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Seismic Retrofit Techniques for Reinforced Concrete Building Columns With Combination of FRP Sheets And Steel Jacketing.

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Abstract :-
To meet up the requirements of advance infrastructure new innovative materials/ technologies in Civil engineering industry has started to make its way. Any technology or material has its limitation and to meet the new requirements new technologies have to be invented and used. With structures be coming old and the increasing bar for the constructed buildings the old buildings have started to show a serious need of additional retrofits to increase their durability and life. With the purpose to provide a seismic retrofit method with good workability for reinforced concrete (RC) building columns under severe construction work conditions, a retrofit method with combination of carbon fiber reinforced polymer (CFRP) sheet and steel jacketing has been proposed in this paper. In this paper CFRP sheet and steel angles was investigated to strengthen the column in order to establish a design for the CFRP sheet- steel angles connection. In this paper we have analysis and design of the multistoried Educational building. We have analyzed and designed the R.C.C structure of G+2 considering all possible forces and according to Indian Standard Code Provision.

I. INTRODUCTION

Attributing to the merits of high strength, light-weight and outstanding workability, fiber reinforced polymer (FRP) sheet has been widely used in repairing or strengthening reinforced concrete (RC) members in the recent decades. As for seismic retrofit of RC building column, FRP sheet is usually used to retrofit columns with premature termination of longitudinal reinforcements without enough development length at the mid height. CFRP sheet was jacketed around the termination sections of the longitudinal reinforcements in the longitudinal direction and circumferential direction to reinforce flexural and shear strength. In some other cases, FRP sheet is also used to reinforce ductility of the columns by jacketing around the plastic hinge in the circumferential direction.

From the point of view, a method with using combination of CFRP sheet and steel jacketing has been proposed in this paper. the longitudinal force induced from the additional anchor bolts must be transmitted to CFRP sheet and thus the steel plate should be bonded with CFRP sheet in the inelastic response of the column.

Composites Are Composed Of:

Epoxy - The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and Environmental damage. The most common resins used in the production of FRP grating are polyesters (including orthophthalic-“ortho” and isophthalic-“iso”), vinyl esters and phenolics.

Reinforcements - The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product The largest volume reinforcement is glass fiber.

Fillers - Fillers are used to improve performance and reduce the cost of a composite by lowering compound cost of the significantly more expensive resin and imparting benefits as shrinkage control, surface smoothness, and crack resistance

Additives - Additives and modifier ingredients expand the usefulness of polymers, enhance their process ability or extend product durability.

The Following Are Major Pros And Cons Of Using Composites
Advantages
1. Corrosion proof
2. Easy in transportation, can be easily rolled
3. Higher UTS and young's modulus
4. High fatigue resistance
5. Light weight. Hence, very high strength to weight ratio
6 .Joints can be easily avoided as they are available in desired length.

Disadvantages
1. Low ductility value and fickly plastic behavior
2. Susceptible to local unevenness.
3. High cost.

The Design Is Based On Following Assumptions :–
· No slip between FRP and Concrete.
· Shear deformation within adhesive layer is neglected.
· Tensile strength of concrete is neglected.
· FRP jacket has a linear elastic stress-strain relationship up to failure.

Fiber Wrapping Is Done On RC Members In Many Different Ways
1. Strengthening of junction area by means of L-Wrap:- It is done at the beam- column joint to strengthen the joint.
2.Strengthening the junction area by flat wrap.
3.Strengthening of the junction area by means of U-Wrap.
4. Column confinement by fully covering the column or beam with fiber wrap.

In actual real life cases a mix of all these techniques is used to attain the designed strengthening requirements. Confinement effectiveness of externally bonded FRP jackets depends on different parameters namely.
· Type of concrete,
· Steel reinforcement,
· FRP jacket stiffness (type of FRP, number of plies and design of wrap),
· Shape of cross section,
· Radius of corners, for non-circular sections, and loading conditions.

Uniaxial compression tests on RC columns confined with CFRP jackets have shown that the increase of ultimate strength is highly influenced and increases with the radius of the corners of square sections. Hence it gives better results for columns with circular cross sections than those with Square/Rectangular cross- sections. For achieving better results in case for effectiveness of FRP confinement with Square/Rectangular cross-sections, the sharp edges are given some curvature to increase FRP wrap effective.

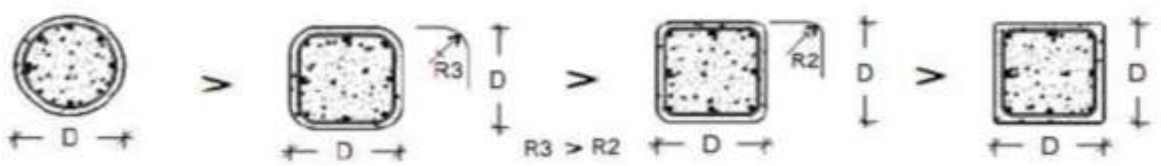


Fig.1.Cross-section effect on FRP strengthening of columns

Installation Of Fiber Wrapping Beams And Columns
Grinding and surface preparation:- for round columns sharp corners are negligible exceptjunctions. For square columns apart from the grinding the plane surface it is also necessary toremove all the sharp corners with grinder and form at least a minimum of 20 mm radius forsmooth functioning. For surfaces with unevenness putty is used to make is even.

Fig.2.Surface grinded and prepared for fiber wrapping

Marking And Drilling:- The centre of column width is marked and drilled at points to the depth of 50-60mm to put anchors.

Primer Coating:- After making sure that all water has evaporated and moisture is minimal aprimer coat is applied to make surface very smooth epoxy application and fiber adhesion. It takes some hours for primer to cure depending on the ambient conditions. It is important to alienate the concrete from the fiber- wrap system so that moisture and other impurities may not affect the process. It also makes the surface very smooth so that the epoxy sticks to the surface nicely and there is no loosening, or layer formation which might make the process less effective.

Fig.3.Surface primer applied on the column

Epoxy Coating and Wrapping of fiber:- After Primer coating the surface is perfect for epoxy application. There are two techniques employed for wrapping fiber.

1. The 2- component epoxy adhesive is mixed properly in required proportion and is applied throughout the surface where fiber is to be put. Immediately after epoxy application fiber is wrapped around the column or as per the design proposed. After which a second coat epoxy is applied
2. It is also sometimes pre- wetted with epoxy with the help of wet-layup machine and then Applied to the surface of application. The fabric is checked again for any air bubbles trapped and roller is rolled over wherever required, which is important as it hampers in functioning of the fiber wrap.

Fig.4.Cutting and applying of fiber sheet on the column

Anchoring And Sand Sprinkling:-A second coat of epoxy is then applied over which anchors are put into the previously drilled holes so that it holds the ends of fiber wrap and does not allow it to peel off. After which sand sprinkling and a minimum layer of 12mm thickness of polymer modified mortar covering is done. This is done to enhance the life of fiber wrap system. Now the whole system is safe and active.

Fig.5.Final look of column after plastering

Steel Jacketing

Steel jacketing refers to encasing the column with steel angles and filling the gap with non-shrinkgrout. The jacket is effective to remedy inadequate shear strength and providepassive confinement to the column. Lateral confining pressure is induced in the concrete as itexpands laterally. Since the plates cannot be anchored to the foundation and made continuous through the floor slab, steel jacketing is not used for enhancement of flexural strength, increase in the stiffness of a jacketed column. Steel jacketing is also used to strengthen the region of faulty splicing of longitudinal bars. As a temporary measure after an earthquake, a steel jacket can be placed before an engineered scheme is implemented. Steel angles are taken within the junction, So that it will be effective in carrying additional moment also.

`Circular jackets are more effective than rectangular jackets. A jacket is made up of twopieces of semi-circular steel plates which are welded at the site. A circular jacket can beconsidered equivalent to continuous hoop reinforcement. Of course circular jackets may not besuitable for columns in a building since the columns are mostly rectangular in cross-section. In arectangular jacket, steel plates are welded to corner angles. Anchor bolts or through bolts mayincrease confinement but it involves drilling into the existing concrete. A simpler form ofstrengthening is to weld batten plates to the corner plates. This form is referred to as steel profilejacketing as opposed to the encasement provided by continuous plates.

II. BUILDING MODELING

This study, a G +2 story building with a 3.65-meters height for each story, regular in plan is modeled. These buildings were designed in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings The buildings are assumed to be fixed at the base and the floors acts as rigid diaphragms. The sections of structural elements are rectangular . Story heights of buildings are assumed to be constant including the ground story. The buildings are modeled using software **'STAAD-PRO V8i'** the actual moment carrying capacity of column was obtain from software was calculated and strengthening of column by CFRP sheet and steel jacketing.

Data For Building –

The design data is as follows-

- **Dead Load-**

1) Slab Thickness assume = 125 mm
2) Floor Finish = 75mm

- **Live Load-**

1) All Floor except Terrace = 5 kN/m^2
   At Terrace = 3kN/m^2

- Earthquake Zone = Zone III
- Zone Factor = 0.16
- Earthquake Resistance Design of Structure = IS 1893 (Part 1) 2002
- Safe Bearing Capacity of Soil = 250 kN/m^3
- Floors = G.F. + 2 Upper Floors
- Plinth Level = 1.5 m
- Ground Floor Height = 3.65 m
- 1^{st} Floor Height = 3.65 m
- 2^{st} Floor Height = 3.65 m
- Thickness of Wall
  Internal and external wall = 230mm
  Internal wall = 115mm
- Grade of Concrete for column and other = M20
- Grade of Steel = Fe415

- **Load Calculation**:-
  Dead Load:
  Floor Load-

1.Self-weight of Slab = 25 x 0.125 x 1 x 1
= 3.125 kN/m^2

2. Floor Finish = 25 x 0.075 x 1 x 1
= 1.875 kN/m^2

TerraceFloor :

1. Floor load = 1.5kN/m^2

Wall Load (0.23 m thick wall):-

1.At Ground Floor = [(Height Of floor- Depth of Beam) x Thickness of Wall x Density of Wall]
=(4.55-0.38)x1x0.23x20 = 19.182 kN/m

2. At 1^{ST} and 2^{nd} floor =(3.65-0.38)x1x0.23x20 = 15.042kN/m

3. Parapet wall = 1.5x 0.23x 1x 20 = 4.83 kN/m

Live Load:-
At 1ST and 2ndAt Terrace= 3kN/m^2 (IS 875 part 2-1987)

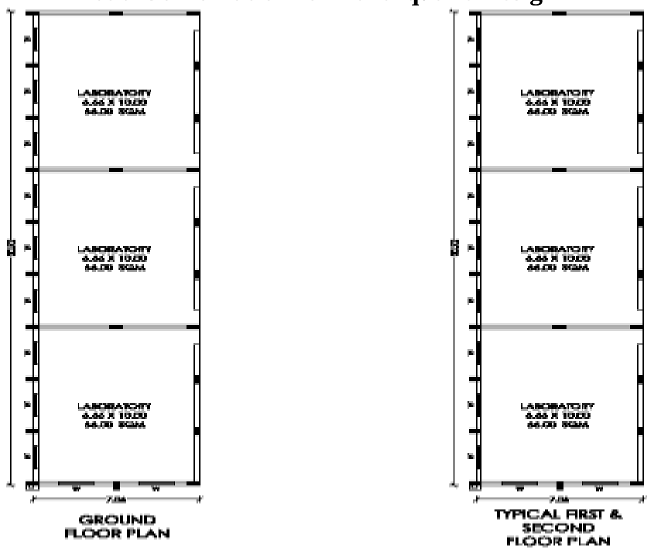
Load Combination

The analysis has been carried out for the dead load (DL), live load (IL), & earthquake load in both the direction i.e. sway to left (-EL) and sway to right (EL) by a standard computer package Staad pro. The combination of above loads has been made according to cl 6.3 of IS 1893 (Part 1) 2002 and they are given below –

Load Combination For Earthquake Design-

Load Case	Details of Load Cases
1.	1.5 (DL + LL+RLL)
2.	1.5 (DL + EQ_X)
3.	1.5 (DL – EQ_X)
4.	1.5 (DL + EQ_X)
5.	1.5 (DL – EQ_Z)
6.	(1.2DL+0.6LL+1.2EQX)
7.	(1.2DL+0.6LL-1.2EQX)
8.	(1.2DL+0.6LL+1.2EQZ)
9.	(1.2DL+0.6LL-1.2EQZ)
10.	0.9 DL + 1.5 EQ_X
11.	0.9 DL - 1.5 EQ_X
12.	0.9 DL + 1.5 EQ_Z
13.	0.9 DL - 1.5 EQ_Z

Load Combination for Earthquake Design



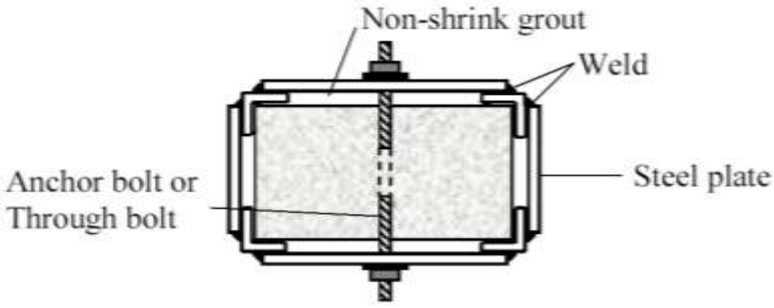
III. WORKINGDRAWING

After analysis we have found the following columns was failed, for the different load combination results are as follows.

Sr no.	Col to be fail	Actual moment capacity KN.M	Required moment capacity KN.M	Difference in moment KN.M
1.	C- 139	137.50	202.908	65.408
2.	C-140	137.50	201.986	64.486
3.	C-142	137.50	201.752	64.252
4.	C-143	137.50	201.722	64.222
5.	C-145	137.50	201.378	63.878
6.	C-146	137.50	203.693	66.193

For Steel Jacketing:-
For length of column = 4550mm
Size of column = 230x530 mm.
Difference in moment = 66.193 KN.M
After calculation the result obtain is as follows.

Two angle of either side is provided for col.
Provide 2 ISA 50x50x6 on one side of column.



Retrofitted section

For CFRP jacketing:-
For length of column = 4550mm
Size of column = 230x530 mm.
Difference in moment = 66.193 KN.M
For the following equations the CFRP jacketing is calculated.

1) Strengthening equations

$$\left(\frac{l_u}{D_g}\right) \leq \left(\frac{6.25}{\left(P_f / f'_c A_g\right)^{0.5}}\right)$$

A_g = gross cross-sectional area of column
f'_c = concrete strength
P_f = factored axial load
l_u = unsupported length
D_g = column diameter

2)Factored axial load resistance for an FRP-confined reinforced concrete column, P_{rmax} :

$$P_{rmax} = k_e \left[\alpha_1 \phi_c f'_{cc} (A_g - A_s) + \phi_s f_y A_s\right] \quad \textit{Eq. 5-9}$$

Same equation as for conventionally RC column, except includes ***confined*** *concrete strength, f'_{cc}*

$$\Rightarrow f'_{cc} = \frac{\left(\frac{P_f}{k_e}\right) - \phi_s f_y A_s}{\alpha_1 \phi_c (A_g - A_s)}$$

k_e = Strength reduction factor to account for un expected eccentricities.
= 0.85
f'_{cc} = Confined concrete strength.
A_g = steel area of column.
α1 = concrete stress block factor.
Φc= 0.6 for concrete.
Φs= 0.85 for steel.

3) Compute volumetric strength ratio :

$$f'_{cc} = f'_c + k_1 f_{l\,frp} = f'_c(1+\alpha_{pc}\omega_w)$$

$$\omega_w : \ldots\ldots\ldots \omega_w = \frac{\left[\frac{f'_{cc}}{f'_c} - 1\right]}{\alpha_{pc}}$$

4) Compute required confinement pressure:

$$\omega_w = \frac{\rho_{frp}\,\phi_{frp}\,f_{frpu}}{\phi_c\,f'_c} = \frac{2\,f_{lfrp}}{\phi_c\,f'_c}$$

$$\boxed{f_{lfrp}:} \ldots\ldots\ldots\ldots\ldots \quad f_{lfrp} = \frac{\omega_w\,\phi_c\,f'_c}{2}$$

4) Compute required confinement pressure $f_1$frp :-

Check $f_1$frp again confinement limits.

$$\Rightarrow Maximum: \; f_{l\,frp} = 4.02 < \frac{1_c}{2\alpha_{pc}}\left[\frac{1}{k_e} - \phi_c\right]$$

Ok limit met

5) Compute required number of FRP layer Nb :

Rearrange for Nb =

$$f_{l\,frp} = \left[\frac{2N_b\phi_{frp}f_{frpu}t_{frp}}{D_g}\right]$$

$$N_b : \ldots\ldots\ldots\ldots\ldots \quad N_b = \left[\frac{f_{l\,frp}D_g}{2\phi_{frp}f_{frpu}t_{frp}}\right]$$

For the above equation we was found the no of layer to confinement of column.
After the calculation use 3 layer of 0.3mm thickness CFRP sheet are used.

IV. CONCLUSION

The purpose of this study is to seismic retrofit the building components which failed at the time of analysis of building. For this 'STAAD-PRO V8i,software was used for analysis anddesigning of building. The retrofit method with using a combination of CFRP sheet jacketing and steel jacketing was proposed in this paper with the purpose to provide a seismic retrofit method for RC columns which failed in analysis and design by software. To meet the required moment caring capacity for strengthening the column the steel angles and CFRP sheet are proposed. The existing investigation have revealed that the use of CFRP materials restores or improve the column original design strength for possible axial shear or flexure, in some cases, allows the structure to carry more load than it was designed for. In most cases, the ductility of the columns have improved. With development of additional design standards and increased demand in the field applications, FRP will continue to grow in popularity as a retrofitmaterial. The FRP wrap stiffness plays a major role in the column jacket design. In order todevelop appropriate confinement forces, the jacket must be stiff enough at a relatively low axial strain in the column.

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