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Seismic Retrofit of Low Rise RC Buildings in NCR Region

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Abstract: Earthquake around the world is one of the reasons liable for the damage to life and property in hefty numbers. In order to lessen such menaces, it is paramount to integrate norms that will enrich the seismic performance of the structures. Seismic waves will be influxes of energy that move through the Earth's layers, and are an aftereffect of earthquakes, volcanic emissions, enormous avalanches and huge man-made detonations that give out low-recurrence acoustic energy. Several other common and anthropogenic sources make low-plentifulness waves usually indicated as surrounding vibrations. Seismic waves are studied by geophysicists called seismologists. Seismic wave pitches are charted by a seismometer, hydrophone (in water), or accelerometer.

Seismic Retrofitting is the amendment of pre-existing structures to make them more resilient to seismic movement, ground motion, or soil failure due to tremors. Seismic retrofitting is the change of prevailing structures to make them increasingly resistant to seismic movement, ground motion, or soil failure because of earthquakes. With better understanding of seismic attention on structures and with our current encounters with massive earthquakes close to urban centres, the need of seismic retrofitting is all around documented. Techniques such as RC jacketing which is addition of steel reinforcement in existing columns to increase its bearing capacity and hence protect it from seismic activity. Shear walls are constructed from the ground up to increase the seismic resistance of a building while not disturbing its aesthetic view.

Keywords: Seismic retrofitting, RC jacketing, earthquake resistant structures, seismic isolator, seismic performance, rehabilitation, strengthening, restoration, remodelling, repairing, seismic evaluation.

1. INTRODUCTION

Seismology is the investigation of the age, proliferation and recording of elastic waves in the earth's crust and their causes (Table 1). A quake is an abrupt tremor or development of the world's covering, which starts normally at or underneath the earth's surface. The word normal is significant here, since it rejects stun waves brought about by atomic tests, manufactured blasts, and so forth. About 90% of all seismic tremors result from structural occasions, fundamentally developments on the deficiencies. The remaining is acknowledged with volcanism, collapse of underground depressions or synthetic effects. Structural seismic tremors are triggered when the gathered strain exceeds the shearing quality of rocks. Flexible bounce back hypothesis gives the material science behind tremor beginning. This section incorporates flexible bounce back hypothesis, plate tectonics, tremor size, quake recurrence and vitality, seismic waves, nearby site impacts on the ground movement qualities, inside of the earth and seismicity of India.

TABLE 1 A Rundown of Regular and Man-Made Seismic Tremor Sources

Seismic Sources	
Natural Source	Man-made Source
Tectonic Earthquakes	Controlled Sources (Explosives)
Volcanic Earthquakes	Reservoir Initiates Quakes
Rock Falls/Breakdown of Cavity	Mining Initiates Quakes
Microseism	Cultural Commotion (Industry, Traffic, and so forth.)

Seismic tremors are occurring in the Indian subcontinent from the days of yore yet dependable verifiable archives are only available throughout the previous 200 years (Oldham, 1883). From the beginning of twentieth century, over 700 seismic tremors of magnitude at least 5 have been recorded and sensed in India, as given in the lists arranged by US National Oceanographic and Barometrical Organization, India Meteorological Office, National Geophysical Exploration Establishment. The seismicity of India can be partitioned in four parts, to be exact, the Himalayan district, Andaman and Nicobar, Kutch locale and the Indian peninsula. A portion of the harming tremors which have happened in these four areas.

2. MATERIALS AND METHODS

For obtaining the displacement and frequency, frame structures ranging for 3, 4 and 5 storeys have been modelled and analysed using STAAD Pro V8i. Each frame has different structural changes after retrofitting like column retrofitting for G+3 and G+5 structures and addition of a shear wall for G+4 frame structure.

2.1 Design data for modelling

- Height of each story: - 3m
- Grade of Concrete: - M25
- Modulus of elasticity: - 25000N/mm^2
- Self-Weight Factor: - 1
- Live Load: - 15 kN/m^2
- Damping: - 5%
- Earthquake zone IV: - 0.24
- Response Reduction Factor: - 4
- Importance Factor: - 1
- Span in X direction: - 4m
- Span in Z direction: - 3m
- No. of bays in X direction: - 3,3,4 for 3,4,5 storeys respectively
- No. of bays in the Z direction: - 5,6,4 for 3,4,5 storeys respectively

3. RESULTS AND DISCUSSIONS:

Seismic analysis is performed on each of the frames as it investigates the beam end displacement and axial, shear, torsion and bending forces on the beams in each frame structure. For the seismic analysis, earthquake loads are considered in the push direction (i.e. X direction), the following results were obtained:-

3.1 Before retrofitting of 3 storey structure

Beam Dimension: - 300 x 450 mm

Column Dimensions: - 300 x 530 mm

Table 2: Beam end displacement summary of 3 story structure before retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	66	57	1:EQX	**20.470**	0.121	0.001	20.470
Min X	150	117	2:EQZ	**-0.008**	-0.167	9.103	9.105
Max Y	10	18	2:EQZ	0.004	**0.176**	9.528	9.530
Min Y	150	118	2:EQZ	-0.004	**-0.176**	9.528	9.530
Max Z	10	18	2:EQZ	0.004	0.176	**9.528**	9.530
Min Z	150	117	1:EQX	20.203	0.119	**-0.005**	20.203
Max Rst	66	57	1:EQX	20.470	0.121	0.001	**20.470**

Table 3: Beam force detail summary of 3 story structure before retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	154	2:EQZ	0.000	**112.551**	-0.010	-25.794	0.105	78.359	-0.017
Min Fx	14	2:EQZ	0.000	**-112.551**	0.010	-25.794	0.105	78.359	0.017
Max Fy	74	1:EQX	0.000	6.125	**35.779**	0.001	-0.037	-0.001	55.790
Min Fy	174	2:EQZ	0.000	-0.559	**-36.155**	1.013	0.000	-1.350	-44.374
Max Fz	182	1:EQX	0.000	-0.217	0.003	**3.463**	0.068	-4.336	0.004
Min Fz	74	2:EQZ	0.000	0.139	0.000	**-34.411**	0.070	57.037	0.000
Max Mx	9	2:EQZ	0.000	2.168	0.033	1.551	**0.225**	-3.200	0.064
Min Mx	7	2:EQZ	0.000	2.168	-0.033	-1.551	**-0.225**	3.004	-0.069
Max My	70	2:EQZ	0.000	0.116	0.000	-33.584	0.063	**85.880**	0.000
Min My	78	2:EQZ	3.000	0.141	0.000	-30.543	0.088	**-51.223**	-0.000
Max Mz	70	1:EQX	0.000	7.732	35.675	0.000	-0.028	-0.001	**81.680**
Min Mz	60	1:EQX	0.000	-1.306	-26.315	-0.179	0.001	0.374	**-54.961**

3.2 After retrofitting of 3 storey structure

Beam Dimension: - 300 x 450 mm

Column Dimensions: - 300 x 600 mm

Table 4: Beam end displacement summary of 3 story structure after retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	66	57	1:EQX	**11.846**	0.078	0.001	11.846
Min X	150	117	2:EQZ	**-0.004**	-0.108	5.310	5.311
Max Y	10	18	2:EQZ	0.002	**0.112**	5.524	5.525
Min Y	150	118	2:EQZ	-0.002	**-0.112**	5.524	5.525
Max Z	150	118	2:EQZ	-0.002	-0.112	**5.524**	5.525
Min Z	150	117	1:EQX	11.713	0.078	**-0.002**	11.713
Max Rst	66	57	1:EQX	11.846	0.078	0.001	**11.846**

Table 5: Beam force detail summary of 3 story structure after retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	154	2:EQZ	0.000	**58.731**	-0.003	-12.561	0.024	31.309	-0.005
Min Fx	14	2:EQZ	0.000	**-58.731**	0.003	-12.561	0.024	31.309	0.005
Max Fy	74	1:EQX	0.000	3.025	**18.343**	0.000	-0.014	-0.001	27.823
Min Fy	174	2:EQZ	0.000	0.291	**-18.829**	0.509	0.000	-0.678	-23.274
Max Fz	182	1:EQX	0.000	-0.109	0.001	**1.722**	0.032	-2.156	0.002
Min Fz	74	2:EQZ	0.000	0.137	0.000	**-17.141**	0.028	26.732	0.000
Max Mx	9	2:EQZ	0.000	1.088	0.018	0.777	**0.109**	-1.603	0.035
Min Mx	7	2:EQZ	0.000	1.088	-0.018	-0.777	**-0.109**	1.505	-0.037
Max My	70	2:EQZ	0.000	0.106	0.000	-16.394	0.014	**35.031**	0.000
Min My	78	2:EQZ	3.000	0.125	0.000	-15.008	0.036	**-24.778**	-0.000
Max Mz	70	1:EQX	0.000	4.786	17.029	0.000	-0.007	-0.000	**31.529**
Min Mz	60	1:EQX	0.000	0.271	-13.339	-0.090	0.000	0.188	**-27.878**

3.3 Before retrofitting of 4 storey structure

Beam Dimension: - 350 x 550 mm

Column Dimensions: - 300 x 500 mm

Table 6: Beam end displacement summary of 4 story structure before retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	85	72	1:EQX	**26.476**	-0.389	-0.052	26.479
Min X	153	117	2:EQZ	**-6.129**	-0.284	7.520	9.706
Max Y	45	41	2:EQZ	2.660	**0.924**	5.633	6.298
Min Y	80	65	2:EQZ	-0.089	**-0.912**	5.635	5.709
Max Z	15	24	2:EQZ	6.075	0.384	**22.043**	22.868
Min Z	15	24	1:EQX	25.927	-0.381	**-0.057**	25.930
Max Rst	85	72	1:EQX	26.476	-0.389	-0.052	**26.479**

Table 7: Beam force detail summary of 4 story structure before retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	86	2:EQZ	0.000	**528.993**	-0.790	-5.695	2.412	12.113	-1.085
Min Fx	51	2:EQZ	0.000	**-535.235**	4.700	-5.664	2.538	12.079	10.667
Max Fy	91	1:EQX	0.000	25.415	**65.160**	-0.098	0.035	0.130	100.049
Min Fy	183	2:EQZ	0.000	0.538	**-59.233**	-1.609	-2.187	2.469	-94.915
Max Fz	229	2:EQZ	0.000	-1.087	-26.993	**12.311**	-0.412	-18.629	-40.492
Min Fz	58	2:EQZ	0.000	17.366	4.548	**-58.652**	3.117	89.050	6.746
Max Mx	20	2:EQZ	0.000	-148.068	9.803	-11.340	**4.111**	18.448	14.440
Min Mx	1	2:EQZ	0.000	-0.550	-11.821	-2.223	**-3.928**	4.272	-25.044
Max My	54	2:EQZ	0.000	30.720	5.637	-55.209	2.431	**95.829**	11.589
Min My	58	2:EQZ	3.000	17.366	4.548	-58.652	3.117	**-86.906**	-6.898
Max Mz	157	1:EQX	0.000	14.374	55.790	0.032	-0.007	-0.064	**101.035**
Min Mz	74	1:EQX	0.000	0.234	-53.302	-0.470	-0.035	1.155	**-115.409**

3.4 After retrofitting of 4 storey structure

Beam Dimension: - 350 x 550 mm

Column Dimensions: - 300 x 500 mm

Shear Wall: - 250mm

Table 8: Beam end displacement summary of 4 story structure after retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	120	96	1:EQX	**13.498**	-0.110	0.000	13.499
Min X	15	24	2:EQZ	**-0.005**	0.171	6.089	6.091
Max Y	13	22	2:EQZ	0.002	**0.175**	6.246	6.249
Min Y	223	166	2:EQZ	-0.002	**-0.175**	6.246	6.249
Max Z	13	22	2:EQZ	0.002	0.175	**6.246**	6.249
Min Z	15	24	1:EQX	13.421	-0.110	**-0.002**	13.421
Max Rst	120	96	1:EQX	13.498	-0.110	0.000	**13.499**

Table 9: Beam force detail summary of 4 story structure after retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	227	2:EQZ	0.000	**95.723**	-0.003	-14.056	0.016	35.504	-0.005
Min Fx	17	2:EQZ	0.000	**-95.723**	0.003	-14.056	0.016	35.504	0.005
Max Fy	126	1:EQX	0.000	2.673	**21.494**	-0.000	-0.000	0.000	33.627
Min Fy	291	2:EQZ	0.000	-0.133	**-27.153**	0.328	0.000	-0.327	-27.159
Max Fz	362	2:EQZ	0.000	-3.065	-7.262	**1.837**	0.002	-1.510	-6.677
Min Fz	126	2:EQZ	0.000	0.000	-0.000	**-19.654**	0.019	31.297	-0.000
Max Mx	12	2:EQZ	0.000	1.393	0.023	0.851	**0.081**	-1.757	0.045
Min Mx	10	2:EQZ	0.000	1.393	-0.023	-0.851	**-0.081**	1.648	-0.047
Max My	122	2:EQZ	0.000	0.000	0.000	-18.616	0.009	**39.936**	0.000
Min My	130	2:EQZ	3.000	0.000	-0.000	-18.624	0.027	**-29.196**	0.000
Max Mz	122	1:EQX	0.000	3.995	19.567	-0.000	-0.000	0.000	**39.439**
Min Mz	109	1:EQX	0.000	-0.009	-15.704	0.000	0.000	-0.000	**-32.429**

3.5 Before retrofitting of 5 storey structure

Beam Dimension: - 200 x 400 mm

Column Dimensions: - 300 x 400 mm

Table 10: Beam end displacement summary of 5 story structure before retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	132	105	7:GENERATEI	**147.447**	-1.028	0.000	147.450
Min X	132	105	9:GENERATEI	**-147.447**	1.028	0.000	147.450
Max Y	129	101	7:GENERATEI	147.447	**1.028**	0.000	147.450
Min Y	132	105	7:GENERATEI	147.447	**-1.028**	0.000	147.450
Max Z	22	33	8:GENERATEI	0.000	1.006	**127.544**	127.547
Min Z	22	33	10:GENERATE	0.000	-1.006	**-127.544**	127.547
Max Rst	132	105	7:GENERATEI	147.447	-1.028	0.000	**147.450**

Table 11: Beam force detail summary of 5 story structure before retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	137	7:GENERATEI	0.000	294.788	48.253	0.000	-0.000	-0.000	125.046
Min Fx	137	9:GENERATEI	0.000	-294.788	-48.253	-0.000	0.000	0.000	-125.046
Max Fy	139	7:GENERATEI	0.000	6.317	68.666	-0.000	-0.000	0.000	111.721
Min Fy	139	9:GENERATEI	0.000	-6.317	-68.666	0.000	0.000	-0.000	-111.721
Max Fz	86	10:GENERATE	0.000	-0.171	-0.000	67.835	-0.000	-120.894	-0.000
Min Fz	86	8:GENERATEI	0.000	0.171	0.000	-67.835	0.000	120.894	0.000
Max Mx	99	9:GENERATEI	0.000	56.952	-25.742	0.017	0.232	-0.027	-24.170
Min Mx	99	7:GENERATEI	0.000	-56.952	25.742	-0.017	-0.232	0.027	24.170
Max My	81	8:GENERATEI	0.000	1.608	0.000	-62.615	0.000	165.728	0.000
Min My	81	10:GENERATE	0.000	-1.608	-0.000	62.615	-0.000	-165.728	-0.000
Max Mz	134	7:GENERATEI	0.000	9.693	63.236	-0.000	-0.000	0.000	139.890
Min Mz	134	9:GENERATEI	0.000	-9.693	-63.236	0.000	0.000	-0.000	-139.890

3.6 After retrofitting of 5 storey structure

Beam Dimension: - 200 x 400 mm

Column Dimensions: - 350 x 450 mm

Table 12: Beam end displacement summary of 5 story structure after retrofitting

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	132	105	7:GENERATEI	147.447	-1.028	0.000	147.450
Min X	132	105	9:GENERATEI	-147.447	1.028	0.000	147.450
Max Y	129	101	7:GENERATEI	147.447	1.028	0.000	147.450
Min Y	132	105	7:GENERATEI	147.447	-1.028	0.000	147.450
Max Z	22	33	8:GENERATEI	0.000	1.006	127.544	127.547
Min Z	22	33	10:GENERATE	0.000	-1.006	-127.544	127.547
Max Rst	132	105	7:GENERATEI	147.447	-1.028	0.000	147.450

Table 13: Beam force detail summary of 5 story structure after retrofitting

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (m)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	137	7:GENERATEI	0.000	294.788	48.253	0.000	-0.000	-0.000	125.046
Min Fx	137	9:GENERATEI	0.000	-294.788	-48.253	-0.000	0.000	0.000	-125.046
Max Fy	139	7:GENERATEI	0.000	6.317	68.666	-0.000	-0.000	0.000	111.721
Min Fy	139	9:GENERATEI	0.000	-6.317	-68.666	0.000	0.000	-0.000	-111.721
Max Fz	86	10:GENERATE	0.000	-0.171	-0.000	67.835	-0.000	-120.894	-0.000
Min Fz	86	8:GENERATEI	0.000	0.171	0.000	-67.835	0.000	120.894	0.000
Max Mx	99	9:GENERATEI	0.000	56.952	-25.742	0.017	0.232	-0.027	-24.170
Min Mx	99	7:GENERATEI	0.000	-56.952	25.742	-0.017	-0.232	0.027	24.170
Max My	81	8:GENERATEI	0.000	1.608	0.000	-62.615	0.000	165.728	0.000
Min My	81	10:GENERATE	0.000	-1.608	-0.000	62.615	-0.000	-165.728	-0.000
Max Mz	134	7:GENERATEI	0.000	9.693	63.236	-0.000	-0.000	0.000	139.890
Min Mz	134	9:GENERATEI	0.000	-9.693	-63.236	0.000	0.000	-0.000	-139.890

CONCLUSION: Model analysis of 3 and 4 story structures concludes that there is a significant difference in the beam end displacement between storeys in x and z directions respectively before and after retro-fitting. There is also a huge displacement occurrence in the G+5 structure. The beam end displacement in the y direction is negligible. The axial force is drastically reduced after retrofitting in each of the structures. Change is only produced in one direction for beams and not much for columns. The shear force is also reduced after retro-fitting in all the structure models. The shear force found in beams and columns is similar in y and z directions respectively and hence the changes are similar too. No comparable changes are being witnessed for torsional force. The bending moments in columns is found to be the maximum. Also the changes in bending moment for columns is greater than for beams between the conventional and retro-fitted structure models. The displacement of the structure decreases after the application of bracing system. The model analysis of the buildings before and after retro-fitting evidently showed that the retro-fitting technique complimented in strengthening of the structural arrangement. It showed that retro-fitting aims in solidifying a structure to fulfil the desires of the current codes for seismic analysis and design. From completing the project it was conclude, that seismic retro-fitting provides existing buildings with greater resistance to earthquakes and accompanying forces.

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