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(Research Article)

Seismic effectiveness of retrofitting techniques for RC framed structure

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Abstract

Many potentially devastating earthquakes have been allowed to occur in India. The Indian subcontinent suffered a devastating earthquake. The resulting human and material costs are enormous. The Bhuj earthquake hit Gujarat around 8:40 a.m. on January 26th, 2001. A lot of things have changed after the earthquake. India's seismic regulations. There is a great need to evaluate the seismic performance of existing RC frame buildings, many of which were designed for a different load, and to retrofit them as necessary to increase their strength against earthquake forces, given what is known about the causes of past earthquakes and the likelihood that similar events will occur in the future.

As we saw in the Bhuj Earthquake of 2001, open ground storey frame structures are especially vulnerable to the destructive forces of earthquakes, making it imperative that the ground story be fortified against massive deformation. The first floor of this G+3 building in Seismic Zone 4 has been retrofitted using three different methods. Here is a list of them: jacketing for the basement's concrete slab. Filler wall made of reinforced concrete. Iron Reinforcement. Therefore, the primary goal of this research is to determine the efficacy of various retrofitting strategies with respect to reducing seismic risk.

Keywords: RCC beam; RCC column; Retrofitting; Base Shear

1. Introduction

The seismic retrofitting industry has seen significant transformations after the Bhuj Earthquake in 2001. Most of the structures were built before the earthquakes using outdated seismic regulations, and others were not even constructed with earthquake safety in mind. In a nation like India, where design regulations are often updated, a thorough evaluation of the current framework is crucial. Structures with RC frames, Masonry walls, and timers. IS:1893-2016 (India Standard) is one of several such codes used to design buildings to withstand earthquakes. IS:4326-2013 (Earthquake Resistance Design and Construction of Building).

In a region that is extremely susceptible to earthquakes, buildings with their ground floors left open for parking or other uses are particularly vulnerable. In the space between the beams and the columns, there are no masonry walls created to infill it. People often refer to these structures as "open ground story buildings." Sometimes, the bottom floor is the only part of the building that has full-height glass windows throughout the perimeter of the structure, despite the fact that there is no wall created in the space between the columns and the window frames.

When there are plastic hinges present in a structure, there is a possibility that the structure as a whole might collapse on a huge scale. Open ground story structures have regularly shown poor performance during historical earthquakes around the globe (for example, during the earthquakes that occurred in 1999 Turkey, 1999 Taiwan, and 2003 Algeria); a considerable proportion of these buildings have fallen.

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Buildings with open ground floors are less likely to be damaged by earthquakes; as a result, their structural rigidity has to be carefully considered.

Research objectives

The following is a statement of the purpose of this case study:

- By applying the approach to the ground storey of the model, we can determine whether or not retrofitting is doable.
- Putting the model through the Dynamic and push over analyses, as well as determining the success of the Retrofitting approach, is a good place to start.

2. Material and methods

2.1. Designing for Seismic Evaluation

All the data required for the design have been discussed in Table 1.

Table 1 Data for Structure

Design Parameters	Values
Seismic Zone	4
Zone Factor	0.24
Soil Type	Medium (Clay containing silt)
Response Reduction Factor	5-SMRF
Damping Ratio	0.05
Structure	G+3 (17m height with 5m ground storey height and 3m of intermediate storey height)
Beam Size	250 ×350 mm
Column Size	400 × 400 mm
Slab Size	Roof- 100mm Intermediate- 150mm

Now, the structure has to be imposed with the loads. The details are given in Table 2.

Table 2 Material Properties

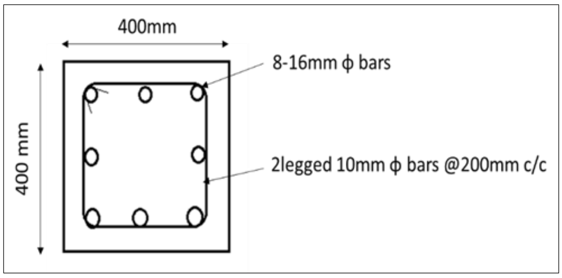
Material Properties	Values
Unit Weight of Concrete	25 KN/m3
Unit weight of Steel	78900 KN/m3
Unit weight of infill	18 KN/m3
Grade of Steel	Fe 415
Grade of Concrete	M30
Modulus of Elasticity of Masonry	3500 N/mm2
Modulus of Elasticity of steel	2 × 105 N/mm2
Modulus of elasticity of concrete	27386 N/mm2
Damping Ratio	0.05

Combinations of Loads used are:

- 0.9DL± 1.5EQx
- 0.9DL± 1.5Eqy
- 1.2 (DL+LL ± EQx)
- 1.2 (DL+LL ± Eqy)
- 1.5(DL ± EQx)
- 1.5(DL ± Eqy)

2.2. Reinforcement and Retrofitting

The following is the strengthening detail of both the external and interior column:



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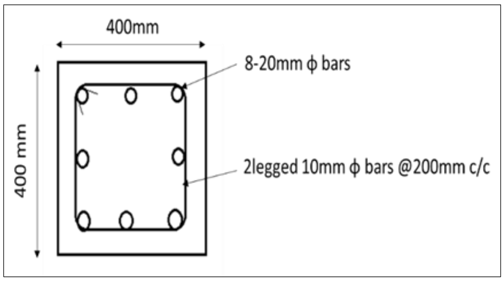


(b)

Figure 1 (a) External Columns (b) Interior Columns of the structure

Steel bracing has been installed on the open ground floor in order to provide resistance to the earthquake effects.

There have been two different kinds of steel bracings used:

- a steel bracing in the form of an X
- V-shaped bracing made of steel

All of the impacts that may be attributed to seismic activity have been analyzed.

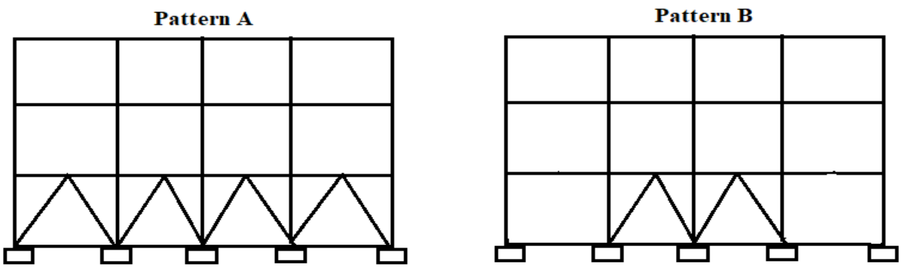


Figure 2 V shaped Bracing

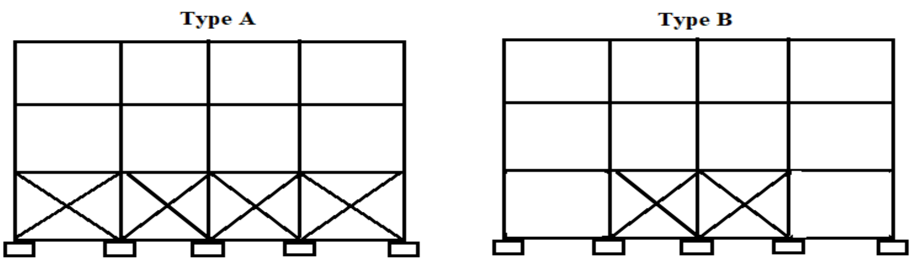


Figure 3 X shaped Bracing

The ground storey is fortified with RC walls that have substantial reinforcement so that it can better withstand the stresses of an earthquake.

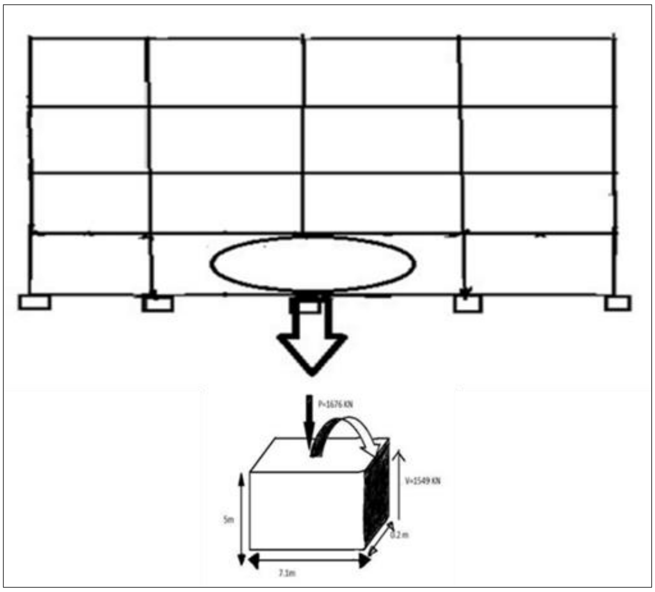


Figure 4 RC Walls for Strength Improvisation

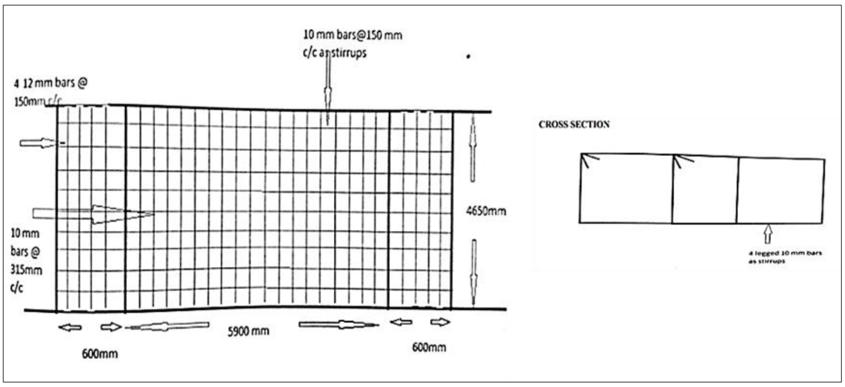
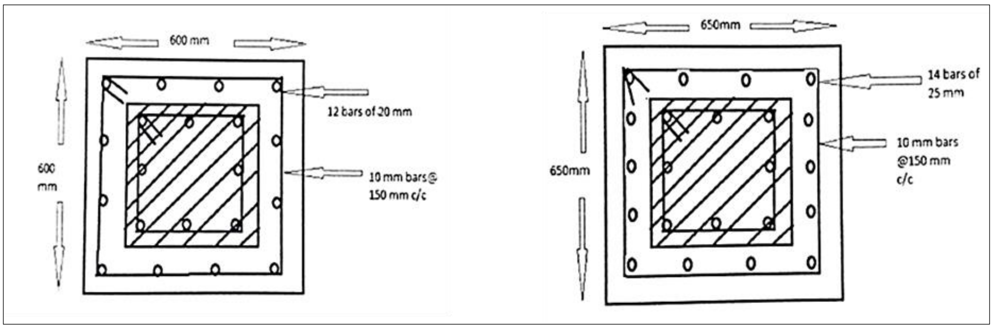


Figure 5 RC wall reinforcement details



(a) (b)

Figure 6 (a) Jacketing of External Columns (b) Jacketing of Interior Columns of the structure

3. Results and discussion

3.1. Calculations of Force and Moments

The columns are subjected to axial loads and two moments. So, the values have been calculated theoretically with simple reinforcement and after retrofitting. The comparative study is shown in Table 3 and Table 4.

Table 3 Observed Values of Forces for Jacketed Portion in Ground Floor

	Type	Col. No	Axial Load (kN)	Moment (M2) (kN-m)	Moments (M3) (kN-m)
EXTERIOR FRAME COLUMN	EXTERIOR	1	-1716.77	-250.20	-248.90
	EXTERIOR	5	-2774	238.10	210.77
	EXTERIOR	9	-2774	-238.10	210.77
	EXTERIOR	13	-1716.77	250.20	-248.90
INTERIOR FRAME COLUMN .	EXTERIOR	17	-2776	-257.52	236.57
	INTERIOR	21	-4271.82	357.10	354.70
	INTERIOR	25	-4271.82	-357.10	354.70
	EXTERIOR	29	-2776	257.52	236.57
	EXTERIOR	33	-2764.60	-257	-234.57
	INTERIOR	37	-4275	355.21	-351.20
	INTERIOR	41	-4275	-355.21	-351.20
	EXTERIOR	45	2764.62	257	234.36
	EXTERIOR	49	2776	-257.50	-236.57
	INTERIOR	53	-4271.77	357.20	-354.77
	INTERIOR	57	-4271.77	-357.20	-354.77
	EXTERIOR	61	-2776	257.50	-236.57
EXTERIOR FRAME COLUMN	EXTERIOR	65	-1716.80	-250.15	248.86
	EXTERIOR	69	-2774	238.07	-210.80
	EXTERIOR	73	-2774	-238.07	-210.80
	EXTERIOR	77	1716.80	250.15	248.85

Table 4 Comparative Values

	BEFORE JACKETING		AFTER JACKETING	
	EXTERIOR COLUMNS	INTERIOR COLUMNS	EXTERIOR COLUMNS	INTERIOR COLUMNS
X_u/D	0.41	0.407	0.429	0.433
P_{ub} (kN)	627.40	580	1417.30	1555.80
M_{ub} (kN-m)	152.50	185.645	285.436	981.40
e (mm)	243	320	201.40	630.80
BALANCED FAILURE				
P_{uo} (kN)	2348	2588.60	5760	7567

3.2. Dynamic Analysis

After is a list of parameters that were discovered following the execution of the dynamic analysis on both the original building model and the retrofitted building model. The displacement and inter-storey drift has been shown in Table 5.

- The greatest possible and the average displacement of a story
- Inter story drift
- The weight of the earthquake on the buildings, in addition to the base shear.

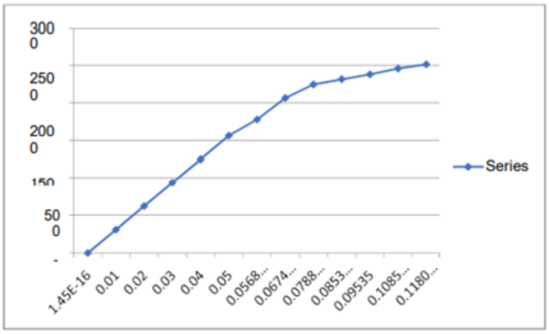
Table 5 Displacement and Inter-storey Drifts for V and X bracing

Storey	Height (m)	Original Building				V Bracing (Type-I)				V Bracing (Type-II)			
		Max. Avg Displacement		Storey Drift		Max. Avg Displacement		Storey Drift		Max. Avg Displacement		Storey Drift	
		X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5	16.75	16.76	16.75	16.76	1.88	1.84	1.89	1.84	3.16	3.10	3.16	3.10
3	9	27.88	28.01	11.22	111.2 6	12.75	11.87	10.87	10.01	13.30	10.20	10.20	9.33
4	13	35.56	35.65	7.56	7.62	22.23	20.65	9.47	8.8	21.93	8.63	8.63	7.99
5	17	39.83	40.10	4.223	4.338	28.01	26.14	5.76	5.43	27.18	5.20	5.20	4.90

Storey	X-Bracing (Type-I)				X-Bracing (Type-II)				Concrete Jacketing				Concrete Jacketing			
	Max. Avg Displacement		Storey Drift		Max. Avg Displacement		Storey Drift		Max. Avg Displacement		Storey Drift		Max. Avg Displacement		Storey Drift	
	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)	X (mm)	Y (mm)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1.43	1.40	1.43	1.40	2.42	2.30	2.41	2.32	5.62	5.65	5.62	5.65	0.072	0.132	0.072	0.132
3	12.4	11.33	10.95	9.93	12.52	11.49	10.20	9.20	16.82	16.90	11.21	11.29	11.18	11.17	11.12	11.04
4	22.1	20.12	9.66	8.77	21.22	19.38	8.70	7.90	25.41	25.61	8.60	8.70	21.96	21.68	10.77	10.5
5	27.90	25.60	5.89	5.42	26.53	24.33	5.30	4.90	30.51	30.84	5.11	5.22	28.67	28.29	6.71	6.61

3.3. Pushover Analysis

The Pushover Analysis was performed on both the original structure of the building and the structure after they were upgraded. The load was applied as a controlled displacement with a monitored control displacement of one percent of the building's height, and the results were obtained.



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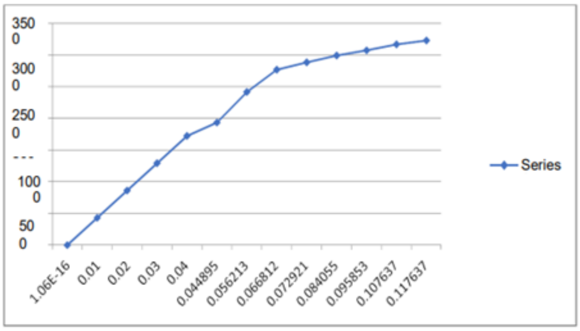

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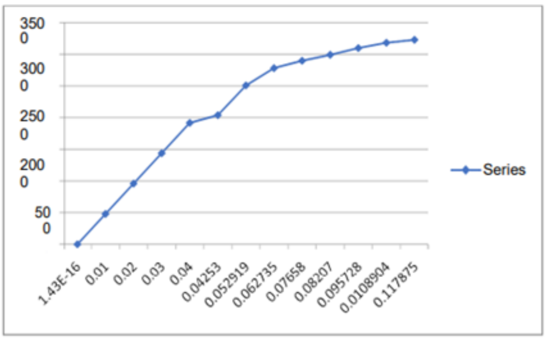

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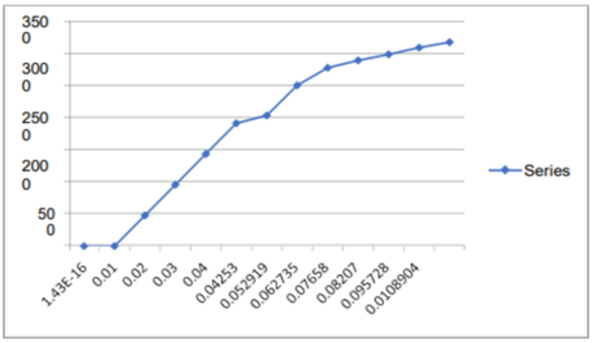

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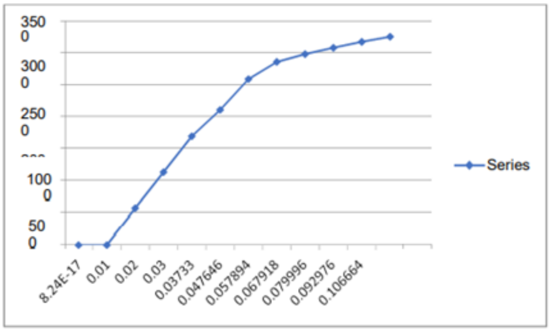

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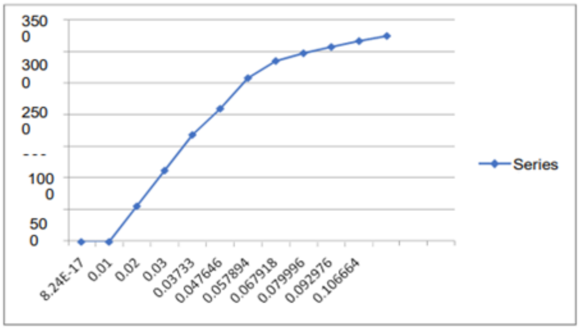

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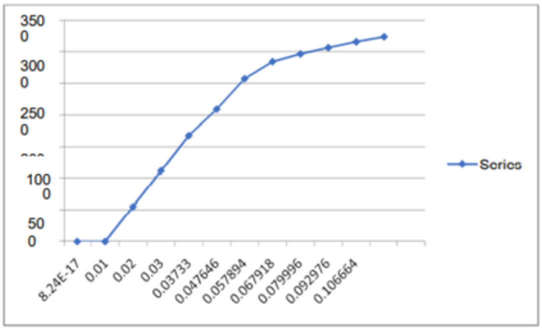

(g)

Figure 7 Graph Showing Pushover Analysis of (a) Original Building (b) Concrete Jacketing (c) V Bracing (Type I) (d) V Bracing (Type II) (e) X Bracing (Type I) (f) X Bracing (Type II) (g) Infill where horizontal axis shows displacement (m) and vertical axis shows base shear (kN)

4. Conclusion

In this research 3 retrofitting strategies have been used to stiffen the open ground storey which is very sensitive to severe earthquake damages due to lower lateral stiffness and the following points can be concluded

- The maximum average displacement of a story has seen a considerable reduction after the installation of retrofitting methods, which indicates that these approaches have been successful.
- Concrete jacketing of the columns improves the axial as well as the moment carrying capacity of the ground floor columns, whilst the insertion of bracings and RC infill walls minimizes the stresses on columns by sharing the loads that are arriving.
- Base shear values rise significantly following the addition of RC infill walls and the inclusion of concrete jacketing, however the increase in bracings is not very noticeable.
- The pushover study reveals that the variables Elastic Stiffness (K) and ductility capacity (c) increase after the retrofitting. This is the conclusion that can be drawn from the changes. Bracings contribute to an increase in the structure's elastic stiffness, but the addition of RC infill walls has the greatest impact on the structure's ductility capacity.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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