Analysis of Seismic Retrofitting on RC Building

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Abstract- *The world has observed a large scale destruction due to frequent earthquakes, resulting in loss of mane lives and imparting failure of structures. It is the need of the hour to offer utmost attention to the adequacy of structures , specially RC framed structure keeping seismic situation into consideration. To represent the same, in this project a Fifty year old, fourstorey building is taken as the base of this study. The structure is constructed in Zone II as specified in IS 893:2000. The non structural members are considered to be infilled with brick masonary.*

The structure considered for this study has been modeled in STAAAD.Pro V8i taking into conisideration M15 grade concrete and Fe 250 grade steel. The structure is designed once without considering seismic loading and also considering seismic loading. The resulting moments and shear forces have been opted from the software analysis and thean a comparative study has been undergone with the capacity of the considered structure.

The most efficient method of retrofitting, FRP jacketing, is then applied of the failing members of considered 4-storey framed structure. For design of retro fittings, the specifications prescribed in ACI 440 2R.02 have been followed. The same code is used in the design calculations. Not only Serviceability checks but also creep rupture limit check are performed for the FRP strengthening system, as the structure is designed based on Limit State Method.

The only limitation involved with this thesis is that the code does not provide a specific method for the design of columns

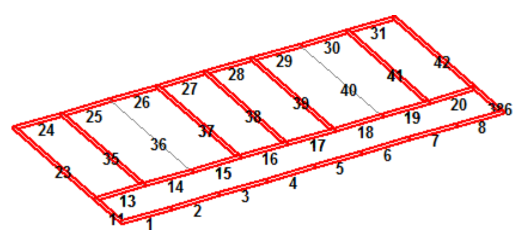
I. INTRODUCTION

India is segmented into four seismic zones, Zone II, Zone III, Zone IV and Zone V, based on Indian Standard 1893:2002. Different zone factors are assigned to respective zones mentioned above, based on intensity of earth quake and importance factors associated with it. Importance factor can be defined as a factor used to get the plan seismic power contingent upon the practical utilization of the construction, portrayed by hazardous consequences of its failure, its post-seismic tremor useful need, notable worth, or on the other hand financial significance. On the other hand, intensity of earthquake is defined as “The intensity of an earthquake at a spot is a measure of the strength of shaking during the earthquake, and is demonstrated by a number as indicated by the adjusted Mercalli Scale or M.S.K. Size of seismic powers”. Based on IS 1893:2002, the sieimic intensities of various zones are indicated below, with reference to mentiond IS code.

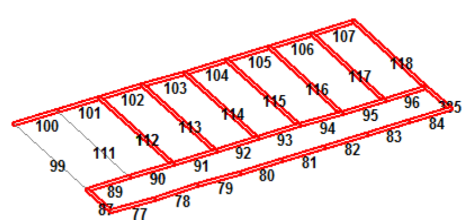
Table 2 Zone Factor, *Z*
(*Clause* 6.4.2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

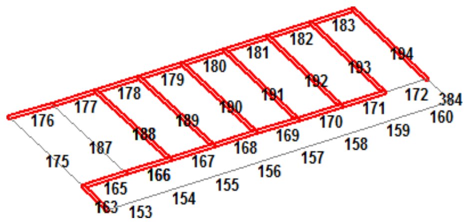
A 4-storey building is considered for the study in this project. The building is designed and analysed as Ordinary Moment Resisting Frame (OMRF), located in zone II (as prescribed in IS 1893:2002), having seismic intensity 0.10. The existing structure is considered to be at-least fifty years old and is not designed for resisting earthquake or seismic shakes. Since, the existing structure is not designed to resist seismic forces, it may fail when subjected to moderate or strong earthquake. On carrying out the seismic analysis of existing structure, it was found vulnerable to earthquakes and suitable retrofitting methods are suggested on priority basis.



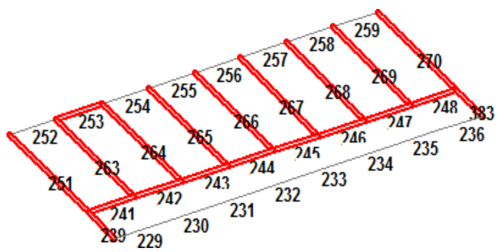
FIRST STOREY



SECOND STOREY



THIRD STOREY



FOURTH STOREY

To make any existing framed structure perform better under seismic situations, seismic retrofitting is the best and most popular method. Seismic retrofitting can be described as the procedure of modifying any existing framed structure, to make them less prone to failure under seismic situations. This resistance for earthquakes can be attained easily by following following mentioned practices-

- By reducing the seismic demands on members and the structures as a whole
- By increasing the member capacities

For performing the seismic analysis, an existing four-storey building is been considered. The existing structures consist of eight bays (rooms) spanning 3.5 meters . A projected slab cantilevered for 1.2 meters is provided in the structure. Floor height of existing structure is considered as 3.3 meters (clear span).

The structure is situated in Seismic Zone II, as specified in IS 1893:2002 Seismic zones classifications, which has the seismic intensity of 0.10. The structure is considered as Ordinary Moment Resisting Frame (OMRF). Also, the structure is built on medium soil.

The structure is then analyzed under seismic loading and the failing members are then retrofit using FRP Jacketing. The method of analysis used in the project is Equivalent Static Method. The initial part of analysis to determine the members that fail under earthquake loading is done by calculating the Demand- Capacity Ratio (DCR) for each member individually. Determining which members will fail is essential because it gives a rough idea about which retrofit technique to proceed with- global or local.

The detailed evaluation of the building involves equivalent static lateral force procedure, load with response reduction factors and Demand Capacity Ratio (DCR) for ductility as in IS 13920:1993. Since the building dates back to a period 50 years early, the grade of concrete is assumed to be M15 and for steel Fe250.

Checks done:

1. DCR for moments of resistance in sagging and hogging for beams
2. DCR for shear capacity in beams
3. DCR for moment of resistance in columns
4. DCR for shear capacity in columns

Demand stands for the forces or loads applied to the structural element under seismic loading.

Capacity of the structural element can be defined as permissible strength of the same

DCR= Demand/Capacity

The member is said to be passing if the demand to capacity ratio does not exceeds unity (one).

Conversely , The member is said to be failed if the demand to capacity ratio exceeds unity (one).

The demand to capacity ratio is proved to be an important and key feature in determining whether the structural element is passed or failed under given loading exposure. In this project, flexure and shear checks are performed for all the structural members for which demand to capacity ratio is exceeding unity (ONE).

II. RESULTS AND OBSERVATIOBS

Moment Capacity of Beams

Table 1 First Storey

Beam No.	Demand (kNm)	Capacity Sagging (kNm)	DCR Sagging	Result Sagging	Capacity Hogging (kNm)	DCR Hogging	Result Hogging
1	44.184	34.011	1.29910911	FAIL	34.011	1.2991091	FAIL
2	42.166	34.012	1.23973891	FAIL	34.012	1.2397389	FAIL
3	42.105	34.012	1.23794543	FAIL	34.012	1.2379454	FAIL
4	41.664	34.012	1.22497941	FAIL	34.012	1.2249794	FAIL
5	41.785	34.012	1.22853698	FAIL	34.012	1.228537	FAIL
6	42.158	34.012	1.23950370	FAIL	34.012	1.2395037	FAIL
7	41.522	34.012	1.22080442	FAIL	34.012	1.2208044	FAIL
8	44.431	34.01	1.30640987	FAIL	34.01	1.3064099	FAIL
11	44.328	35.622	1.24439952	FAIL	58.201	0.7616364	PASS
13	101.59	58.086	1.74895844	FAIL	125.645	0.8085479	PASS
14	102.405	50.328	2.03475202	FAIL	123.639	0.8282581	PASS
15	99.518	50.329	1.97734904	FAIL	112.7	0.8830346	PASS
16	92.931	40.971	2.26821410	FAIL	108.49	0.8565859	PASS
17	92.767	40.971	2.26421127	FAIL	108.49	0.8550742	PASS
18	98.034	50.328	1.94790176	FAIL	123.639	0.7929052	PASS
19	100.109	50.329	1.98909177	FAIL	110.541	0.9056278	PASS
20	92.615	44.856	2.06471820	FAIL	93.613	0.9893391	PASS
23	400.526	243.567	1.64441816	FAIL	460.281	0.8701771	PASS
24	109.261	75.889	1.43974752	FAIL	141.761	0.7707409	PASS
25	112.292	72.906	1.54022988	FAIL	127.291	0.8821676	PASS
26	106.209	69.672	1.52441439	FAIL	125.197	0.848335	PASS
27	97.311	51.021	1.90727347	FAIL	110.859	0.8777907	PASS
28	97.158	55.001	1.76647697	FAIL	111.248	0.873346	PASS
29	105.714	69.673	1.51728790	FAIL	126.993	0.8324396	PASS
30	107.219	69.673	1.53888880	FAIL	126.993	0.8442906	PASS
31	97.257	57.234	1.69928713	FAIL	122.974	0.7908745	PASS
35	306.418	301.599	1.01597817	FAIL	373.599	0.8201789	PASS
36	448.541	556.128	0.80654273	PASS	560.128	0.800783	PASS
37	294.079	190.597	1.54293614	FAIL	366.239	0.8029702	PASS
38	291.341	190.597	1.52857075	FAIL	366.239	0.7954942	PASS
39	292.528	190.597	1.53479855	FAIL	366.239	0.7987353	PASS
40	446.49	521.15	0.85673990	PASS	521.15	0.8567399	PASS

Table 2 Second Storey

Beam No.	Demand (kNm)	Capacity Sagging (kNm)	DCR Sagging	Result Sagging	Capacity Hogging (kNm)	DCR Hogging	Result Hogging
77	41.635	33.966	1.225784608	FAIL	33.966	1.225784608	FAIL
78	39.868	33.966	1.173761997	FAIL	33.966	1.173761997	FAIL
79	39.349	33.966	1.158482011	FAIL	33.966	1.158482011	FAIL
80	38.981	33.966	1.147647648	FAIL	33.966	1.147647648	FAIL
81	38.954	33.966	1.146852735	FAIL	33.966	1.146852735	FAIL
82	39.358	33.966	1.158746982	FAIL	33.966	1.158746982	FAIL
83	39.193	33.966	1.153889183	FAIL	33.966	1.153889183	FAIL
84	41.485	33.966	1.221368427	FAIL	33.966	1.221368427	FAIL
87	39.57	16.443	2.406495165	FAIL	16.297	2.428054243	FAIL
89	94.49	69.548	1.358630011	FAIL	48.516	1.947604914	FAIL
90	97.854	69.548	1.406999482	FAIL	48.516	2.016942864	FAIL
91	94.792	69.548	1.362972336	FAIL	48.516	1.953829664	FAIL
92	87.456	69.548	1.257491229	FAIL	48.516	1.802621815	FAIL
93	87.048	69.548	1.251624777	FAIL	48.516	1.794212219	FAIL
94	93.008	69.548	1.337320987	FAIL	48.516	1.91705829	FAIL
95	95.088	69.548	1.367228389	FAIL	48.516	1.959930744	FAIL
96	86.691	69.548	1.246491632	FAIL	48.516	1.786853821	FAIL
99	394.924	970.763	0.406818142	PASS	409.104	0.965338887	PASS
100	99.675	40.446	2.464396974	FAIL	40.446	2.464396974	FAIL
101	106.372	40.446	2.62997577	FAIL	40.446	2.62997577	FAIL
102	100.11	40.446	2.475152055	FAIL	40.446	2.475152055	FAIL
103	90.447	40.446	2.236240914	FAIL	40.446	2.236240914	FAIL
104	90.01	40.446	2.225436384	FAIL	40.446	2.225436384	FAIL
105	99.33	40.446	2.455867082	FAIL	40.446	2.455867082	FAIL
106	100.827	40.446	2.492879395	FAIL	40.446	2.492879395	FAIL
107	89.468	40.446	2.212035801	FAIL	40.446	2.212035801	FAIL
111	302.934	480.549	0.63039149	PASS	313.796	0.965385155	PASS
112	440.714	137.43	3.206825293	FAIL	136.211	3.235524297	FAIL
113	290.215	136.436	2.127114545	FAIL	135.57	2.14070222	FAIL
114	287.427	129.37	2.221743836	FAIL	128.566	2.235637727	FAIL
115	288.638	129.37	2.231104584	FAIL	128.566	2.245057014	FAIL

Table 3 Third Storey

Beam No.	Demand (kNm)	Capacity Sagging (kNm)	DCR Sagging	Result Sagging	Capacity Hogging (kNm)	DCR Hogging	Result Hogging
153	32.794	33.966	0.965494907	PASS	33.966	0.965494907	PASS
154	32.611	33.966	0.960107166	PASS	33.966	0.960107166	PASS
155	32.97	33.966	0.970676559	PASS	33.966	0.970676559	PASS
156	32.597	33.966	0.959694989	PASS	33.966	0.959694989	PASS
157	32.457	33.966	0.95557322	PASS	33.966	0.95557322	PASS
158	32.859	33.966	0.967408585	PASS	33.966	0.967408585	PASS
159	33.18	33.966	0.976859212	PASS	33.966	0.976859212	PASS
160	32.423	33.966	0.954572219	PASS	33.966	0.954572219	PASS
163	32.127	16.443	1.95384054	FAIL	16.297	1.971344419	FAIL
165	74.554	69.548	1.071979065	FAIL	48.516	1.536688927	FAIL
166	80.358	69.548	1.155432219	FAIL	48.516	1.656319565	FAIL
167	77.532	69.548	1.114798413	FAIL	48.516	1.59807074	FAIL
168	70.557	69.548	1.014507966	FAIL	48.516	1.454303735	FAIL
169	69.716	69.548	1.002415598	FAIL	48.516	1.436969247	FAIL
170	75.755	69.548	1.089247714	FAIL	48.516	1.561443647	FAIL
171	77.483	69.548	1.114093863	FAIL	48.516	1.597060763	FAIL
172	69.493	69.548	0.999209179	PASS	48.516	1.432372825	FAIL
175	362.301	970.763	0.373212617	PASS	409.104	0.885596328	PASS
176	76.084	40.446	1.881125451	FAIL	40.446	1.881125451	FAIL
177	85.568	40.446	2.115610938	FAIL	40.446	2.115610938	FAIL
178	80.124	40.446	1.981011719	FAIL	40.446	1.981011719	FAIL
179	71.249	40.446	1.761583346	FAIL	40.446	1.761583346	FAIL
180	70.217	40.446	1.736067844	FAIL	40.446	1.736067844	FAIL
181	79.147	40.446	1.956856055	FAIL	40.446	1.956856055	FAIL
182	80.246	40.446	1.984028087	FAIL	40.446	1.984028087	FAIL
183	68.936	40.446	1.704395985	FAIL	40.446	1.704395985	FAIL
187	275.402	480.549	0.573098685	PASS	313.796	0.877646624	PASS
188	429.371	137.43	3.124288729	FAIL	136.211	3.152249084	FAIL
189	264.009	136.436	1.935039139	FAIL	135.57	1.947399867	FAIL
190	262.013	129.37	2.025299528	FAIL	128.566	2.037964936	FAIL
191	262.65	129.37	2.03022339	FAIL	128.566	2.04291959	FAIL

Table 4 Fourth Storey

Beam No.	Demand (kNm)	Capacity Sagging (kNm)	DCR Sagging	Result Sagging	Capacity Hogging (kNm)	DCR Hogging	Result Hogging
229	17.826	33.966	0.524818937	PASS	33.966	0.524818937	PASS
230	22.182	33.966	0.65306483	PASS	33.966	0.65306483	PASS
231	21.264	33.966	0.626037803	PASS	33.966	0.626037803	PASS
232	20.986	33.966	0.617853147	PASS	33.966	0.617853147	PASS
233	20.92	33.966	0.615910028	PASS	33.966	0.615910028	PASS
234	21.106	33.966	0.621386092	PASS	33.966	0.621386092	PASS
235	21.8	33.966	0.641818289	PASS	33.966	0.641818289	PASS
236	17.114	33.966	0.503856798	PASS	33.966	0.503856798	PASS
239	26.452	16.443	1.608708873	FAIL	16.297	1.62312082	FAIL
241	32.311	20.766	1.555956853	FAIL	20.766	1.555956853	FAIL
242	37.358	20.766	1.798998363	FAIL	20.766	1.798998363	FAIL
243	34.641	20.766	1.668159491	FAIL	20.766	1.668159491	FAIL
244	29.257	20.766	1.408889531	FAIL	20.766	1.408889531	FAIL
245	29.388	20.766	1.41519792	FAIL	20.766	1.41519792	FAIL
246	33.476	20.766	1.612058172	FAIL	20.766	1.612058172	FAIL
247	35.213	20.766	1.695704517	FAIL	20.766	1.695704517	FAIL
248	28.521	20.766	1.373446981	FAIL	20.766	1.373446981	FAIL
251	181.786	124.965	1.454695315	FAIL	124.361	1.46176052	FAIL
252	34.818	40.446	0.860851506	PASS	40.446	0.860851506	PASS
253	42.967	40.446	1.06233002	FAIL	40.446	1.06233002	FAIL
254	38.097	40.446	0.941922563	PASS	40.446	0.941922563	PASS
255	31.638	40.446	0.782228156	PASS	40.446	0.782228156	PASS
256	31.923	40.446	0.789274588	PASS	40.446	0.789274588	PASS
257	37.402	40.446	0.924739158	PASS	40.446	0.924739158	PASS
258	39.093	40.446	0.96654799	PASS	40.446	0.96654799	PASS
259	30.256	40.446	0.748059141	PASS	40.446	0.748059141	PASS
263	177.643	129.279	1.374105617	FAIL	128.6	1.381360809	FAIL
264	182.458	106.074	1.720101062	FAIL	105.328	1.732283913	FAIL
265	170.208	140.375	1.212523598	FAIL	139.656	1.218766111	FAIL
266	168.496	140.375	1.200327694	FAIL	139.656	1.206507418	FAIL

III. CONCLUSION

The analysis of beams by Equivalent Static Method revealed that most of the beams failed in flexural capacity. The number of failing beams decreased with increasing storeys. However, the number of beams failing in shear capacity were very less i.e. beams 23, 36, 40 in 1st storey; 112, 116, 118 in 2nd storey; 188, 192 in 3rd storey.

Based on the above observations, the immediate need to counter deficiency in flexural capacity was identified and the FRP jacketing scheme was suggested only for beams, failing in flexure. Due to the high tensile strength and stiffness, stability under high temperatures and resistance to acidic/alkali/organic environments, carbon fiber was chosen as the FRP material to be used.FRP strips that are commercially available are not made to a universal standard but a localized standard as set by the manufacturing company. Thus, the dimensions considered for the strips were strictly as per a design example in ACI 440.2R-02. The code states though, that wider and thinner FRP strips have lower bond stresses and hence, provide higher level of strength.The FRP design method used in this project is essentially trial and error where the value of the depth of neutral axis has to be assumed and compared with the value obtained. Thus, efforts were made so that the number of plies to be applied to a continuous series of beams, say in the longitudinal or transverse direction, would remain the same. This would ensure feasibility of application of the FRP system to the beams.

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