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Study of FRP Jacketing with Multy-Storey RC Building Construction

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Abstract— In the recent past, India has seen mass destruction due to failure of structures hit by earthquakes and consequently, lost a lot of lives. Hence, it is of utmost importance that attention be given to the evaluation of the adequacy of strength in framed RC structures to resist strong ground motions. In this project, a 50-year old four storey reinforced concrete structure has been considered, which lies in Zone II according to IS 1893:2000 classification of seismic zones in India. For non-structural members masonry infill has been assumed. In the Equivalent Static Method of analysis, the seismic load acting on the structure is assumed to be an equivalent static horizontal force applied to individual frames. The total force applied shall be equal to the product of the acceleration response spectrum and the seismic weight. It is used only for low to high rise buildings without significant coupled lateral-torsional modes. The structure is designed in STAAD.Pro v8i, considering M15 concrete and Fe250 steel reinforcement for with and without earthquake loading conditions. The demand moments and shear have been noted down from the software analysis and compared to the capacities of the given section. The limitations of this project are that not much is known about the behavior of FRP materials and thus, no standardization has been achieved in it commercially. Also the code does not give a specific method of jacketing columns.

Key words: Demand Capacity Ratio, Shear Capacity, Reinforced Concrete Structure, FRP Strengthening

I. INTRODUCTION

According to the Seismic Zoning Map of IS 1893:2002, India is divided into five seismic zones, in ascending order of a certain zone factor which is assigned to them on the basis of their seismic intensity. The 4-storey RC Structure being analysed in this particular project is the main institute building of AJANTA Apartment, Indrapuri, Bhopal. Which is located in the least susceptible zone i.e. zone II. However, considering that the primary structural system of the building is at least 50 years old, it was not designed according to the design provisions given in IS 1893:2002. Hence, it may fail in the event of any moderately strong tectonic activity in its vicinity. Studying the performance of the structure and suggesting suitable retrofit measures for the building would therefore be a necessity. Performance-based earthquake engineering deals with the seismic design of structures that will meet more than one performance level. The levels are-Operational, Immediate Occupancy, Life-Safety and Near Collapse and they are based on their hazard level as well as annual probability of exceedance.

Any Reinforced Concrete frame building has the following sources of weakness

- Discontinuous load path/interrupted load path/irregular load path
- Lack of deformation capability of structural members
- Quality of workmanship and materials

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. This goal maybe achieved by adopting one of the following strategies:-

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

II. DEMAND CAPACITY RATIO

The calculation of Demand Capacity Ratio to identify the failing members, is the part of Equivalent Static Analysis. Demand is the amount of force or deformation imposed on an element or component (in this case, with respect to earthquake loading). Capacity is the permissible strength or deformation of a structural member or system (from the existing frame of the building).

DCR= Demand/Capacity

If DCR is lesser than 1, the member passes, else it passes. It is an important tool used to determine whether a certain member of the structure is passing or failing due to moment and/or shear. The check for DCR exceeding 1 was performed for both flexural and shear capacities of the beams as well as columns of the structure.

III. CALCULATION OF DCR

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.

IV. FRP STRENGTHENING OF CONCRETE MEMBERS

The design philosophy for such sections is coherence with limit state principles. This approach sets acceptable levels of safety against the occurrence of both serviceability limit states (excessive deflections, cracking) and ultimate-limit states (failure, stress rupture, fatigue). While calculating the flexural resistance of a section strengthened with an externally applied FRP system,

V. EXPERIMENTAL RESULTS

The experimental investigation describes in detail of the materials and its fundamental constituents.

A. *Shear Capacity of Beams*

Beam No.	Max Shear (kN)	Shear Resisted (kN)	DCR	Result
1	57.278	131.97	0.434022884	PASS
2	52.439	131.97	0.39735546	PASS
3	52.464	131.97	0.397544897	PASS
4	52.069	131.97	0.394551792	PASS
5	52.035	131.97	0.394294158	PASS
6	52.506	131.97	0.397863151	PASS
7	51.974	131.97	0.393831931	PASS
8	56.553	131.97	0.428529211	PASS
11	34.446	119.133	0.289139029	PASS
13	102.93	131.97	0.779949989	PASS
14	113.103	131.97	0.85703569	PASS
15	111.837	131.97	0.847442601	PASS
16	106.236	131.97	0.805001137	PASS
17	106.308	131.97	0.805546715	PASS
18	110.865	131.97	0.84007729	PASS
19	112.105	131.97	0.849473365	PASS
20	107.247	131.97	0.812661969	PASS
23	231.938	220.076	1.053899562	FAIL
24	113.554	152.455	0.744836181	PASS
25	113.181	152.455	0.742389558	PASS
26	110.244	152.455	0.723124857	PASS
27	102.256	152.455	0.670729068	PASS
28	102.539	152.455	0.672585353	PASS
29	109.94	152.455	0.721130825	PASS
30	110.66	152.455	0.725853531	PASS
31	104.293	152.455	0.684090387	PASS
35	171.364	293.98	0.582910402	PASS
36	296.167	285.796	1.036288122	FAIL
37	170.205	293.98	0.578967957	PASS
38	168.774	293.98	0.574100279	PASS
39	169.559	293.98	0.576770529	PASS
40	295.45	253.308	1.166366637	FAIL
41	169.327	293.98	0.575981359	PASS
42	104.764	198.252	0.528438553	PASS
386	34.178.	75.522	0.452556871	PASS

Table 5.1: 1st Storey

Beam No.	Maximum Shear (kN)	Shear Resisted (kN)	DCR	Result
77	53.15	53.15	8.50724365	PASS
78	51.57	51.57	8.767888307	PASS
79	50.969	50.969	8.871274696	PASS
80	50.642	50.642	8.928557324	PASS
81	50.504	50.504	8.952954221	PASS
82	51.033	51.033	8.860149315	PASS
83	51.074	51.074	8.85303677	PASS
84	52.378	52.378	8.632632021	PASS
87	30.349	30.349	7.449339352	PASS
89	109.243	109.243	3.592907555	PASS
90	110.005	110.005	3.568019635	PASS
91	108.609	108.609	3.613880986	PASS
92	102.573	102.573	3.826543047	PASS
93	102.416	102.416	3.832408999	PASS
94	107.406	107.406	3.65435823	PASS
95	108.612	108.612	3.613781166	PASS
96	103.131	103.131	3.805839175	PASS
99	231.911	231.911	4.231149018	PASS
100	106.664	106.664	5.151691292	PASS
101	109.105	109.105	5.036432794	PASS
102	106.042	106.042	5.181909055	PASS
103	97.652	97.652	5.627124892	PASS
104	97.624	97.624	5.628738835	PASS
105	105.507	105.507	5.208185239	PASS
106	106.144	106.144	5.176929454	PASS
107	98.937	98.937	5.554039439	PASS
111	157.938	157.938	9.940609606	PASS
112	296.119	296.119	4.750522594	FAIL
113	170.183	170.183	3.690145314	PASS
114	168.795	168.795	3.720489351	PASS
115	169.552	169.552	3.703878456	PASS
116	256.629	256.629	5.481531705	FAIL
117	169.147	169.147	3.712746901	PASS
118	230.11	230.11	0.982486637	FAIL
385	33.344	33.344	6.780230326	PASS

Table 5.2: 2nd Storey

Beam No.	Maximum Shear (kN)	Shear Resisted (kN)	DCR	Result
153	48.561	48.561	9.311175635	PASS
154	51.073	51.073	8.853210111	PASS
155	50.061	50.061	9.032180739	PASS
156	49.421	49.421	9.149147124	PASS
157	49.069	49.069	9.214779188	PASS
158	50.072	50.072	9.030196517	PASS
159	50.334	50.334	8.983192276	PASS
160	47.29	47.29	9.561429478	PASS
163	24.88	24.88	9.08681672	PASS
165	95.266	95.266	4.120042827	PASS
166	98.287	98.287	3.993407063	PASS
167	96.887	96.887	4.051111088	PASS
168	91.341	91.341	4.297084551	PASS
169	90.744	90.744	4.325354844	PASS
170	95.686	95.686	4.101958489	PASS
171	96.609	96.609	4.062768479	PASS
172	91.921	91.921	4.269970953	PASS
175	232.136	232.136	4.227047937	PASS
176	90.344	90.344	6.082307624	PASS
177	95.091	95.091	5.778675164	PASS
178	92.349	92.349	5.950253928	PASS
179	84.903	84.903	6.472091681	PASS
180	84.265	84.265	6.521094167	PASS
181	91.671	91.671	5.994262089	PASS
182	92.011	92.011	5.97211203	PASS
183	85.495	85.495	6.427276449	PASS
187	171.341	171.341	9.163014106	PASS
188	295.941	295.941	4.753379897	FAIL
189	170.148	170.148	3.690904389	PASS
190	168.927	168.927	3.717582151	PASS
191	169.573	169.573	3.703419766	PASS
192	295.571	295.571	4.759330246	FAIL
193	169.424	169.424	3.70667674	PASS
194	105.565	105.565	2.141618908	PASS

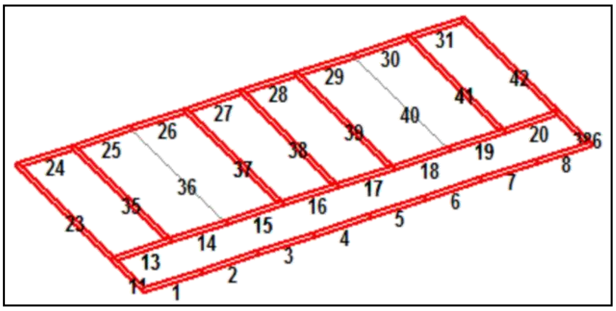
384	30.348	30.348	7.449584816	PASS

Table 5.3: 3rd Story

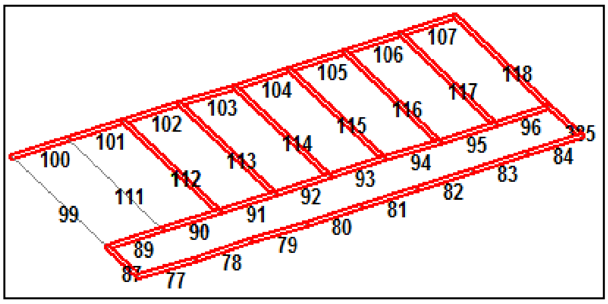
Beam No.	Maximum Shear (kN)	Shear Resisted (kN)	DCR	Result
229	36.349	36.349	12.43940686	PASS
230	37.414	37.414	12.08531566	PASS
231	36.406	36.406	12.41993078	PASS
232	35.968	35.968	12.57117438	PASS
233	35.725	35.725	12.656683	PASS
234	36.479	36.479	12.39507662	PASS
235	36.982	36.982	12.22648856	PASS
236	35.584	35.584	12.70383453	PASS
239	30.462	30.462	7.421705732	PASS
241	38.499	38.499	10.19507	PASS
242	41.603	41.603	9.434415787	PASS
243	40.21	40.21	9.76125342	PASS
244	35.537	35.537	11.04482652	PASS
245	35.652	35.652	11.00920004	PASS
246	39.336	39.336	9.978137075	PASS
247	40.173	40.173	9.0243696	PASS
248	35.501	35.501	11.05602659	PASS
251	118.319	118.319	1.326921289	PASS
252	41.524	41.524	13.23331086	PASS
253	46.056	46.056	11.93112732	PASS
254	43.73	43.73	12.56574434	PASS
255	37.674	37.674	14.58565589	PASS
256	37.896	37.896	14.5002111	PASS
257	43.134	43.134	12.73937033	PASS
258	43.687	43.687	12.57811248	PASS
259	30.912	30.912	17.77626812	PASS
263	128.945	128.945	1.753305673	PASS
264	129.056	129.056	3.114306968	PASS
265	128.192	128.192	1.224725412	PASS
266	127.467	127.467	1.23169134	PASS
267	127.979	127.979	1.226763766	PASS
268	128.581	128.581	3.125811745	PASS
269	127.817	127.817	1.228318612	PASS
270	118.121	118.121	1.329145537	PASS
383	32.8	32.8	6.892682927	PASS

Table 5.4: Terrace

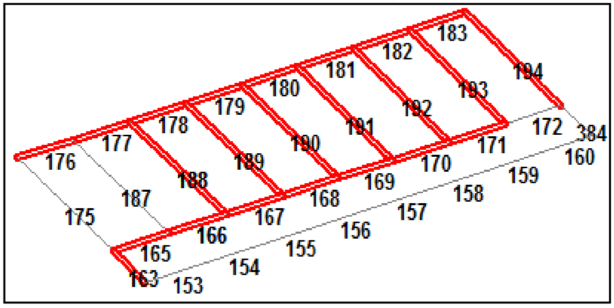
VI. EXPERIMENTAL SETUP



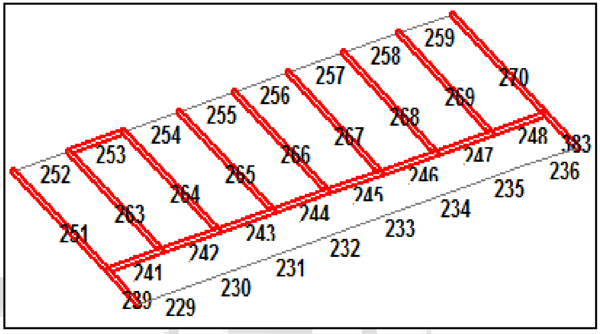
(a) First Storey



(b) Second Storey



(c) Third Storey



Terrace

Fig. 1: Beams Failing Due To Flexural Capacity

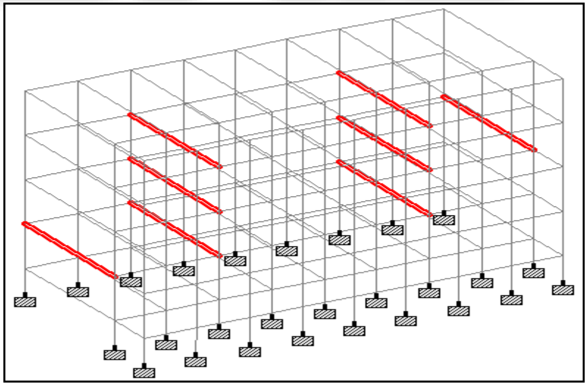
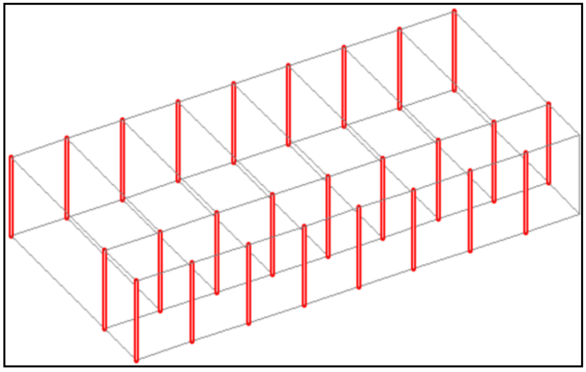
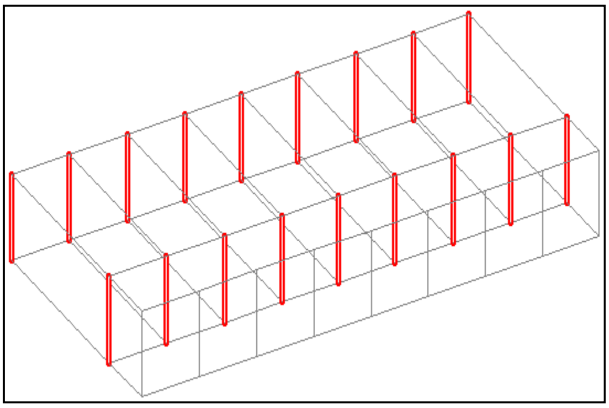


Fig. 2: Beams Failing Due To Shear Capacity



1st Level



2nd, 3rd And 4th Levels
Fig. 3: Columns Failing Due To Flexural Capacity

VII. CONCLUSIONS

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. For columns too, the analysis revealed that most of them failed in flexural capacity but were safe in shear.

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.

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