

# Seismic Retrofitting of Reinforced Concrete Frame Building with Soft Storey

S.Anbarasu<sup>1</sup>, K.Tamilvanan<sup>2</sup>P.G. Student, Department of Civil Engineering, Prist University, Thanjavur, Tamilnadu, India<sup>1</sup>Assistant Professor, Department of Civil Engineering, Prist University, Thanjavur, Tamilnadu, India<sup>2</sup>

**ABSTRACT:**Earthquakes are one of the natural phenomena that are relatively unexpected which results in the loss of life. In past, an earthquake has occurred due to the collapse of buildings which were not particularly engineered to be earthquake resistant. In view of this, the structure has to be designed with seismic resistance. Hence in this study a soft storey building was selected and analysed for its strength. Then the ordinary building frame drift values were identified and it was compared with the building using bracing and brick wall. Finally the best retrofit technic was identified to make that building resist to the seismic forces which occurs during earthquakes.

**KEYWORDS:**earthquake, retrofit, bracing, building frame.

## I. INTRODUCTION

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. It is also known as a quake, tremor or temblor. Due to Improper design of the structure without seismic resistance many buildings have collapsed and lives have lost during earthquakes. Many analyses like Base Isolation, Damping Devices and Bracing Systems have been carried out to protect the structure and lives which does not improve the performance of the structure. Soft storey is one in which the lateral stiffness is less than 70 percentage of that in the storey above or less than 80 percentage of the average lateral stiffness of the storey above. It is also known as weak storey in which the storey lateral strength is less than 80 percentages of that in the storey above. The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction. Open ground storey buildings are inherently poor systems with sudden drop in stiffness and strength in the ground storey. Stiff masonry wall are neglected in the current design practice, and only bare frames are considered in the design calculations. Thus, the load path is completely misrepresented and the inverted pendulum effect is not captured in the structural design. Thus, the ground storey columns are under-designed for the actual earthquake effects likely to occur on the building. Such buildings are abruptly flexible and weak in the ground storey, and perform poorly during earthquake shaking. There is a need for seismic evaluation of existing building for the following reasons: The building may not have been designed and detailed to resist seismic forces. The building may have been designed for seismic forces, but before the publication of the current codes. The construction is apparently of poor quality. The condition of the building has visibly deteriorated with time. There have been additions or modifications or change of use of building, which has increased the vulnerability. The soil has a liquefaction potential. Especially under such situations, structural assessment of the existing buildings for their adequacy to withstand the design seismic loads is important.

Retrofit specially aims to enhance the structural capacities (strength, stiffness, ductility, stability and integrity) of a building that is found to be deficient or vulnerable. In the specific context of enhancing the resistance of a vulnerable building to earthquakes, the term seismic retrofit is used. The retrofit is intended to mitigate the effect of a future earthquake. Seismic retrofit can effectively raise the performance of a building against earthquakes to a desired level, and even to satisfy the requirements of an upgraded seismic design code. Providing Infill walls and Bracing without affecting parking and aesthetic appearance to avoid the damages and collapse of building. Hence in this study different types of retrofitting techniques are used for strengthen the RC frame building with soft storey. Bracing and Infill wall techniques are more effective to minimize the storey drift and to resist seismic forces.

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

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

## II. METHODOLOGY

In the RC frame building with soft storey has several disadvantages in the seismic active areas. Nowadays the proposed building designed properly to resist the seismic forces. So we have to concentrate the existing building make seismic resistant nature by providing an effective retrofit technique. The existing five storey RC frame building with soft storey is to be modelled and analysed by STAAD Pro software. The dead, live and seismic loads are to be considered for the analysis. As per IS 1893 (Part 1): 2002 clause 6.3.1.2, in the limit state design of reinforced and pre-stressed concrete structures, the following load combinations shall be accounted for: (a) 1.5 (DL + LL), (b) 1.2 (DL + LL + EL), (c) 1.2 (DL + LL - EL), (d) 1.5 (DL ± EL) and (e) 0.9 DL ± 1.5 EL.

<b>Table-1: Existing building details</b>	
<b>Material Properties</b>	
Grade of concrete	M20
Grade of steel	Fe 415
Density of reinforced concrete	25 kN/m <sup>3</sup>
Density of brick masonry	20 kN/m <sup>3</sup>
<b>Member Properties</b>	
Thickness of slab	0.15 m
Beam size	0.23 x 0.4 m
Column size	0.23 x 0.45 m
Thickness of wall	0.23 m
<b>Dead Load Intensities</b>	
Floor finishes	1.0 kN/m <sup>2</sup>
<b>Live Load Intensities</b>	
Floor	2.0 kN/m <sup>2</sup>
Roof	1.5 kN/m <sup>2</sup>
<b>Earthquake LL on slab as per Cl. 7.3.1 and 7.3.2 of IS 1893(part 1)-2002</b>	
Roof	0 kN/m <sup>2</sup>
Floor	0.25 x 2.0 = 0.5kN/m <sup>2</sup>

The earthquake forces shall be calculated for the dead load plus the percentage of imposed load as per given in Table 8 of IS 1893 (part 1): 2002. The imposed load on roof is assumed to be zero. The lumped masses of each floor are worked out and tabulated in table-2.

<b>Table-2: Lumped mass on all floors</b>	
Lumped mass on roof	113.24 ton
Lumped mass on 4th, 3rd, 2nd floors	215.88 ton
Lumped mass on ground floor	160.058 ton
Seismic weight of building	920.94 ton

As per IS 1893 (part 1): 2002, clause 7.4.1, The approximate fundamental natural period of a vibration ( $T_a$ ), in seconds, of a moment resisting frame building without brick infill wall is 0.5873 Sec. As per IS 1893 (part 1): 2002, clause 7.5.3, the total design lateral force or design seismic base shear ( $V_B$ ) along any principle direction shall be determined as 410.163 kN. As per IS 1893 (part 1): 2002, clause 7.7.1, the design base shear ( $V_B$ ) computed shall be distributed along the height of the building as per expression,  $Q_i = V_B \times [(W_i \times h_i^2) \div (\sum_{i=1}^n W_i \times h_i^2)]$

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

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

<b>Table-3: Base shear calculation</b>						
<b>Floor level</b>	<b>h<sub>i</sub> in m</b>	<b>W<sub>i</sub> in kN</b>	<b>W<sub>i</sub> × h<sub>i</sub><sup>2</sup></b>	$\frac{W_i h_i^2}{\sum_{i=1}^n W_i h_i^2}$	$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^n W_i h_i^2}$	<b>V<sub>i</sub> in kN</b>
1	2.95	1600.575	13929.004	0.016	6.563	410.188
2	6.1	2158.75	80327.09	0.0908	37.243	410.165
3	9.25	2158.75	184708.05	0.209	85.724	410.163
4	12.4	2158.75	331929.4	0.375	153.811	410.162
5	15.55	1132.373	273810.62	0.309	126.74	410.161

**Storey drift calculation:** It is the displacement of one level relative to the other level above or below. As per IS 18936 (part 1): 2002 clause 7.11.1, the storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height. Permissible limit for storey drift at ground floor level = 11.8 mm; Permissible limit for storey drift at 1<sup>st</sup> to 4<sup>th</sup> floor level = 12.6 mm. the calculated Storey Drift value for Ground Floor= 2.25 mm < 11.8 mm and Storey Drift value for other = 2.74 mm < 12.6 mm. Hence it is safe.

<b>Table-4: Storey drift for ordinary building frame</b>				
<b>Storey height in m</b>	<b>Drift values for different load combinations in mm</b>			
	<b>1.5DL + 1.5EL</b>	<b>1.2ELX + 1.2 ELZ</b>	<b>1.5DL + 1.5ELX</b>	<b>1.5DL - 1.5ELZ</b>
2.95	1.28	1.01	1.28	0.02
6.10	2.13	1.66	2.13	0.05
9.25	2.09	1.60	2.08	0.06
12.4	1.73	1.31	1.73	0.07
15.55	1.17	0.87	1.16	0.08
19.55	1.62	0.93	1.57	0.4

<b>Table-5: Storey drift for building frame with brick wall</b>				
<b>Storey height in m</b>	<b>Drift values for different load combinations in mm</b>			
	<b>1.5DL + 1.5EL</b>	<b>1.2ELX + 1.2 ELZ</b>	<b>1.5DL + 1.5ELX</b>	<b>1.5DL - 1.5ELZ</b>
2.95	0.2	0.46	0.21	0.01
6.10	1.89	1.49	1.89	0.04
9.25	2.19	1.71	2.19	0.05
12.4	1.84	1.42	1.84	0.07
15.55	1.24	0.93	1.23	0.07
19.55	1.71	1.01	1.65	0.4

<b>Table-6: Storey drift for building frame with bracing</b>				
<b>Storey height in m</b>	<b>Drift values for different load combinations in mm</b>			
	<b>1.5DL + 1.5EL</b>	<b>1.2ELX + 1.2 ELZ</b>	<b>1.5DL + 1.5ELX</b>	<b>1.5DL - 1.5ELZ</b>
2.95	0.45	0.36	0.45	0.003
6.10	1.90	1.48	1.89	0.04
9.25	2.07	1.59	2.06	0.07
12.4	1.73	1.32	1.73	0.08
15.55	1.17	0.86	1.16	0.081
19.55	1.62	0.94	1.57	0.39

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

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

**Table-7: Dynamic analysis (response spectrum method)**

Storey height in m	Storey Drift value in mm					
	Ordinary building frame		Frame with brick wall		Frame with bracing	
	X direction	Z direction	X direction	Z direction	X direction	Z direction
2.95	5.16	0.63	0.87	0.2	1.79	0.20
6.10	8.06	0.84	7.05	0.59	7.23	0.74
9.25	7.06	0.69	7.55	0.86	7.50	0.93
12.4	4.97	0.49	5.33	0.62	5.89	0.7
15.55	2.65	0.25	2.61	0.29	3.78	0.45
19.55	4.01	1.59	5.64	1.49	3.41	1.91

### III. RESULTS AND DISCUSSION

Analysis of retrofitted G+4 open ground storey reinforced concrete frame building with Bracing and Brick wall model is done using STAAD Pro for Seismic coefficient method and Manual analysis also done. The Dynamic analysis of the building frame for the load combination is done using response spectrum method in STAAD Pro software. From the analysis, the results of different types of load combinations for the retrofitted frame and ordinary frame models are compared. The comparison of these results shows X bracing system and Brick wall provided frame are effective in terms of storey drift. Bracing is done with ISMC 200 steel channel section.

**Table-8: Comparison of results for static analysis**

S.No	Storey height in m	Storey drift value in mm			
		Manual analysis	Static analysis		
			Ordinary frame	Frame with brick wall	Frame with bracing
1	2.95	2.25	1.28	0.21	0.45
2	6.10	2.74	2.13	1.89	1.90
3	9.25	2.72	2.09	2.19	2.07
4	12.4	2.73	1.73	1.85	1.74
5	15.55	2.74	1.17	1.24	1.18

**Table-9: Comparison of results for dynamic analysis**

S.No	Storey height in m	Storey drift value in mm		
		Dynamic analysis		
		Ordinary frame	Frame with brick wall	Frame with bracing
1	2.95	5.16	0.87	1.79
2	6.10	8.06	7.05	7.23
3	9.25	7.06	7.55	7.50
4	12.4	4.97	5.33	5.89
5	15.55	2.65	2.61	3.78

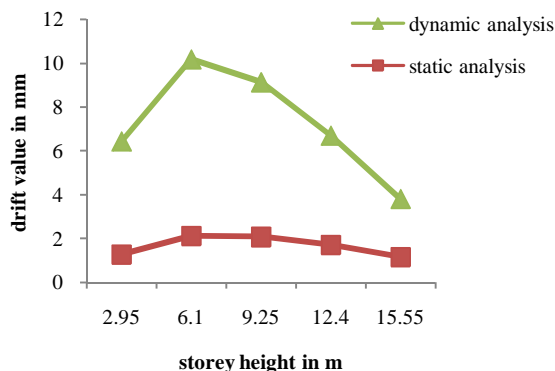


Fig-1: comparison of results for ordinary frame

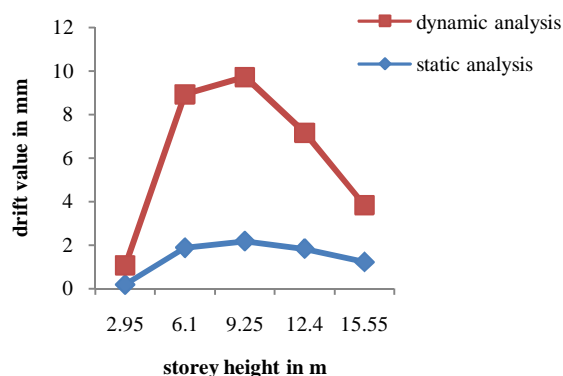


Fig-2: comparison of results for building frame with brick wall

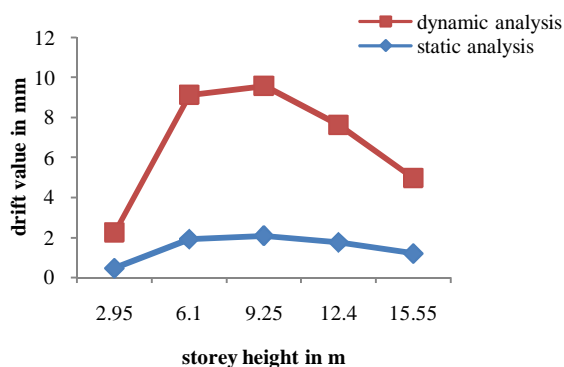


Fig-3: comparison of results for building frame with bracing

## IV. CONCLUSION

The modelling and analysis of G+ 4 reinforced concrete frame building with soft storey retrofitted by Bracing and Brick wall is done using STAAD Pro. From the results of analysis, building frame with X bracing and Brick wall shows the minimum storey drift value as compared to the ordinary frame. From the Static analysis, the percentage of reduction in Storey drift for Frame with brick wall is 84% as compared to the ordinary frame. From the Static analysis, the percentage of reduction in Storey drift for X braced building with ISMC 200 is 63% as compared to the ordinary frame. From the Dynamic analysis, the percentage of reduction in Storey drift for Frame with brick wall is 83% as compared to the ordinary frame. From the Dynamic analysis, the percentage of reduction in Storey drift for X braced building with ISMC 200 is 65% as compared to the ordinary frame. Design of X bracing and their connection were also done. For retrofitting the existing building, X bracing and Brick wall techniques are effective to reduce storey drift value.

## REFERENCES

- [1] Mohammad EyniKangavar Seismic Propensity of Knee Braced Frame (KBF) As Weighed Against Concentric Braced Frame (CBF) Utilizing ETABS and OPENSEES, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-5 June-2012 pp 141-152
- [2] AlurwadRajeshwar Reddy. R, Dr. ArshadHashmi Seismic Behaviour of Reinforced Concrete Frame with Infill Walls, International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 4, Jul-Aug 2013, pp.1419-1423.
- [3] M.R. Maheri and H. Ghaffarzadeh seismic design basis for internally-braced rc frames, The 14thWorld Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.
- [4] Arturo Tena-Colunga Review of the Soft First Story Irregularity Condition of Buildings for Seismic Design, The Open Civil Engineering Journal, 2010, 4, 1- 15
- [5] Amit V. Khandve Seismic Response of RC Frame Buildings with Soft Storeys, International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3, May-Jun 2012, pp.2100-2108.

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

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 3, March 2016**

- [6] Takuya Nagae, Keiichiro Suita, Masayoshi Nakashima Performance Assessment for Reinforced Concrete Buildings with Soft First Stories, *Annals of Disas. Prev. Res. Inst., Kyoto Univ.*, No. 49 C, 2006 pp 189-196.
- [7] Dr. SaraswatiSetia and Vineet Sharma (2012) Seismic Response of R.C.C Building with Soft Storey, *International Journal of Applied Engineering Research*, ISSN 0973-4562 Vol.7 No.1 -2012.
- [8] Dr. Kulkarni A.B. Mulgund G. V. seismic assesement of rc frame buildings with brick masonry infills *International Journal of advanced engineering sciences and technologies* vol no. 2, issue no. 2, 140 – 147
- [9] MangulkarMadhuri.N., Misam.A Structural response of soft story-high rise buildings under different shear wall location *International Journal of civil engineering and technology (ijciet)* Volume 3, Issue 2, July- December (2012), pp. 169-180
- [10] SharanyHaque, Khan Mahmud Amanat Seismic Vulnerability of Columns of RC Framed Buildings with Soft Ground Floor *International Journal of Mathematical models and methods in applied sciences* Issue 3, Volume 2, 2008,pp.364-371
- [11] IS 1893: 2002 Indian standard criteria for earthquake resistant design of Structures Part 1: general provisions and buildings, Bureau of Indian Standards, New Delhi.
- [12] IS 456: 2000 Indian Standard code of practice for plain and reinforced concrete, Bureau of Indian standards New Delhi.
- [13] PankajAgarwal, Earthquake Resistant Design of Structures, PHI Learning Pvt. Ltd.