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Exterior RC Beam-Column Joints Retrofitted with CFRP Sheets and their Seismic Behavior

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ABSTRACT

The findings of a full-scale experiment involving two beam-column connections are presented. Initially, samples were examined without being harmed. Following that, recovery was carried out using various techniques, including externally bonded carbon fiber reinforced polymer and highly high-performance mortar reinforced with metallic fibers. The specimens were then re-tested. On each specimen, specific loading protocols were used to assess their effect on load-deformation capability. These protocols were displacement-controlled and quasi-statically implemented. Before and after recovery, the specimens' overall performance is provided and reported in power and drift intensity, electricity dissipation, equivalent viscous damping, effective stiffness, cracking, and visual harm. Several essential studies can aid in the restoration of concrete structures following large earthquake floor motions.

KEYWORDS: *beam-column joints, reinforced concrete*, *FRP, retrofit, finite element analysis.*

I. INTRODUCTION

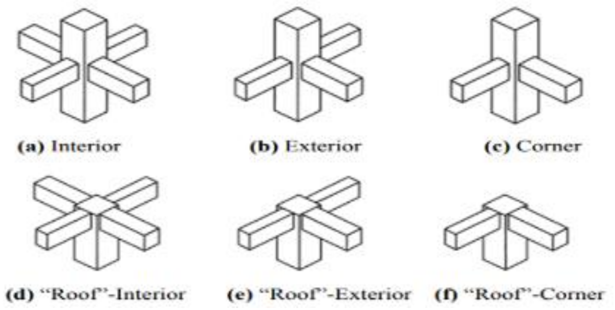
The beam-column joint in concrete structures is studied as a highly vulnerable structural feature exposed to lateral loads. It is summarized the seismic activity of complete exterior reinforced concrete (RC) beam-column joints retrofitted with exteriorly bonded Carbon Fiber Polymers (CFRP). The action of beam-column joints has been studied both experimentally and numerically to determine the seismic safety of reinforced concrete (RC) structures. They have good fatigue resistance as well as exceptional corrosion resistance. The FE modelling of reinforced RC beams to state the bonding problem of FRP plates and sheets has been the subject of most research work in terms of numerical studies. To conduct the FE study, more researchers used widely available software packages such as ANSYS, ABAQUS, SAP 2000, and ATENA. There are just a few studies on the modelling of RC joints using FRP materials.

BEAM-COLUMN JOINTS

The intersection of a beam and a column is known as a joint or junction. The primary purpose of a joint, which is the area where beams and columns come together, is to allow adjoining members to create and retain their total capacity. The joints must be strong and rigid enough to withstand the internal forces generated by the framing members.

TYPES OF JOINTS IN FRAMES

The three types of beam-column connections are internal, external, and corner.

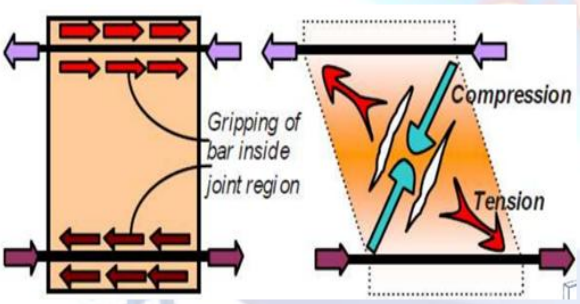


Highlights

- Two beam-column links were tested at full scale in the laboratory.
- Specimens were examined without being damaged at first, then rehabbed and re-tested.
- As a form of recovery, CFRP wraps and steel fiber reinforced mortar was used.
- Specimen performance parameters are discussed and described.
- Both methods of rehabilitation were effective in achieving adequate seismic efficiency.

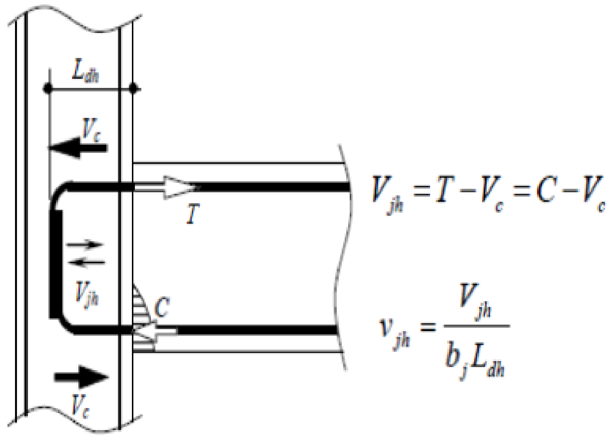
II. LITERATURE REVIEW

Earthquake properties One inclined length stretches while the other compacts as the pulsate forces at the top and bottom ends of the joint shift. If the cross-sectional size of the column is too small, the concrete in the joint develops oblique cracks.



EXTERIOR BEAM-COLUMN JOINT SHEAR FAILURE

With active horizontal forces, a typical exterior beam-column joint is used. The compressive stress in the bent portion of the beam bars rises as the acting load rises, causing the bond production in the straight portion to deteriorate. The transfer of joint shear in a concrete strut formed between bent access points is studied using both compression and tensile stress.



At the exterior beam-column joint, a force is exerted.

V_{iu} F_j b_j D_j

The joint configuration coefficient for the external joint is k=0.7, and the coefficient of life of transverse beams is 1.0(both side0.85) (others)

- B 0.7(N/mm2) Fj=0.8 shear power of the joints
- bj denotes the joint's substantial width. Dj denotes the length of growth or the depth of the column (interior joint) Ldh is the length of the hooked bar (exterior joint)
- The following are the critical steps in the finite element analysis method:
- The region is divided into a finite number of elements.
- Interpolation functions are determined.
- The element's element matrix is being created.
- To obtain the global matrix for the entire field, assemble the element matrices for each element.
- Boundary conditions are breached.
- Equation's resultant.
- If any additional calculations are needed, they will be done.

Finite element analysis is a statistical method that can be used to solve problems. In this research, the numerical analysis involves developing a non-linear finite element model to simulate the behaviour of beam-column joints retrofitted with exteriorly bonded FRP.

OBJECTIVES

- The primary goal of this study is to examine the strength and serviceability of a CFRP retrofitted beam-column joint.
- Enhancement and analysis of a finite element model for retrofitted beam-column joints with externally bonded FRP (CFRP and GFRP).
- To improve the portrayal of damaged buildings in terms of matched strength and serviceability after a seismic event.
- When a damaged beam-column joint reinforced

with CFRP is subjected to cyclic loading, the load-deflection behaviour must be resolved.

- To compare and contrast the action of weak and robust specimens.

III. METHODOLOGY

The numerical form of reinforced concrete structures and structural elements has become a significant research field in the last two decades. Several tasks must be performed for the finite element model to operate appropriately in MIDAS. Models are generated by typing commands into a command prompt or using a graphical program (GUI). The GUI was used to create the modality in this analysis.

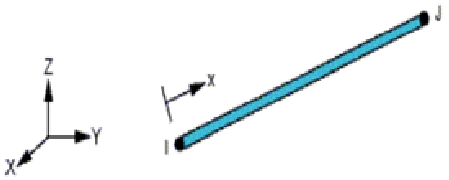
The relation between the beam and the column Model element forms, constitutive equations, assumptions, and parameters for various materials, model geometry, loading and boundary conditions, non-linear analysis procedures, and convergence criteria are all thoroughly explained.

ELEMENT TYPES

The different element forms that need to be entered in MIDAS for different materials are addressed.

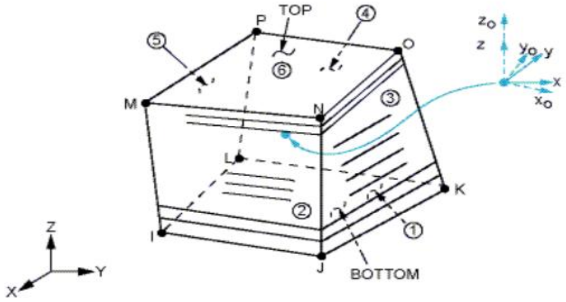
REINFORCEMENT MATERIALS

This is a three-dimensional scrap element with nodes and three degrees of freedom at each node (centroidal x, y, and z translations).



FRP COMPOSITES

Modelling of Fiber Reinforced Polymer (FRP). Homogeneous structural solid (a) and layered structural solid (b) are the two types (b). A solid layered element with three degrees of freedom and translations in the x, y, and z directions is created at each node.



Structural Solid with Layers (ANSYS)

CONCRETE

Assuming a model, the solid part necessitates a large number of rebar constants. The material number suggests the form of reinforcement material. The volume ratio refers to the proportion of steel to concrete in a structure.

IV. REINFORCEMENT MATERIAL

Material Properties:

I.S.456:2000 was used to determine the stress-strain relationship.

The following are the basic material characteristics: Es = 2.1x105MPa, steel modulus of elasticity

EC = 26429.81 MPa,

concrete modulus of elasticity.

Cu = 0.0035 for ultimate bending pressure

fck = 20 MPa, concrete's characteristic strength

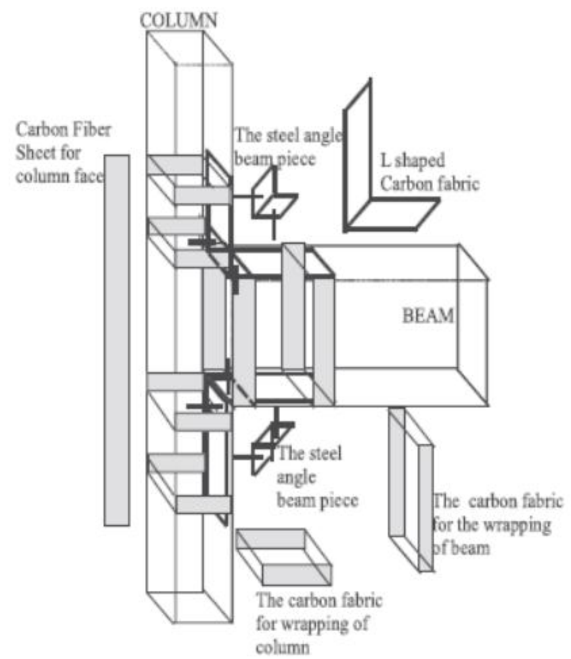
fy = 415 MPa yield stress in steel

Beam-column joint geometries

1000mm in height

The cantilever has a length of 500 millimetres.

The col in cross-section



The carbon-fiber reinforced polymer fabric's strengthening mechanism in depth

Modelling in ANSYS

ANSYS is a popular finite element software program that can accurately model concrete and reinforced concrete. It is incredibly accurate in predicting concrete cracks and crushing behaviour. One of the most critical aspects of FE research is modelling. The simulation of detail types and sizes, geometry, material houses, boundary conditions, and hundreds lack inaccuracy.

Functioning of the concrete

ANSYS is the preferred FE platform for modelling concrete and reinforced concrete at a higher level of accuracy. It is incredibly accurate in predicting concrete cracks and crushing behaviour. One of the most critical aspects of FE research is modelling. Detail form and dimension, geometry, cloth houses, boundary conditions, and masses must be accurately modelled.

V. Retrofitting Beam-Column Joint By Using CFRP

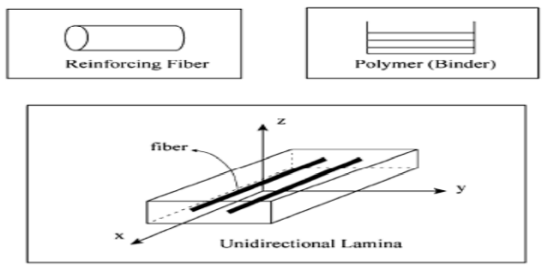
Fiber-bolstered polymer (FRP) structures have recently been used in the field of home strengthening and recovery. Carbon fiber (CFRP) and glass fiber are the most commonly used fiber-bolstered polymers (FRPs) (GFRP). These materials can be constructed and applied inside laminates, rods, dry fibers (sheets) adhesively bonded to concrete, moist lay-up sheets mounted on the surface, and so on. This paper used ANSYS19.Zero simulation software to carry out parametric research on polymer carbon fibre to retrofit deficit reinforced concrete beam-column joints.

Applied Retrofitting Techniques of Control Specimen

These days, fiber-reinforced polymer (FRP) structures are used to build reinforcement and repair. Carbon fiber (CFRP) and glass fiber are the most widely used fiber-reinforced polymers (FRPs) (GFRP). These materials are often crafted and used in laminates, rods, dry fibers (sheets) adhered to concrete, and moist lay-up sheets.

CFRP Material belongings CFRP

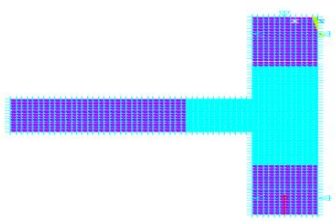
Composites are anisotropic, which means that their properties vary in a variety of ways. The figure below shows a diagram of CFRP composites. The unidirectional lamina has three orthogonal planes of material properties (x–y, x–z, and y–z planes), as can be shown. The XYZ coordinate axes are used as the primary fabric coordinates, with the x course being the same since the fiber is the same.



FRP composites schematic diagram

Geometry for CFRP Retrofitting version of beam-column joint

The joint position was subjected to significant shear stresses, resulting in massive diagonal cracks and concrete degradation within the joint vicinity, according to the experimentally manipulated specimen's validation. The primary aim of the FRP strengthening was to restore the ability of the beam-column joint while also preventing damage within the reinforced joint region. CFRP is a non-profit organization dedicated to



A CFRP retrofitting solution was used.

VI. RESULTS

The analysis and testing were wrapped around the last load, and the result was 24.85kN, which is 9.56 percent different from the experimental value and 18.91 mm deflection at the loose end of the beam. However, the experimental values revealed 22.68kN with a deflection of 23.24mm and 22.76 KN yield load, compared to 20kN in the experimental rate. In the case of CFRP jacketed beam-column joints, it became clear from the FEM and graphs that the CFRP jacketed finite detail version of the joint indicates an upward thrust in the last load-carrying capability. For CFRP two-layer retrofitted joints of finite detail model, the load-carrying capability increased from 24.83kN to 26.94kN, as shown by 8.5 this transformation from experimental charge. The deflection of the finite element model for CFRP two-layer retrofitted models was reduced to 19.25mm, compared to 22.00mm for two layers CFRP retrofitted joint, and a yield load of 22.95 KN was determined, versus 23kN in the experimental fee.

There were no cracks within the jacketed portion of the joints in the finite element model of two layers CFRP jacketed joints. In contrast to experimental values, CFRP jacketed joints showed significantly less deflection at higher masses.

VII. CONCLUSIONS

- In comparison to managing joint specimens, CFRP retrofitted joints showed an upward thrust in remaining load sporting capability of 9.47 percent, indicating the utility of CFRP for retrofitting. However, in the FEM review, finite detail models of CFRP retrofitted joints confirmed this beam.
- The CFRP retrofitted joints confirmed a 15.46 percent increase in stiffness as compared to the control joint, according to the experimental results. In the FEM study, however, finite detail fashions of the CFRP retrofitted joint showed a 43.29 percent increase compared to the changing pattern at remaining loading.
- The chosen upgrading system comprises CFRP laminates with unidirectional cloth glued to the concrete substrate with epoxy adhesive and arranged in parallel with the beam longitudinal reinforcement.
- The residual crack patterns of the improved joint models were very different from those of the as-built specimen, resulting in more diffuse damage but usually more minor cracks, confirming the findings of the numerical analyses.
- The damage moved to the column without causing it to yield. This type of damage in the improved joints appears to be perfectly acceptable if the action aims to enhance the seismic potential of RC buildings in terms of the Life Safety restriction state.

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