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Finite Element Analysis of Retrofitted Exterior Beam Column Joint

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ABSTRACT: The issue of upgrading civil engineering infra-structure has been of great importance for over a decade. It is common observation that structures are unable to give service as much as they are expected as per design. Deterioration of concrete structures may be attributed to ageing, environmentally induced degradation, poor initial designed construction, lack of maintenance, accidental loads such as blast loads. Hence the aspect of retrofitting had received considerable attention throught the world. The use of retrofitting technique to repair and strengthen the deficient infra-structure had become very popular due to their advantages. In the present study, finite element modelling of an exterior RC beam column joint retrofitted with externally bonded carbon fibre reinforced polymer and aluminium plate was carried out with the help of commercially available software ANSYS. Nonlinear static analysis was carried out to evaluate the performance of original and retrofitted models. Comparative study was done for obtaining better retrofitting material.

KEYWORDS: concrete structures, Beam column joint, Aluminium, Carbon fibre reinforced polymer, Retrofitting.

I. INTRODUCTION

Now a day, the most important problem that are facing the construction industry are deterioration of concrete. Most of the concrete structures were deteriorated due to environmental factors and applied load. Structural members become incapable of resisting applied loads due to marginal design, poor construction, using inferior quality materials. Reinforced concrete structures even in the seismic zone were designed only for gravity loads. Hence the existing structures should need assessment to avoid building collapse.

Under the action of seismic forces, beam column joints are subjected to large shear stresses in the joint region. These shear stresses are as a result of moments and shear forces of opposite signs on the member ends on either side of the joint core. Typically, high bond stresses are also imposed on reinforcing bar entering in to joint. The axial compression in the column and shear stresses results in principal tension and compression stresses that lead to diagonal cracking or crushing of concrete in the joint. Two major failure modes for the failure at joints are joint shear failure and anchorage failure. These stresses in the joint core are resisted by the strut and tie mechanism. To assure an increase of the shear strength after the cracking of joint core by diagonal tension and sufficient rotational capacity, joint shear reinforcement is needed.

The strengthening and enhancement of the performance of deficient structural elements in a structure as a whole is referred to retrofitting. Fibre reinforced composites have the properties such as high strength, corrosion resistance, electrical and thermal conductivity, reflectivity, ductility, impermeable and odourless. This study is divided in to two cases, 1) analysis of control specimen, 2) analysis of CFRP retrofitted specimen, 3) analysis of aluminium plate retrofitted specimen.

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II. DESIGN AND MODELLING

Designing of bam column joint was done by ACI and IS 456:2000. The designed structure has column with a cross section of 200 X 200 mm with an overall length of 1500 mm and beams with a cross section of 200 X 200 mm with an overall length of 600 mm. The column portion was reinforced with 2 numbers of 16 mm diameter bars in the tension zone and 2 numbers of 16 mm diameter bars in the compression zone. The main reinforcement has yield strength of 415 MPa, lateral ties in the column were 6 mm diameter at 180 mm centre to centre spacing and beam has vertical stirrups of 6 mm diameter at 120 mm centre to centre. The lateral ties and vertical stirrups had yield strength of 250 MPa. Concrete strength of specimen was adopted as 20 MPa. The detailingwith the dimensions are shown in figure 1.

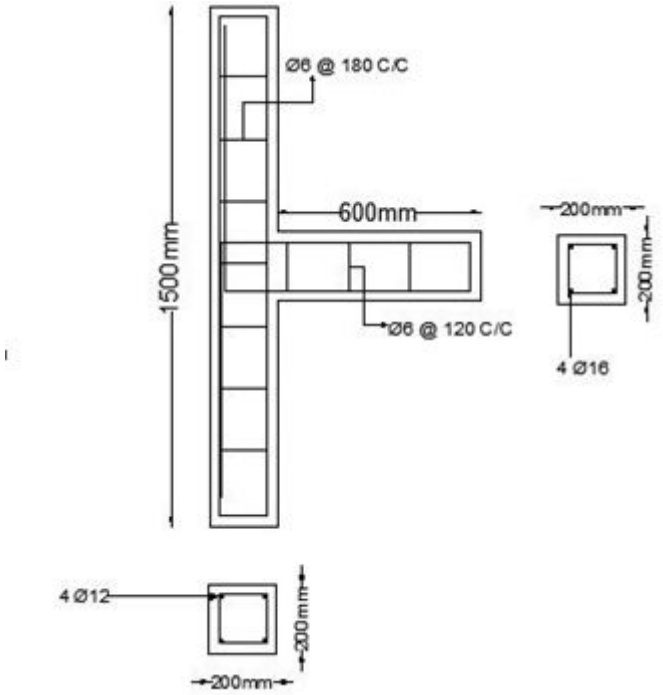

Figure 1. Dimensions and detailing of beam column joint

The finite element modelling is a computer aided mathematical technique for obtaining approximate numerical solution for abstract equation of calculus that predicts the response of physical systems subjected to external influences. Finite element model for the structure was prepared using the software ANSYS.

1) Element type: From the pre-processor of ANSYS, there assigned the element types. An eight nodded SOLID65 was used to model the concrete. The solid element has eight nodes with three degrees of freedom for each node. Theelement is capable of plastic deformation, cracking in orthogonal directions, crushing. This element is usually used for the three dimensional modelling of solids with or without reinforcing bars. Figure 2(a) represents SOLID 185 element and figure 2(b) represents SOLID 65 element. Link 180 element was used to model the steel reinforcement. Link element has two node with two degrees of freedom for each node. Link element is capable of plastic deformation. SOLID185 was used to model retrofitting by CFRP and aluminium plate. This element is defined by eight nodes having three degrees of freedom for each node. This element is capable of plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities.

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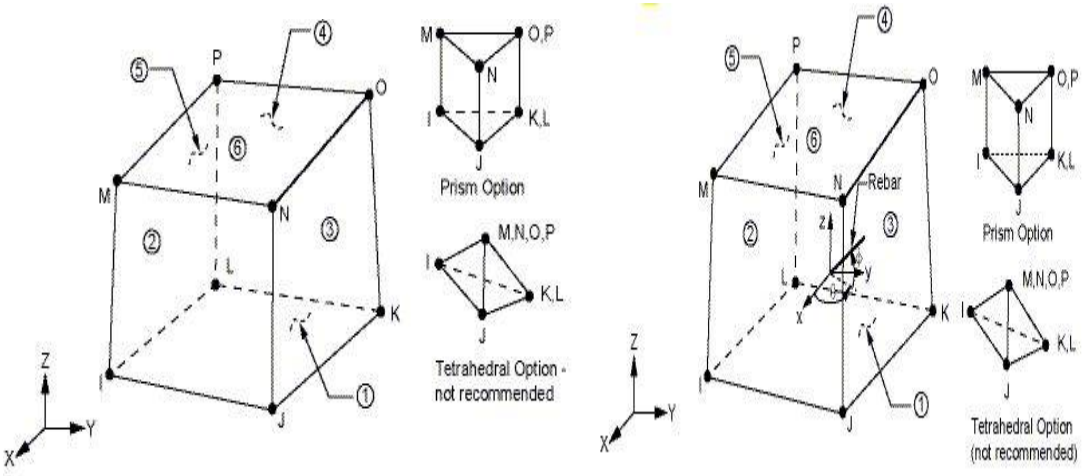

(a) (b)

Figure 2. (a) SOLID 185 element (b) SOLID 65 element

2) Material properties: Young's modulus and Poisson's ratio were chosen as linear isotropic material for concrete. The modulus of elasticity of concrete based on the ACI 318M-11 equation

$$E = 4700\sqrt{fc'}$$

Poisons ratio for concrete was assumed to be 0.2 based on the compressive strength of concrete used in beam and column. The uniaxial crushing stress fc' was considered to be 20 MPaand uniaxial cracking stress of concrete was considered to be 2.5 MPa. The analysis needs stress strain curve based on the equation

$$\sigma_{cu} = \sigma_{cu}'*2*\left(\left(\frac{\epsilon}{\epsilon 0}\right)-\left(\frac{\epsilon}{\epsilon 0}\right)^2\right)$$

whereσ_{cu}= fc' when $\epsilon \leq \epsilon_c \leq \epsilon_0$, ϵ is the strain and ϵ_0 is the maximum strain. σ_{cu} is the stress and σ_{cu}'maximum stress. The ratio between stress and strain must be equal to Young's modulus at first point of stress strain curve and then decreased to last data when compressive strength increases.
The modulus of elasticity f steel was taken as $2*10^5$MPa and poisons ratio was 0.3.the bilinear isotropic behaviour of LINK180element is satisfied by Von misesfailure criterion and requires the yield stress for main reinforcement was taken as 420MPa, while for shear reinforcement was 250 MPa and tangent modulus was taken as zero for both.
The modulus of elasticity of CFRP is $2.3* 10^5$MPa and Poisson's ratio 0.3, the ultimate strength of CFRP was 3400 MPa. Al plate has Young's modulus $69*10^3$ and poisson's ratio as 0.33 with yield strength of 110 MPa and ultimate strength of 210 MPa.

3) Meshing: As an initial step, finite element analysis required meshing of the model. The model divides in to a number of small elements, and after loading stress and strain are calculated at the integration points of small elements. An important step infinite element modelling is the selection of mesh density. The meshing divided the deometry in to small brick elements with 20X20X20 mmdimensions. Figure 4 represents the meshed geometry.

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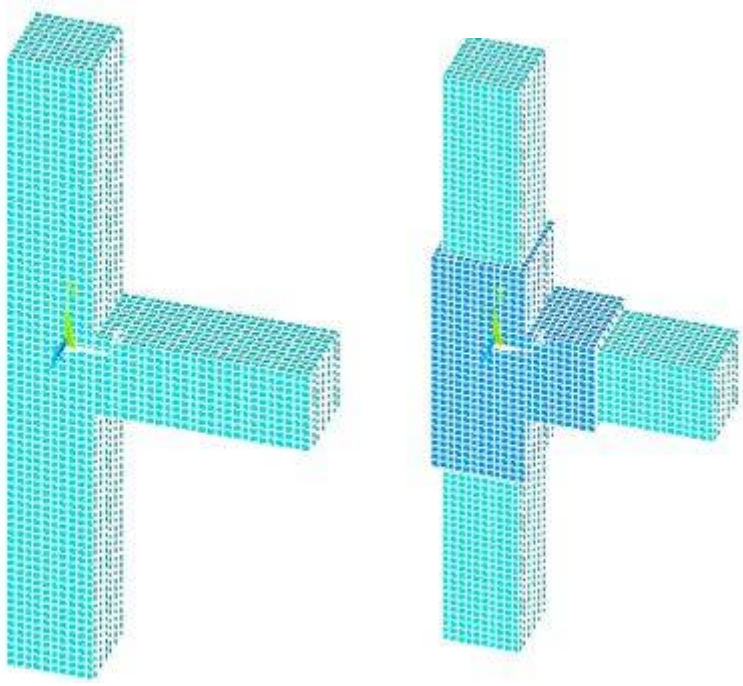

(a) (b)

Figure 3.Meshed geometry of (a) Control specimen, (b) Retrofitted specimen.

4) Loads and boundary conditions: The boundary conditions will be simulated as in the original situation to the maximum possible extent. The model will be built to be hinged at the column bottom end. Degrees of freedom constrained at x, y, z directions with zero displacement value will be applied at the nodes located at the top and bottom of column. An axial load of 200 kN was applied at the top end. The load was performed as static load at the free end of cantilever beam as small forces divided by number of nodes.

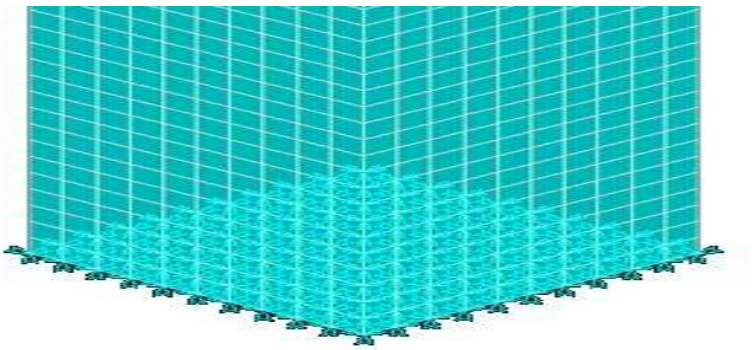

Figure 4.Restrains for the specimen

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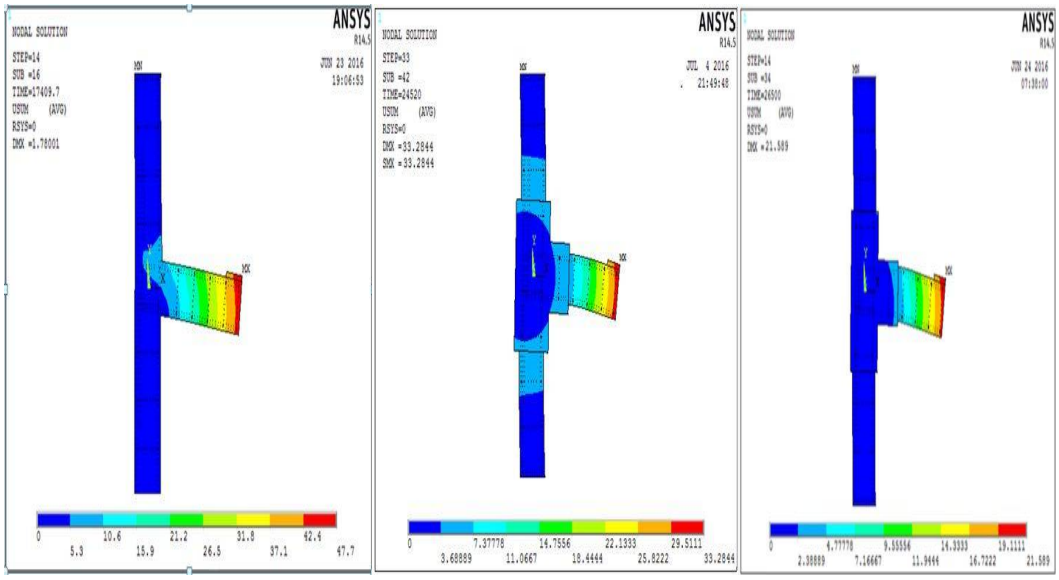
III. FINITE ELEMENT ANALYSIS RESULTS

This section represents the results of the original case and retrofitted case. A comparison between load carrying capacity for the original and retrofitted specimen was held to identify the improvements and the effects that each retrofitting has accomplished. The behaviour of retrofitted beam column joint was investigated using the finite element software ANSYS.

1) Control specimen: Nonlinear static analysis was carried out for the control specimen using the software ANSYS. An increasing static load was applied at the free end of cantilever beamat a load interval of 20 kN for a load of 17 kN. The maximum deflection found to be 47.7 mm for a load of 17 kN. The crack or crushing plot was obtained by crack/crushing plot option in ANSYS. Tensile crack was developed between the column and beam at the joint region due to lack of shear reinforcement. Figure 5 (a) represents the deformation behaviour of control specimen. Figure 6 (a) represents the crack pattern obtained for control specimen.
2) Aluminium plate jacketing of 20 mm: Aluminium plate of 20 mm thickness was applied as retrofitting material. The analysis shows significant improvements when applying the retrofitting material. When performing the same analysis , 20 mm thick Al plate retrofitted specimen shows 5.94 mm lesser deflection compared to control specimen. The maximum deflection obtained was 42 mm for a load of 22 kN.
3) Aluminium plate jacketing of 40 mm: After performing the analysis on beam column joint using aluminium plate, the analysis shows significant improvements when increasing the plate thickness. The nonlinear analysis shows a decrease in the deflection of 8 mm compared to 20 mm thick aluminium plate. The maximum deflection obtained is 33.2 mm for a load of 24 kN. Figure 5(b) represents the deformation of 40mm thick aluminium plate retrofitted specimen. Figure 6 (b) represents the crack pattern obtained for the control specimen.



(a) (b) (c)

Figure 5 Deflection of (a) control specimen (b) 40 mm thickAl plate retrofitted specimen (c) CFRP retrofitted specimen

4) CFRP: The final retrofitting technique was CFRP wrapping. The result shown that the use of this technique could increase the load carrying capacity. The maximum deflection obtained was 21.5 mm for a load of 26

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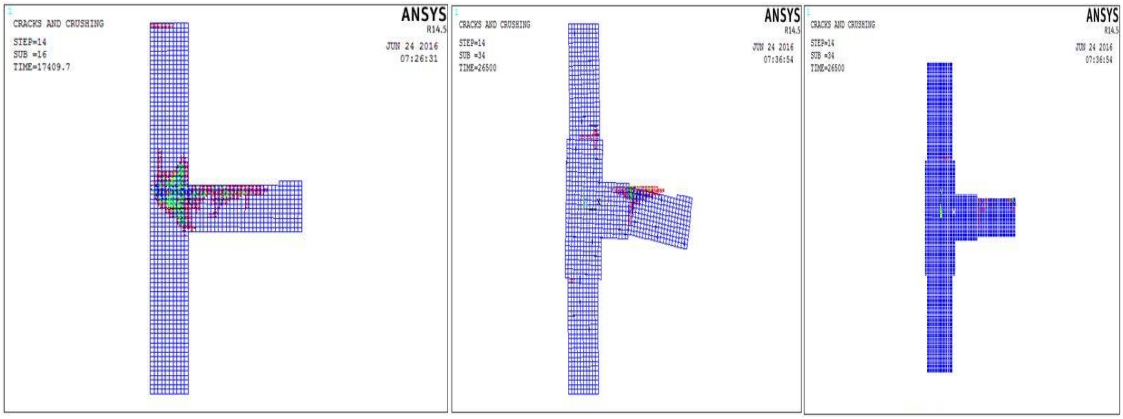
kN.Figure 5 (c) shows the deflection values of CFRP retrofitted specimen from ANSYS There shows a smaller deflection compared to aluminium plate retrofitted specimen.



(a) (b) (c)

Figure 6 Crack pattern for (a) control specimen (b) Al plate retrofitted specimen (c) CFRP retrofitted specimen

IV. CONCLUSION

From the study, it was concluded that ANSYS is able to model different components of load deflection curve, i. e. the linear region, initial cracking, the nonlinear region, yielding of steel and failure. Comparison between load deflection results fromANSYS for control specimen shows that the deflection values are less for retrofitted specimen. While comparing retrofitted specimens, CFRP shows lesser deflection compared to aluminium pate retrofitted specimen. The crack pattern obtained was less compared to control specimen.

REFERENCES

[1] Abadel, A. A., "Numerical Investigation on Seismic Behaviour of FRP and TRM Upgraded RC Exterior Beam column joint", American Society of Civil Engineers, Vol 16, pp. 308-321,2012.
[2] Antonopolous, P. C., and Triantafillou, C. T., "Experimental Investigation of FRP Strengthened RC Beam column Joints", Journal of Composites for Construction, Vol 7, pp. 39-49, 2003.
[3] Bsisu, D. A., and Hiari, O. B., "Finite Element Analysis of Retrofitting techniques for Reinforced Concrete Beam Column Joint", Journal of American Science, Vol 11, pp. 48-56, 2015.
[4] Ghobarah, A and Said, A., Shear Strengthening of Beam Column Joints", Engineering Structures, Vol24, pp.881-888,2002.
[5] Hamid, H. N., Hadi, D. N., Ghani, D. K., "Retrofitting Of Beam Column Joint Stiffened With Steel and CFRP", International Journal Civil Environmental, Structural, Construction And Architectural Engineering, Vol 7, pp. 941-946,2013.
[6] Karlovsek,J., Wagner, N., Scheuermann, A., 14th International Conference On Ground Water Penetrating Radar (GPR), June 4-8, Shanghai, China.
[7] Kitamaya, k., Otani, S., Aoyama, h., "Development Of Design Criteria For RC Interior Beam Column Joints", American Concrete Institute, Vol 1, pp. 97-123, 1991.
[8] Lowes, N. L.,and Altoontash, A., "Modelling Reinforced Concrete Beam Column Joint Subjected To Cyclic Loading", Earthquakes and Structures, Vol 3, pp. 37-57, 2003.
[9] Murali,G., Vardhan, V. M. C.,Sruthee, P., Charmiley, P., "Influence Of Steel Fiber On Concrete", Journal of Engineering Research and Applications, Vol 2., pp. 75-78,2012.
[10] Rafi, M. M., Nadjai., A., Ali, F., "Analytical Modeling of Concrete Beams Reinforced with Carbon FRP Bars", Journal of Composite Materials, Vol 41, pp. 2675-2690, 2007.
[11] Ravi, S. R., and Arulraj, P. G., "Experimental Investigation On Behaviour Of Reinforced Concrete Beam Column Joint Retrofitted With AFRP-GFRP Hybrid Wrapping", International Journal of Civil and Structural Engineering, Vol 1, pp. 245-253, 2010.
[12] Tahir, F. M., "Response Of Seismically Detailed Beam Column Joints Repaired CFRP Under Cyclic Loading". Arab Journal of Science and Engineering, Vol 1, pp. 1-8.