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Seismic study of X braced, zipper braced and strong back system in RCC, steel and composite structures

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Abstract— Steel braced frame is one of the structural systems used to resist earthquake loads in multistoried buildings. Many existing reinforced concrete buildings need retrofit to overcome deficiencies to resist seismic loads. The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In the present study, the seismic study of conventional X brace, zipper brace and SBS in RCC, steel and composite structures using ETABS software is investigated. The bracing is provided at each corner. A G+6, G+12 and G+18 story with 6 bay in X direction and 3 bay in Y direction is analyzed using ETABS.. The effectiveness of various types of steel bracing is examined. The effect of the distribution of the steel bracing along the height of the steel structure on the seismic performance of the rehabilitated building is studied. Provision of conventional X braced, zipper braced and SBS is provided in each stories. The percentage reduction in lateral displacement is found out. It is found that the zipper of steel bracing significantly contributes to the reduction in displacement and SBS contributes in the reduction of story shear compared to conventional X bracings in steel and composite structures whereas both reduction in displacement and base shear is found out for SBS braced in case of RCC structures. It is also found that when the SBS spring is provided at all floors, the lateral storey displacement is reduced compared to the SBS DS of composite structure when the spring is provided at lower storey.

Index Terms— X BRACE, ZIPPER BRACE , SPRING BACK SYSTEM , ETABS 2016 , TIME HISTORY ANALYSIS

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1 INTRODUCTION

Most of the multistoried buildings using today are made up of reinforced concrete framed buildings. A reinforced concrete building should be designed to have a capacity to carry combined loads (dead, live and seismic loads) at certain safety level and at certain degree of reliability. There are several techniques to improve the strength and lateral stability of buildings. Use of steel bracing systems is one of such method which is highly efficient and economical.
A viable solution for enhancing earthquake resistance is to use steel bracing systems for strengthening and retrofitting seismically inadequate reinforced concrete frames. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing the weak columns while increasing strength. Conventional steel concentrically braced frames are prone to form- ing a soft-story mechanism during strong earthquake ground shaking. This concentration of deformations in one or a few stories intensifies damage to braces at these levels, leading to greater nonstructural and structural dam- age and premature rupture of the braces at these levels compared to systems having more uniform distribution of damage over height. The concentration of damage can amplify P-Δ effects, which can in turn increase lateral displacements in the softened story. Soft stories are also likely to result in significant residual displacements, which can be costly or infeasible to repair.
As such, it is desirable to enhance the ability of concentric braced frames to avoid concentration of deformations and damage in a few stories. If a system is able to mitigate soft or weak story behavior, the peak deformation demands on individual braces and maximum residual displacements might be reduced. Several approaches have been explored by various researchers to reduce damage concentration and achieve smaller residual displacement. These systems include:

1. Zipper or vertical tie bar systems

2. Tied-truss, masted, or strongback systems (SBS)

2 VALIDATION

To conduct dynamic analysis of an H- shaped reinforced concrete building located in seismic zone IV, which is modeled in ETABS by performing Response spectrum analysis. 5 models are created in ETABS software with 5 different types of bracings. They are X type, V type, inverted V type, diagonal bracing and K bracing but for validation only one single model is taken with X type bracings.

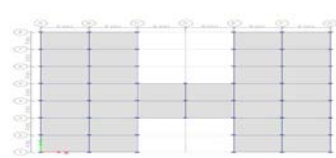

Figure 1: plan of H shaped structure

Table 1:comparison of validated result

	PAPER VALUE		VALIDATED VALUE	
	MAXIMUM VALUE		MAXIMUM VALUE	
	X direction	Y direction	X direction	Y direction
DEFORMATION (mm)	10.266	10.618	10.41	10.73
STORY SHEAR (kN)	844.4	820	842.4454	818.2929

2 PROCEDURE

Modeling of G+6 story structures providing ;

I. Without bracing (WB)
II. With x bracing (XB)
III. With zipper bracing(ZB)
IV. With SBS [1.Typical double-story X (DS X)
2. Intermittent chevron (IC)
3. Shifted double-story X (SDS X)
4. Tied-to-ground with single spring (SS)
5. Tied-to-ground with double spring (DS)]

Modeling of G+12 story structures providing;

1. With zipper bracing (ZB)
2. Tied-to-ground with double spring (DS)
3. With x bracing (XB)

Modeling of G+18 story structures providing;

1. With zipper bracing (ZB)
2. Tied-to-ground with double spring (DS)
3. With x bracing (XB) Static and dynamic analysis of structures were carried out

Models of the structures are shown below in figure 1.

3MODELING

Dimensions are shown below

RCC structures

	Column	beam	bracing
G+6	350X350	250X350	ISA 150X115X15
G+12	400X500	300X400	ISA 150X150X15
G+18	450X550	350X450	ISA 150X150X15

Steel structures

	Column	beam	bracing
G+6	ISMB 300	ISMB 250	ISA 150X115X15
G+12	ISMB 400	ISMB 350	ISA 150X150X15
G+18	ISMB 400	ISMB 350	ISA 150X150X15

Composite structures

	Column	beam
G+6	.3X.3m with embedded ISHB 200	ISMB 200
G+12	.35X.35m with ISHB 250	ISMB 250
G+18	.4x.4with ISHB 300	ISMB 300

Table 2:earthquake parameters and material properties

Seismic Zone	III(0.24)
Soil type	Hard type 1
Importance factor	1
Time period	Program calculated
Earthquake load in	X and Y direction
Type of diaphragm	Rigid
Response reduction factor	5
Unit weight of masonry	20kN\m^3
Unit weight of R.C.C	25 kN\m^3
Unit weight of steel	78 kN\m^3
Grade of concrete	M_{25}
Grade of reinforcing steel	Fe 415 HYSD bar
Grade of structural steel	Fe 250
Modulus of Elasticity for R.C.C	25kN\m^2
Modulus of Elasticity for Steel	210kN\m^2
Dead load	Self-weight
Live load	4kN\m^2
Floor finishes	1kN\m^3
Density of steel	76.8kN\m^3
Analyzed as per IS 800 and IS 1893-2002	

4RESULTS

RCC

when constructing an RCC structure with higher stories it is the better option to provide SBS DS as the bracing to this structure inorder to reduce baseshear and deformation. Also we can say that as the height is increased from lower storey to higher storey the deformation and base shear is decreasing from lower to higher storey. When comparing SBS DS with X bracing there is an average reduction of deformation to 15% and base shear is reduced to 20%. When comparing the height of the structure it is observed that an average of 3.59% reduction compared to X bracing.

STEEL

when constructing a steel structure with an aim of lower deformation, it is better option to select for the structure with zipper bracing. Similarly when the aim of the structure is with a lower base shears, it is better option to select the structure with SBS DS bracing. Here as the height increases deformation and base shear get reduces. While comparing SBS DS with X bracing it is observed that an average reduction of deformation to 36% and average reduction of base shear to 21%. As the weight is considered, an average reduction of 0.16% is observed.

COMPOSITE

while comparing the SBS DS with conventional X bracing the average deformation value is reduced to 45% and when comparing the base shear value an average base shear value is reduced to 32% compared to X bracing. The weight of the composite structure is observed and found out that an average reduction of weight to 8.07% is observed.

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Table 3: RCC structures

G+6 storey RCC structures					
Sno	Mod-els	Deformation (mm)		Base shear (kN)	
		X direc-tion	Y direction	X direc-tion	Y direc-tion
1	D X	10.508	10.55	1114.65	1113.29
2	IC	9.38	9.26	1005.79	998.46
3	ZB	9.51	9.538	1156.19	1154.15
4	SDS X	9.50	9.414	1017.44	1014.99
5	XB	10.408	10.44	1047.501	1046.99
6	WB	16.208	17.27	409.980	399.700
7	SS	8.96	8.45	1014.88	1007.87
8	DS	7.64	7.65	792.715	789.92

G+6 STOREY COMPOSITE STRUCTURES							
S no	Mod els	Defor-mation(mm)		Base shear (kN)		Time peri-od(seconds)	
		X direc-tion	Y direc-tion	X direc-tion	Y direc-tion	X direc-tion	Y direc-tion
1	D X	6.63	6.69	1331.76	1025.74	0.637	0.626
2	IC	8.95	11.08	687.75	797.422	0.771	0.761
3	ZB	7.71	8.11	1286.39	1350.36	0.601	0.599
4	SDS X	11.46	9.29	689.51	739.911	0.918	0.819
5	XB	9.74	9.73	875.89	875.68	0.715	0.715
6	WB	26.06	29.08	269.16	263.07	2.361	2.308
7	SS	9.039	11.205	916.60	874.49	0.732	0.698
8	DS	8.792	8.73	670.83	673.88	0.952	0.948

Table 5:comparison of results

STRUCTURE	STOREIES	MODELS	DEFORMATION (mm)	BASE SHEAR(kN)	%VARIATION IN DE-FORMATION	AVG	%VARIA-TION IN BASE SHEAR	AVG	WEIGHT(kN)	%VARIATION IN WEIGHT	AVG
STEEL	6	XB	11.72	662.91	24%	36%	20%	21%	20645	0.10%	0.16%
		DS	8.83	527.39					20623		
	12	XB	11.43	376.48	27%		27.40%		41945.19	0.21%	
		DS	8.33	273.28					42033.54		
	18	XB	5.46	197.86	58.42%		16.51%		62898.58	0.17%	
		DS	2.27	165.19					63008.88		
COM-POSITE	6	XB	9.74	875.89	9%	45%	23%	32%	21451	2.08%	8.07%
		DS	8.792	670.83					21906.75		
	12	XB	23.33	1034.9	66%		45.65%		41945.19	9.38%	
		DS	7.898	562.41					46291.41		
	18	XB	17.188	437.7	66.00%		27.57%		62898.58	12.77%	
		DS	6.782	317.04					72113.98		
RCC	6	XB	10.408	1047.5	26%	15%	24%	20%	27491.66	0.85%	3.59%
		DS	7.64	792.71					27729.4		
	12	XB	6.57	566.721	17%		18.00%		60372.41	1.70%	
		DS	5.45	459.46					61420.27		
	18	XB	7.61	551.64	2.62%		18.00%		112852.04	8.22%	
		DS	7.41	450.16					103568.42		

The results are compared between RCC, steel and composite structures. The best model name SBS with double spring is compared with conventional X bracing. Weight of each structure, deformation and base shear was compared. Average percentage increase of weight, deformation and base shear for SBS with double spring was compared with conventional X bracing and tabulated the results as shown in table 8.10. From the below table it is clear that composite structure shows less storey deformation and base shear compared to RCC and steel structures. It is also clear that compared to X bracing the deformation and base shear is reduced for SBS bracing provided with double spring. Also the weight of composite structure is lesser compared to RCC and steel structures.

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BEHAVIOURAL STUDY OF DS AND MODIFIED DS ON COMPOSITE STRUCTURES

From the obtained result, it was observed that composite structure is having higher decrease in deformation and base shear provided with strong back system with double spring. This structure is again modelled by providing springs at all floors for G+6, G+12 and G+18 storey structures as shown in Figure 8.4. From the figure it is clear that, for G+6 storey composite structure with springs at all floors the deformation reduced to 5.33mm and the comparative results of DS and modified DS

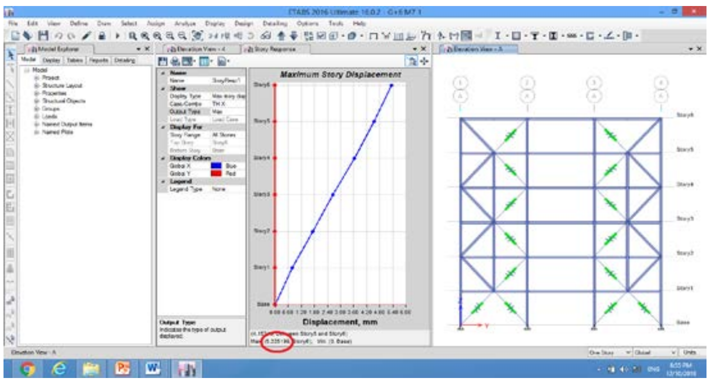

Figure 2: modified SBS with DS at all floors

It was observed that, around 29.57% decrease in deformation for composite structures with double spring at all stories when compared to composite structures with double spring at ground level.

Table 6: comparison of DS and MODIFIED DS

Composite structures			
Deformation(mm)			
Structure	G+6	G+12	G+18
DS	8.792	7.898	6.782
Modified DS	5.33	6.282	4.83
% Reduction in deformation compared to ds	39.37	20.46	28.78

5 CONCLUSION

- Implementation of static and dynamic analysis to study the best pattern and location analytically using ETABS software was done successfully, thereby achieving the objective of the study.
- G+6, G+12, and G+18 story structures was considered for the study with different models of arrangement of SBS,X brace, without brace and zipper systems.
- When G+6 story is considered, providing 8 different models and static and dynamic analysis is carried out and their results were obtained. The best out of 8 models are selected and provided to G+12 and G+18 structures.

RCC STRUCTURES

- The result extracted from G+6 story shows that the model with SBS tied to double springs have less story displacement and base shear compared to structure without bracings and X bracing.
- As the best model for G+6 storey RCC structure is the only SBS with double spring, similar analysis is done in G+12 and G+18 storey RCC structures with X bracing and SBS with double spring bracings. Similar result obtained for those structures.
- Deformation was compared with SBS DS braced and conventional X braced and observed a 15% reduction in deformation compared to X bracing
- Base shear was compared with SBS DS braced and conventional X braced and observed a 20% reduction in base shear compared to X bracing
- Weight of the structures were compared with X bracing, it is observed an average percentage of decrease in weight to 3.59% was observed.
- As the story height increases, storey displacement and base shear increases in RCC structure.

STEEL STRUCTURES

- The result extracted from G+6 storey shows that the model with zipper braced and SBS tied to double springs have less story displacement and base shear respectively compared to structure without bracings and X bracing .
- As the best model for G+6 storey steel structure is the zipper and SBS with double spring, similar analysis is done in G+12 and G+18 storey steel structures with X bracing. Result obtained was SBS DS is having lower storey deformation and base shear.
- Deformation was compared with SBS DS braced and conventional X braced and observed an 36% reduction in deformation compared to X bracing
- Base shear was compared with SBS DS braced and conventional X braced and observed a 21% reduction in base shear compared to X bracing
- Weight of the structures were compared with X bracing, it is observed an average percentage of decrease in weight to 0.16% was observed.
- As the story height increases, storey displacement and base shear gets reduced in steel structures.

COMPOSITE STRUCTURES

- The result extracted from G+6 story composite structure shows that the model with zipper bracings and SBS tied to double springs (SBS DS) has less story displacement and base shear respectively compared to structure without bracings and X bracing.
- As the best model for G+6 storey composite structure is the zipper and SBS with double spring, similar analysis is done in G+12 and G+18 storey steel structures with X bracing. Result obtained was SBS DS is having lower storey deformation and base shear.
- Deformation was compared with SBS DS braced and conventional X braced and observed an 45% reduction in deformation compared to X bracing
- Base shear was compared with SBS DS braced and conventional X braced and observed a 32% reduction in base shear compared to X bracing

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- Weight of the structures were compared with X bracing, it is observed an average percentage of decrease in weight to 8.07% was observed.
- The maximum displacement value of composite structure without bracing is found to be 154.22mm in X direction. But when the implementation of zipper braces it is reduced to 6.022mm in X direction. This shows that there is 96.095% reduction in X direction.
- Similarly SBS (DS) has reduced the base shear value to 49.62% in X direction compared to all other bracings.
- While comparing deformation, around 45% variation is observed for composite structure when compared to X bracing.
- While comparing base shear, around 32% variation is observed for composite structure when compared to X bracing.
- In composite structures, when spring is provided at all stories, it was observed that the deformation value get reduced compared to double spring at ground level.

COMPARISON OF RCC STEEL AND COMPOSITE STRUCTURES

- DS is modified by providing spring at all floors for composite structures
- Comparison of deformation of DS and MODIFIED DS was done.
- Around 29.57% decrease in deformation compared to DS
- So we can conclude that, for a composite structure with lower deformation, better option is to adopt **MODIFIED SBS DS** bracings.

- While comparing the RCC, steel and composite structures, the lower deformation and base shear value is found out for composite structures.
- While comparing weight of RCC, steel and composite structures, around 8.07% variation in weight is observed for composite structures.
- Maximum value of storey drift for SBS (DS) was found to be 0.001443 which is within the limit as per IS : 1893:2002.
- So we can conclude that, if our aim is to build a steel or composite structure with lesser base shear, then it is more suited to select the SBS model with double springs and if our aim is to build a steel or composite structure with lesser deformation, then it is more suited to select zipper braces model for those structures.
- If our aim is to build a RCC structure with lesser base shear and deformation, then it is more suited to select SBS with double spring for the structure.
- Overall response of composite structure is better than RCC structure i.e. composite structure produces less displacement and resists more structural forces.
- Composite structures are best solution for high rise buildings and they are resulted in speedy construction.
- Steel construction is better than RCC but the composite construction for high rise building is best.
- Steel has excellent resistance to tensile loading but prone to buckling and concrete gives more resistance to compressive force.
- Steel can be used to induce ductility and concrete can be used for corrosion and fire protection.
- Composite structures are resulted into lighter construction than traditional concrete construction as well as speedy construction. So completion period of composite building is less than RCC building.
- Base shear in steel structure is less than the RC structures because of less seismic weight which gives better response during earthquake.

- As a whole, we can conclude that providing zipper and SBS is more effective in comparison to X bracings and without bracing in RCC, steel and composite structures to resist lateral loads.

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