP2000.

To decide an optimum retrofitting scheme it is required to find out current performance level of the structure. Hence capacity curves also known as pushover curves are good measure to evaluate performance level of the structure. Figure 2 and figure 3 shows capacity curves for 8 and 12 storied gravity designed buildings. To model design spectrum coefficient of acceleration ( $C_a$ ) and coefficient of velocity ( $C_v$ ) are required. Seismic zone is IV and zone factor ( $Z$ ) is 0.24. The demand spectrum for design basics earthquake is obtained from peak ground acceleration (PGA) of  $(Z/2 \times g = 0.12g)$ . The soil is considered as medium soil and  $C_v = 1.36 \times Z/2$  for medium soil as per IS: 1893-2002. Therefore, the demand spectra is plotted with  $C_a = 0.12g$  and  $C_v = 1.36 \times 0.12g = 0.1632g$  for 5% damping.

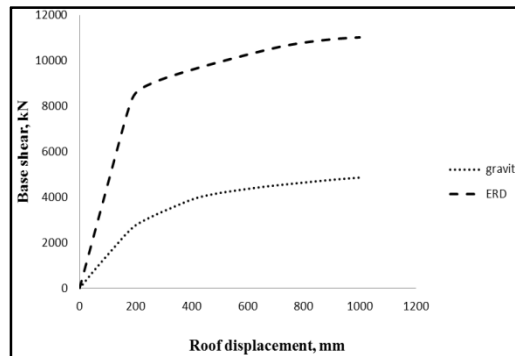
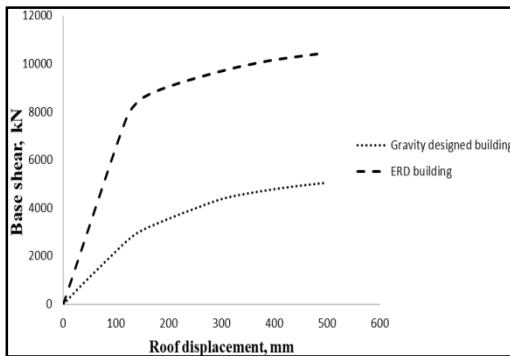


Figure.2 Capacity curves of 8 storied building in Y direction. Figure 3 Capacity curves of 12 storied building in Y direction.

Also figure 4 shows hinge formation pattern at performance point. From figure 4 and table no 3 it is clear that building designed as per IS456:2000 are seismically deficient and life safety (LS) to collapse prevention level (CP) hinges are formed in beams at middle storey level. But buildings designed as per seismic codes are atoperational (B) to immediate occupancy (IO) performance level so they do not need retrofiting.

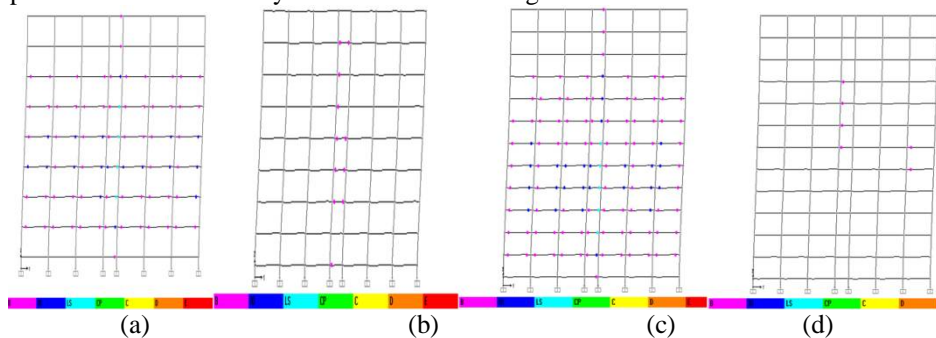


Figure1 Hinge formation at performance point (a) 8 storied gravity designed (b) 8 storied ERD (c) 12 Storied gravity designed (d) 12 storied ERD

Table 3 shows Performance point & performance level of 8 and 12 storied buildings designed for gravity loads are at LS-CP performance level where as buildings designed as per seismic codal provision are at B-IO levels.

Table 3 Performance point & performance level of 8 & 12 building

Building Type	Performance point in Y direction (V kN: D mm)	Seismic level range for DBE
8 storied gravity designed building	( 3643.64, 209)	LS-CP
8 storied ERD building	(7060, 108)	B-IO
8 storied gravity designed building	( 3335.453, 290)	LS-CP
8 storied ERD building	(7201.898, 159)	B-IO

**V. RETROFITTING OF RC BUILDING USING SHEAR WALL AND STEEL BRACES**

To study the effect of different retrofitting scheme 8 and 12 storied buildings are retrofitted by using following schemes. For seismic analysis only Y direction is considered. After retrofitting of buildings target performance level was operational (B) to immediate occupancy (IO).

Retrofit scheme-I: Steel concentric X braces are added to 8 and 12 storied gravity designed building as shown in figure 5 (a)

Retrofit scheme-II: Steel concentric inverted V braces are added to 8 and 12 storied gravity designed building as shown in figure 5 (b)

Retrofit scheme-III: Concrete shear wall extending full height of building is added to exterior bay of 8 and 12 storied gravity designed building as shown in figure 6 (a)

Retrofit scheme-IV: Same concrete shear wall extending full height of building is added to interior bay of 8 and 12 storied gravity designed building as shown in figure 6 (b)

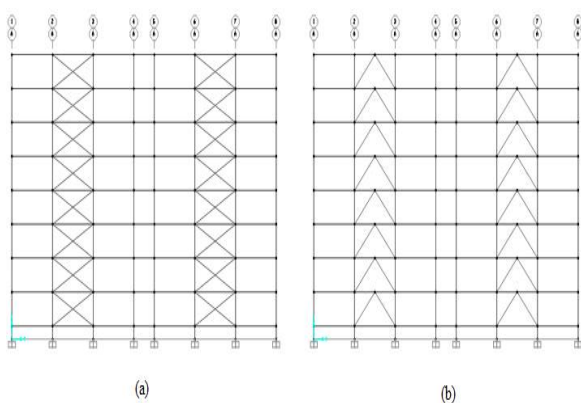


Figure 5 (a) Scheme I- Steel X braces  
(b) Scheme -II- inverted V braces

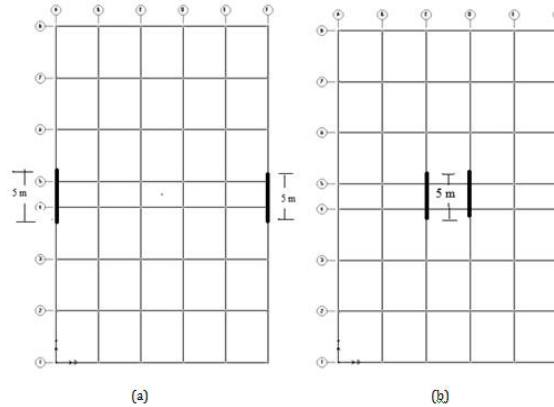


Figure 6 (a) Scheme III - shear wall outer  
(b) Scheme IV- shear wall inner

**VI. MODELING AND DESIGN OF STEEL BRACES AND SHEAR WALL**

In present study all the retrofitting schemes are designed to resist the base shear for DBE level earthquake according to IS 1893 part 1 as a first trial, and then trial and error method is adopted to bring the structural performance level within IO range. Braces are modeled as truss element having pin joints at both the ends. Brace members are selected as round hollow section both for concentric X and inverted V braces with modulus of elasticity  $E = 200,000$  MPa and  $f_y = 350$  MPa. Based on following method final section for 8 storied building retrofitted with X braces and inverted V braces are shown in Table 4 and table 5.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Table 4 Sectional properties of concentric X braces for 8 storied building.

Storey	Sections(diameter in mm, thickness in mm)
1	130,10
2,3	130,5
4,5	125,5
6	100,5
7,8	90,5

Table 5 Sectional properties of concentric inverted V braces for 8 storied building

Storey	Sections(diameter in mm, thickness in mm)
1	130,8
2,3	145,8
4,5	140,8
6	130,8
7	110,6
8	100,5

Since all shear walls in the building are slender with wall height-to-length ratio well above 3 and therefore seismic response of the shear walls is expected to be dominated by flexure. The shear walls are modeled as equivalent frame elements.

Modeling is carried out as per assumption in the wide column frame analogy. Shear wall is represented by line element (center line of shear wall) and rigid beam as line element (center line of beam). In order to provide connectivity between walls and frames, the rigid beams are connected at each floor level. Rigid beam is defined with rigid material and shear wall with concrete. The modulus of elasticity of rigid beam is taken 1000 times more than concrete. The modeling of shear wall is shown in figure 7.

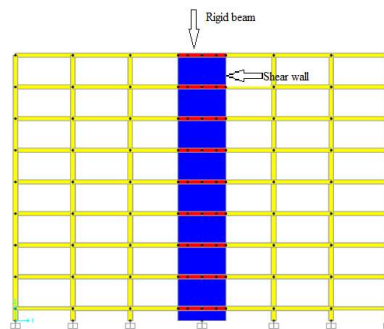


Figure 7 Modeling of shear wall by equivalent frame method

In order to model nonlinear behavior in structure, nonlinear hinges are assigned to shear wall and steel braces. User defined hinges are assigned to shear wall. Properties of hinges are taken from FEMA 356. Typically PMM-interaction hinges are assigned to shear wall ends, near floor levels, and shear hinges are assigned at mid height level of shear wall. In case of steel braces axial hinges are assigned at the ends.

## VII. DISCUSSION AND SUMMARY OF RESULTS

Figure no 8 to figure no 15 shows Capacity curve and Performance points of gravity designed buildings and retrofitted buildings for various retrofitting schemes. From graph it can be concluded that buildings which were designed for gravity loads are lagging in carrying base share and also their displacement at performance points is high as compared

to same building when it is retrofitted. After retrofitting not only base shear carrying capacity of building is increased but also displacement at performance point is also reduces.

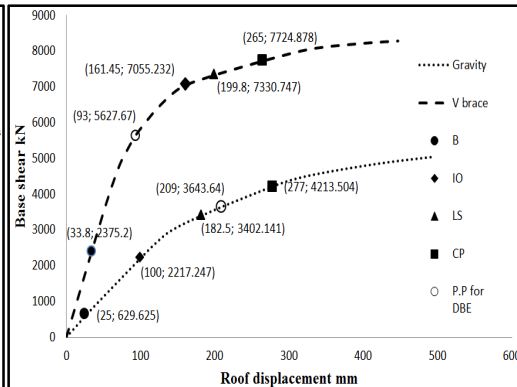
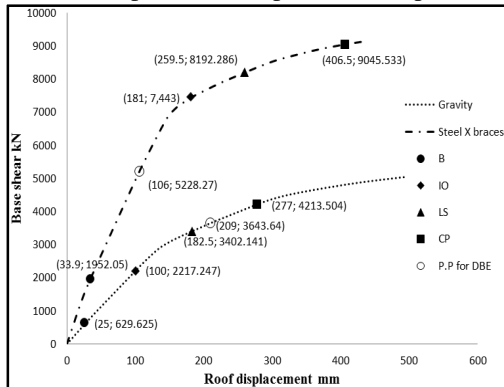


Figure 8 Capacity curve and Performance points for 8 storied gravity building and retrofitting with scheme I

Figure 9 Capacity curve and Performance points for 8 storied gravity building and retrofitting with scheme II

8 storied gravity building and retrofitting with scheme I for 8 storied gravity building and retrofitting with scheme II

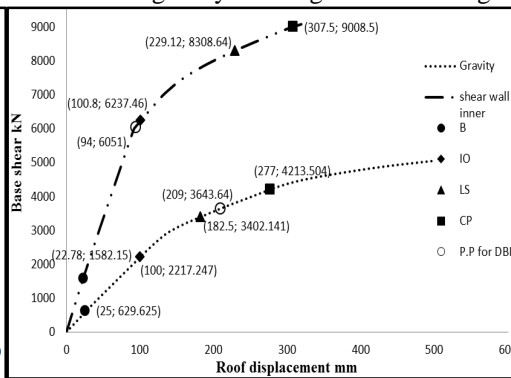
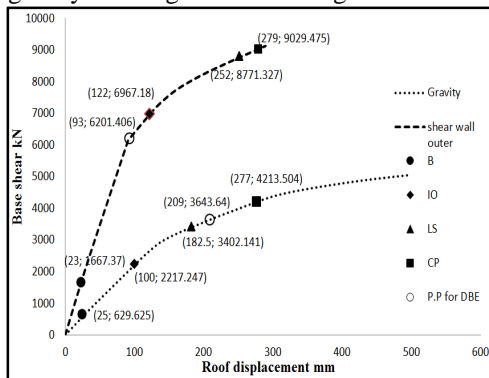


Figure 10 Capacity curve and Performance points for 8 storied gravity building and retrofitting with scheme III

Figure 11 Capacity curve and Performance points for 8 storied gravity building and retrofitting with scheme IV

8 storied gravity building and retrofitting with scheme III 8 storied gravity building and retrofitting with scheme IV

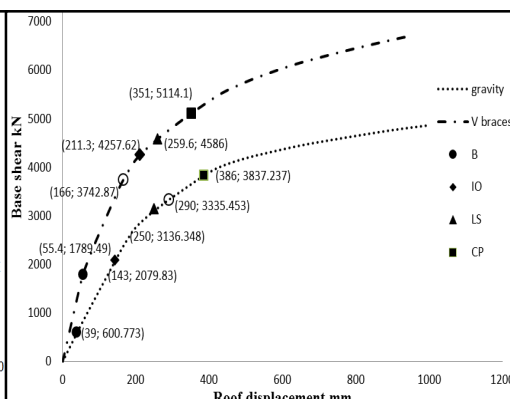
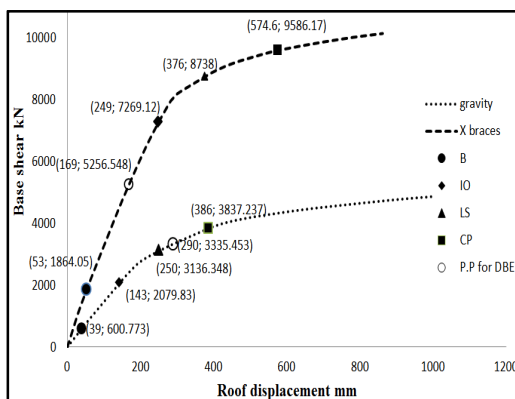


Figure 12 Capacity curve and Performance points for 12 storied gravity building and retrofitting with scheme I

Figure 13 Capacity curve and Performance points for 12 storied gravity building and retrofitting with scheme II

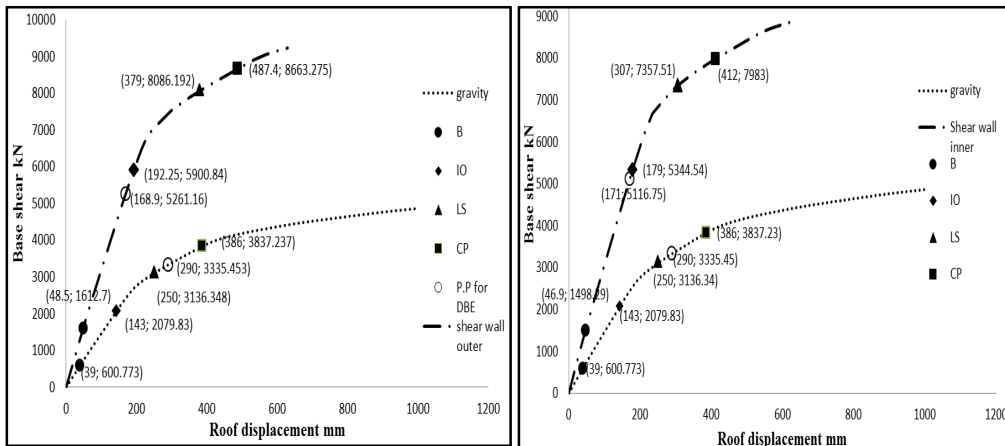


Figure 14 Capacity curve and Performance points for 12 storied gravity building and retrofitting with scheme III  
Figure 15 Capacity curve and Performance points for 12 storied gravity building and retrofitting with scheme IV

Figure 16 and figure 17 shows hinge formation at performance points of scheme I to IV. It is observed that most of the steel braces fail in compression because of buckling at performance point, but if stronger braces are used; failure mechanism is transferred to column. In case of shear wall, beams which are connected to the shear walls suffered to more damage.

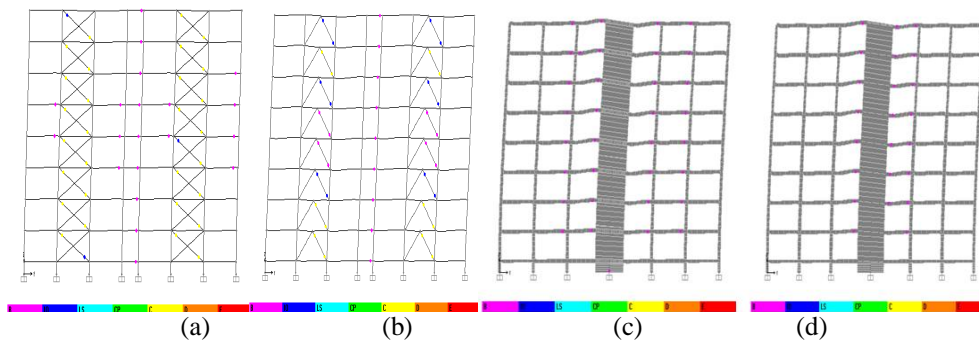


Figure 16 Hinge formation at performance point of 8 storied retrofitted building (a) Scheme I (b) Scheme II (c) Scheme III (d) Scheme IV

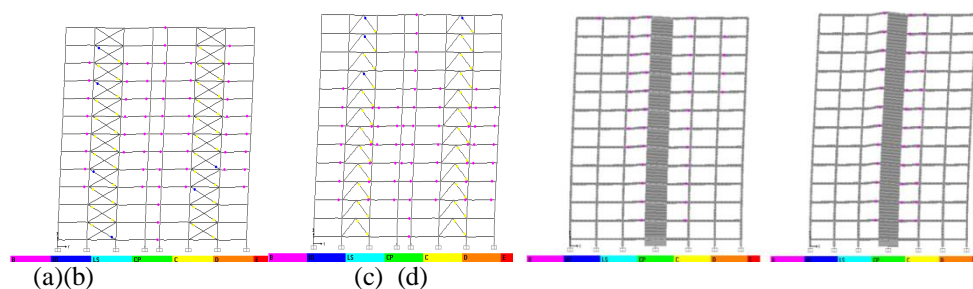


Figure 17 Hinge formation at performance point of 12 storied retrofitted building (a) Scheme I (b) Scheme II (c) Scheme III (d) Scheme IV



## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

### VIII. VIII EVALUATION OF GLOBAL PERFORMANCE CHARACTERISTIC OF STRUCTURE

The nonlinear force displacement relationship between base shear and roof displacement of retrofitted building is replaced with idealized bilinear relationship to calculate the different seismic parameters. Different seismic parameters for 8 and 12 storied retrofitted schemes are tabulated in table 6 and table 7

Table 6 Seismic parameters for 8 storied gravity building retrofitted with different schemes

Seismic Parameters	Scheme I	Scheme II	Scheme III	Scheme IV
Time period for cracked section(T sec)	1.76	1.68	1.50	1.49
Effective lateral stiffness(KekN/mm)	49.83	69.63	71.21	68.18
Post yield stiffness( $\alpha$ KekN/mm)	6.84	5.375	12.17	10.62
Idealized Yield strength( VykN)	7325	6615	6765	6750
Strength at LC condition(VtkN)	8988.07	8200.64	9144.85	9089.51
1st significant Yield strength(VskN)	1952.05	2375.2	1667.37	1582.15
Target Displacement( $\Delta_{max}$ mm)	390	390	290.631	319.204
Yield Displacement( $\Delta_y$ mm )	147	95	95	99
Structure Ductility ( $\mu$ )	2.65	4.10	3.06	3.22
Ductility Reduction Factor ( $R_\mu$ )	2.65	4.10	3.06	3.22
Strength Reduction factor ( $\Omega_d$ )	3.75	2.79	4.05	4.26
Behaviour Factor (R)	9.94	11.43	12.41	13.75

Table 7 Seismic parameters for 12 storied gravity building retrofitted with different schemes

Seismic Parameters	Scheme I	Scheme II	Scheme III	Scheme IV
Time period(T sec)	2.27	3.02	2.71	2.71
Effective lateral stiffness(KekN/mm)	32.86	27.33	32.62	31.26
Post yield stiffness( $\alpha$ KekN/mm)	5.58	4.41	6.13	5.68
Idealized Yield strength( VykN)	7690.00	4100.00	6850.00	6690.00
Strength at LC condition(VtkN)	9581.80	5967.24	9070.55	8726.10
1st significant Yield strength(VskN)	1864.05	1789.49	1612.70	1498.29
Target Displacement( $\Delta_{max}$ mm)	573.00	573.00	572.50	572.36
Yield Displacement( $\Delta_y$ mm )	234.00	150.00	210.00	214.00
Structure Ductility ( $\mu$ )	2.45	3.82	2.73	2.67
Ductility Reduction Factor ( $R_\mu$ )	2.45	3.82	2.73	2.67
Strength Reduction factor ( $\Omega_d$ )	4.13	2.29	4.25	4.47
Behavior Factor (R)	10.10	8.75	11.58	11.94

After retrofitting Both 8 and 12 storied gravity designed building significant improvement in the seismic performance of gravity designed building is observed when retrofitting schemes are used. However all strengthening schemes are able to provide the same target level. The results of nonlinear static pushover analysis shows that building retrofitted with schemes I to IV provided targeted performance level of IO. Table no 8 comparison of Ratio of initial stiffness and yield strength it is observed that for 8 storied building Ratio of initial stiffness is maximum for scheme III and yield strength (kN) are maximum for scheme I. Whereas for 12 storied building Ratio of initial stiffness and yield strength (kN) are maximum for scheme.

Table 8 Comparison of Ratio of initial stiffness and yield strength

Parameters	8 storied building			
	Scheme I	Scheme II	Scheme III	Scheme IV
Ratio of initial stiffness	2.17	3.03	3.12	2.98
Increase in yield strength (kN)	4000	3290	3440	3425
Parameters	12 storied building			
	Scheme I	Scheme II	Scheme III	Scheme IV
Ratio of initial stiffness	2.17	1.80	2.15	2.06
Increase in yield strength (kN)	4540.00	950.00	3700.00	3540.00

Figure 18 and figure 19 show capacity curves for 8 and 12 storied buildings respectively from curves it can be seen that roof displacement at performance point is higher for gravity building whereas it is lower for ERD building for both 8 and 12 storied building. Base share value is lower for gravity building at performance point where as it is higher for ERD 8 and 12 storied buildings.

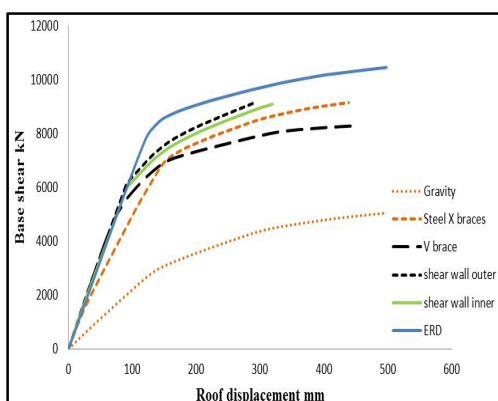


Figure 18 Comparison of various capacity curves of 8 storied building

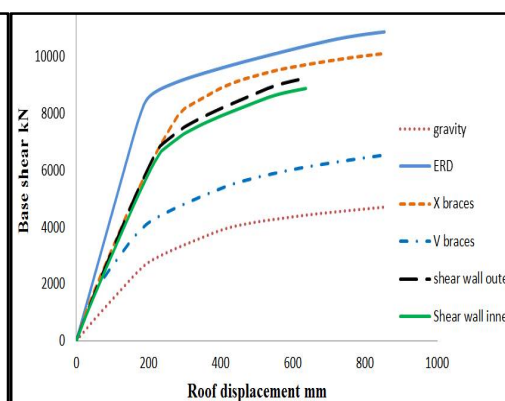


Figure 19 Comparison of various capacity curves of 12 storied building

### IX. CONCLUSIONS

Assessment of the performance levels of gravity designed buildings shows that they are seismically deficient and found at LS-CP level. As a result different strengthening schemes are used and all these different strategies are aimed at providing IO level for DBE condition. Based on same following conclusions are drawn:

- I. Gravity designed buildings are found in LS-CP range for DBE condition whereas buildings designed for seismic loading according to IS 1893:2002 and ductile detailing are at operational (B) to immediate occupancy (IO) level.
- II. Comparison between three strengthening strategies shows that most increase in the lateral strength is related to using steel X braces and is about 2.2 and 2.4 times to that of 8 and 12 storied gravity designed building respectively.
- III. With regards to the performance levels of buildings, the best strengthening system is adding X braces, however all the strengthening system improved the performance level to immediate occupancy (IO).
- IV. Comparison between three strengthening strategies shows that most increase in the stiffness is related to using shear wall and is about 3.12 and 2.15 times to that of 8 and 12 storied deficient building respectively.
- V. A number of different strengthening systems can be adopted to improve the seismic performance of gravity designed building. The performance of particular retrofitting strategies depends upon the structural properties of

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

original gravity designed building. In this case shear wall placed in inner bay, improved the performance to desired level but interconnecting beams with shear wall may need local retrofitting strategy to give better performance since they are very near to LS performance level.

- VI. Provision of shear wall on outer frame is more effective than provision on inner frames.
- VII. In case of 8 storied building slightly increase in yield strength observed but lateral stiffness increases around 14.3% .for 12 storied increase in lateral stiffness is not significant.
- VIII. The seismic behavior of buildings designed as per IS 1893 part 1 and detailed with IS 13920 is superior when compared with gravity load designed buildings. Plastic hinges are formed first in the beams. They exhibit higher ductility than gravity designed buildings.
- IX. Comparing the seismic performance of shear wall, X and inverted V braced retrofitted building, it is concluded that all retrofitting schemes have comparable abilities to increase the ductility reduction factor and the over-strength factor; inverted V brace have better ductility reduction factor and shear wall have better overstrength.

### REFERANCES

- [1] Applied Technology Council 40 (ATC40), "Seismic evaluation and retrofit of concrete buildings", Vol.1 & 2, Applied Technology Council, Redwood City, CA, USA, Report No.SSC 96-01,1996.
- [2] FEMA 356, "Prestandard and commentary for the seismic rehabilitation of buildings" American society of civil engineers, Reston, Virginia, Nov.2000.
- [3] SAP2000 V14.2.4, "Integrated finite element analysis and design of structures basic analysis reference manual", Berkeley, CA, USA: Computers and structures INC, Aug. 2010.
- [4] AgarwalPankaj and Shrikhande Manish, "Earthquake resistance design of structures", PHI learning private limited, pp.524-555, 2006.
- [5] IS 13920,"Ductile detailing of reinforced concrete structures subjected to seismic forces- Code of practice". (1993). Bureau of indian standards,New Delhi.
- [6] IS 1893 (part1):2002, "Indian standard criteria for earthquake resistant design of the structures-code of practice". Bureau of indian standards,New delhi.
- [7] IS 456:2000,"Indian standard plain and reinforced concrete- code of practice". Bureau of Indian standards,New delhi.
- [8] Paul Gopen and AgarwalPankaj, "Experimental verification of seismic evaluation of RC frame building designed as per previous IS codes before and after retrofitting by using steel bracing", Asian Journal of Civil Engineering (Building and Housing) Vol. 13, 2011.
- [9] Viswanath K.G, Prakash K.B., Anant Desai, "Seismic analysis of steel braced reinforced concrete frames", International journal of civil and structural engineering, Volume 1, No 1, Research article ISSN 0976 – 4399, pp-114-122, 2010.
- [10] Prof.Y.PPawar, RanjitV.Survey and Prof.M.M.More,"Use of RC shear walls in strengthening of multistoried building with soft storey at different level", international journal of engineering research-online, volume 3,issue 02,pp.464-468,2015.