SEISMIC PERFORMANCE OF RC BUILDING WITH JACKETING ON BEAM-COLUMN JOINTS

G. Hemalatha, Assistant Professor, Department of Civil Engineering, Geethanjali college of Engineering and Technology

U. Thirumalesh, Assistant Professor, Department of Civil Engineering, Matrusri Engineering College

Syed Mushtaq Hashmi, Assistant Professor, Department of Civil Engineering, Muffakham Jah College of Engineering and Technology

ABSTRACT

Seismic retrofitting of contructions are vulnerable to earthquake.Most of the indian building stock is vulnerable to seismic action even if located in areas that have long been consideredof high sesmic hazard. 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.The structure is designed in STAAD.Pro v8i, considering M20 concrete and Fe250 steel reinforcement for with and without earthquake loading conditions. Aim is to focus on beam-column joints safe for occupation.

The limitations of this project in existing building which may require extensive repair before it is generally useful or considered 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

Keywords- *Equivalent Static Method, Demand Capacity Ratio, Flexural Capacity, Shear Capacity, Reinforced Concrete Structure, FRP Strengthening*

1. GENERAL

Fibre reinforced polymer (FRP) composites consist of high strength fibres. Fibres typically used in FRP are glass, carbon and aramid. These fibres are all linear elastic up to failure, with no significant yielding compared to steel. The repair and upgrading of reinforced concrete structures damaged by seismic actions are challenging fields of study in earthquake engineering, which have been developed during the last two decades guidance. On the other hand, the failure of joints may, in many cases, lead to general failure of the whole construction. Research in this area is essential since engineers in seismic-prone regions often face the problem of designing repair or strengthening works for damaged buildings without quantitative.The primary functions of the matrix in a composite are to transfer stress between the fibres, to provide a barrier against the environment and to protect the surface of the fibres from mechanical abrasion. Adhesives are used to attach the composites to other surfaces such as concrete. The most common adhesives are acrylics, epoxies and urethanes. Epoxies provide high bond strength with high temperature resistance, whereas acrylics provide moderate temperature resistance with good strength and rapid curing. Several considerations are involved in applying adhesives effectively. Careful surface preparation such as removing the cement paste, grinding the surface by using a disc sander, removing the dust generated by surface grinding using an air blower and carful curing are critical to bond

- Ductile components are to be designed with sufficient deformation capacity at least to satisfy displacement-based demand-capacity ratio to have good energy dissipation.
- Brittle components should be designed to achieve sufficient strength levels so as to satisfy

strength-based demand-capacity ratio

- Jacketing is a member-level retrofit technique. It can be used to increase concrete confinement, shear or flexural strength of the members. Popular practices involve jacketing with concrete, steel or fiber reinforced polymers (FRP).

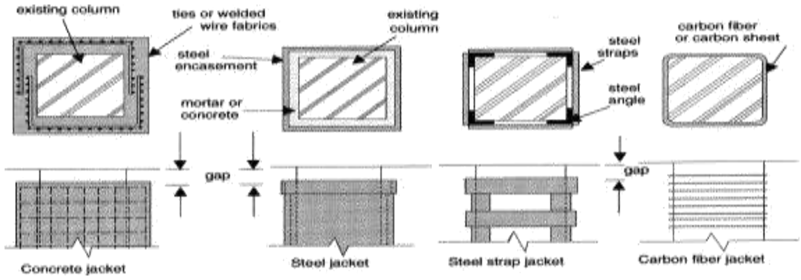


Fig. 1.1 Types of jacketing in seismic retrofitting

2 .THEORY

2.1 Demand Capacity Ratio

The calculation of Demand Capacity Ratio to identify the failing members, is the part of Equivalent Static Analysis.

DCR= Demand/Capacity

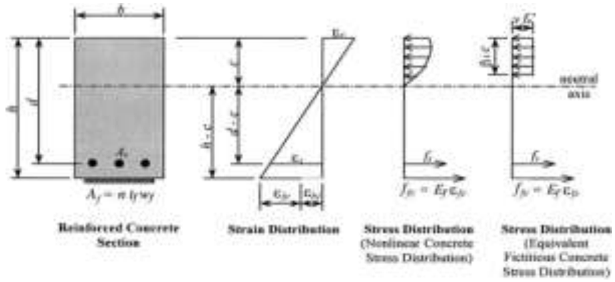
If DCR is lesser than 1, the member passes, else it passes. It is an important tool used to determine whether a certain member of the structure is passing or failing due to moment and/or shear. The check for DCR exceeding 1 was performed for both flexural and shear capacities of the beams as well as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

2.2 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).

By applying limit state analysis, the internal strain and stress distribution for a rectangular section of concrete can be found out at the ultimate stage. Thereafter, the strain level in the FRP reinforcements can be determined.. The maximum strain for the FRP will be developed at the point at which concrete crushes, FRP ruptures or FRP debonds from the substrate.

ACI- 440.2R-02 (Clause 11.3.2) mentions that confining rectangular sections with FRP is effective in improving the ductility of compression members but not in increasing their axial strength. Hence, due to lack of any suggested method, the design of FRP jacketing was performed only for the failing beams.



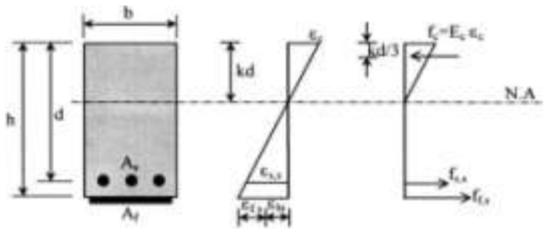


Fig 2.1 Internal strain and stress distribution for a stress rectangular concrete section (FRP strengthened) under ultimate stage

Fig 2.2 Elastic strain and distribution flexure at

3. CALCULATION OF DCR

The structural engineering group that tried to use the design spectra for the analysis and retrofit of the bridge found that a large number of members in the structure required retrofit. After a careful study of the maximum peak values of the member forces (especially the large peak axial forces), it was decided to run new time-history analyses using the basic time-history records that were used to create the design spectra. After running all the time-history records, the maximum Demand/Capacity Ratios were reduced by approximately a factor of three compared to the design spectra results.

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 M20 and for steel Fe250.

Checks done by these types :

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.

For finding DCR for moments of resistance in sagging and hogging:

- In hogging, the capacity moment of resistance is calcuated by the formula-
  Mr (H) = 0.36fckbXu (d- 0.44Xu) + fscAsc (d-d')
- In sagging, the capacity moment of resistance is calcuated by the formula-
  Mr (S) = 0.36fckbXu (d- 0.44Xu) + fscAst (d-d')
  d' = effective cover= 33 mm

For finding DCR for moments of resistance in columns:

- The Interaction diagram in SP-16 has been used to find the value of Mu/fckbD^2 for the corresponding values of P/fck and Pu/fckbD

For finding DCR for shear capacity of beams:

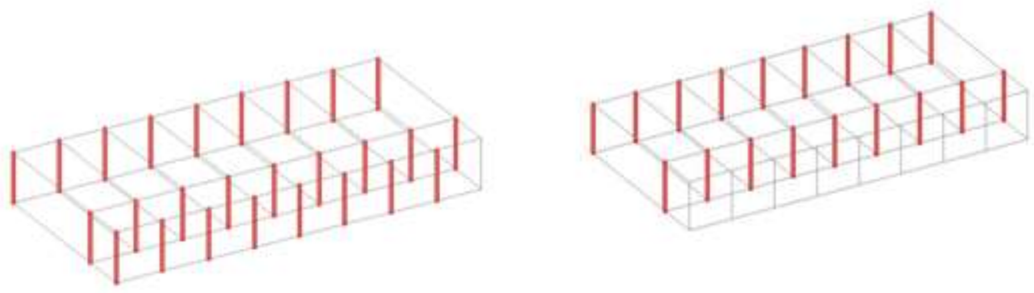
- Calculate the percentage of steel 100As/bd.
- For the corresponding percentage, find the value of τc(design shear strength of concrete) from table 19 of IS 456: 2000. The following are calculated-Vus = 0.87 fyAsv d / Sv Vu1 = Vus+ τcbd Vu2= 1.4 [MR(H) + MR(S)]/ Lc whereLc= clear span of the member
- Shear resisted (capacity) is given by the maximum of Vu1 and Vu2

For finding DCR for shear capacity of columns:

- From table 19 of IS 456: 2000. The calculation are follows

Fig. 3.1 Beams Failing due to Flexural Capacity


Fig. 3.2 Beams Failing due to Shear Capacity



1st Level 2nd, 3rd and 4th Levels

Fig. 3.3 Columns Failing due to Flexural Capacity

3.1 DESIGN OF FRP JACKETING:

3.1.1 PROVIDING FLEXURAL STRENGTHENING TO BEAMS USING FRP:

Stress level in the reinforcing steel and FRP-

$f_s = E_s \varepsilon_s <= f_y$

ffe= Efεfe

Design flexural strength of the section-

ΦMn = Φ[Asfs (d- b1c/2) + yAfffe(h-b1c/2))]

This should be greater than the required moment strength Mu

Calculation of service stresses in the reinforcing steel and the FRP by-

k= $[(psEs/Ec + pfEf/Ec)^2 + 2 (psEs/Ec + pfEfh/Ecd)-(psEs/Ec + pfEf/Ec)]^{0.5}$

$f_{s,s} = \dfrac{[M_s + \varepsilon_{bi} A_f E_f (h - kd/3)](d - kd) E_s}{A_s E_s (d-kd/3)(d-kd) + A_f E_f (h - kd/3)(h-kd)}$

$f_{s,s} <= 0.80\ f_y$ (Serviceability conditions)

$f_{f,s} = f_{s,s}\ [E_f(h-kd)/E_s(d-kd)] - \varepsilon_{bi} E_f$

$f_{f,s} <= 0.55\ f_u$ (Creep-rupture stress limit)

For the calculations values assumed are as follows-

Environmental Reduction Factor Ce for carbon fibers = 0.89

Rupture Strain of FRP system efu* = 0.020

Ultimate Tensile strength of FRP system ffu * = 0.70kN/mm2

Modulus of Elasticity of FRP system Ef = 35kN/mm2

Dimensions of FRP strips

Thickness tf = 0.04" = 1.016 mm

Width wf = 12 in = 304.8 mm

4 . RESULTS

4.1 FRP Design Calculations

Table3.1.1 **1st STOREY**

Beam No.	Demand Moment (kNm)	ΦMn (kNm)	fs,s (N/mm^2)	ff,s (N/mm2)	No. of plies
20	100.034	98.259	68.401	15.106	4
25	99.5.261	106.137	52.397	10.973	5
30	115.292	102.12	55.977	11.696	5

Table3.1.2 **2nd STOREY**

Beam No.	Demand Moment (kNm)	ΦMn (kNm)	fs,s (N/mm^2)	ff,s (N/mm2)	No. of plies
65	50.485	75.61	40.716	9.749	3
90	40.57	44.369	51.64	10.299	4
92	100.49	96.42	70.259	12.691	5

Table3.1.3 **3rd STOREY**

Beam No.	Demand Moment (kNm)	ΦMn (kNm)	fs,s (N/mm^2)	ff,s (N/mm2)	No. of plies
183	70.836	99.196	50.963	10.678	3
184	482.371	530.496	90.604	15.872	3
190	280.009	348.326	92.495	19.212	4

Table3.1.4 **TERRACE**

Beam No.	Demand Moment (kNm)	ΦMn (kNm)	fs,s (N/mm^2)	ff,s (N/mm2)	No. of plies
250	192.458	245.06	100.08	20.627	2
264	180.208	210.564	110.47	22.239	2
282	170.496	118.565	108.391	22.517	2

4. 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. 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. 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. This would ensure feasibility of application of the FRP system to the beams. From the results of the experimental program, effective methods for rehabilitating existing deficient beamcolumn joints are developed. A comparison between the performance of original specimens and rehabilitated ones shows that the GFRP jacket was capable of increasing the shear resistance of the joint and enhancing the performance of the connection from a ductility point of view. The proposed rehabilitation techniques for beam-column joints

5. REFERENCES:

1. *Ghobarah, Ahmed, and Aly Said. "Shear strengthening of beam-column joints." Engineering structures 24.7 (2002): 881-888.*
2. *Agarwal, P. and Shrikhande, M. (2004), Earthquake Resistant Design of Structures, PHI Publication*
3. *Antonopoulos, Costas P., and Thanasis C. Triantafillou. "Experimental investigation of FRP-strengthened RC beam-column joints." Journal of composites for construction 7.1 (2003): 39-49.*
4. *Mukherjee, Abhijit, and Mangesh Joshi. "FRPC reinforced concrete beam-column joints under cyclic excitation." Composite structures 70.2 (2005): 185-199.*
5. *Fardis, Michael N. (2009), Seismic Design, Assessment and Retrofitting of Concrete Buildings, Springer*
6. *Fukuyama, H., Sugano, S. (2000), Japanese seismic rehabilitation of concrete buildings after the Hyogoken-Nanbu Earthquake, Cement and Concrete Composites,Vol. 22 Issue 1*
7. *Griffith, M. C. and Pinto, A. V. (2000), Seismic Retrofit of RC Buildings - A Review and Case Study, The University of Adelaide, Adelaide, Australia and European Commission, Joint Research Centre, Ispra Italy.*
8. *Kumar, E. S, Murugesan, A, Thirugnanam, G.S. (2010) Experimental study on behaviour of Retrofitted with FRP wrapped RC Beam-Column Exterior Joints Subjected to cyclic loading, International Journal of Civil and Structural Engineering, Vol. 1 No. 1.*
9. *Syal, I.C., Goel, A.K. (2010), Reinforced Concrete Structures, S. Chand Publications*
10. *Thermou, G. E. and Elnashai, A. S. (2006), Seismic retrofit schemes for RC structures and local–global consequences, Prog. Struct.Engng Mater, 8*
11. *Wang, Y. P. (1998), Fundamentals of Seismic Base Isolation, International Training Programs for Seismic Design of Building Structures*
12. *Wha Bai, J. (2003), Seismic Retrofit for Reinforced Concrete Building Structures, Texas A&M University, Mid-America Earthquake Center, CM-4: Structure Retrofit Strategies*
13. *BIS, IS 13920:1993, Ductile detailing of reinforced concrete structures subjected to seismic forces — Code of practice, Bureau of Indian Standards, Second revision*
14. *BIS, IS 456:2000, Plain and reinforced concrete code of practice‖ Bureau of Indian Standards, Fourth revision*
15. *BIS, IS 1893 (Part 1): (2002), Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings, Bureau of Indian Standards, Fifth revision*
16. *ACI Committee, ACI 318-99, Building Code Requirements for Structural Concrete- Code of Practice, American Concrete Institute*
17. *ACI Committee, ACI 440.2R-02, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures- Code of Practice, American Concrete Institute.*
18. *Sasmal, S., Ramanjaneyulu, K., Novák, B., Srinivas, V., Kumar, K. S., Korkowski, C., ... & Iyer, N. R. (2011). Seismic retrofitting of nonductile beam-column sub-assemblage using FRP wrapping and steel plate jacketing. Construction and Building Materials, 25(1), 175-182.*