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Analysis of Exterior RCC Beam Column Joint Using Abaqus Software

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ABSTRACT
The aim of this paper to study various literatures on beam column connection and compare their Finite Element Analysis results. The beam column connection must be strong enough to transmit force between the members before the members reach their maximum strength without failure. Many previous researchers have studied the behavior and strength of beam column joints in the laboratory, but they are costs and time consuming. Computer simulation offers the potential for improved understanding of the local and global mechanisms that determine the response of structures to severe loading.
Keywords: *Load-displacement, Ductility, Shear Reinforcement, Retrofitting, Behaviour and Strength, Bond-Slip Effect, Eurocode.*

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I. INTRODUCTION

Beam column joint is a portion where a portion of column intrudes into the beam. The beam column joint is the significant zone in a reinforced concrete structure. The beam column joint is subjected to large forces during earthquakes and its behaviour has important influence in the response of the structure. Abaqus is a kind of software application used for modeling and analysis. A three dimensional structure can also be analysed easily by considering it as a two dimensional structure without any little variation in the results. Abaqus software is capable of pre-processing, post-processing, and monitoring the processing stage of the solver. Every complete finite-element analysis consists of 3 separate stages: (i) Pre-processing or modeling involves creating an input file, (ii) Processing or finite element analysis produces an output visual file,(iii) Post-processing involves generating report, image, animation, etc. from the output file.

II. LITERATURE REVIEW

2.1 Load displacement curve

Ruban Daniel et al (2018) analysed the shear behaviour of beam-column joints with special confinement in the joint region along with different reinforcement detailing for anchorage of beam bars. They used Glass Fiber Reinforced Polymer (GFRP) as an external confinement. The cyclic load- versus displacement curves of different specimens are compared. The load-deflection results obtained from ABAQUS is very close to the Load deflection curves obtained from the experimental study. They found out that the ultimate load has significantly increased for the special confined specimen.

S.V.Chaudhari et al (2014). made a study on Exterior RCC Beam Column Joint Subjected to Monotonic Loading by using ANSYS and ABAQUS software. The exterior beam-column joint is modelled and a monotonic loading of 5 kN to 30kN is applied at the free end tip of the beam until failure of beam takes place. The graph plotted by using ANSYS shows that as the load increases the model is getting stiffer and stiffer, whereas in ABAQUS the model shows flexible behavior. ABAQUS results show more realistic results for reinforced concrete and also as the mesh size of the model reduces, the accuracy of the results increases. It is observed that the ABAQUS software is giving realistic reinforced concrete load-displacement behavior.

Deng Sihua et al (2015) made a nonlinear analysis of a reinforced concrete beam based on the finite element analysis software ABAQUS. This simply supported beam of 1500mm long, with a section of 180mm×100 mm and Concrete strength is M25 is modeled in ABAQUS. While testing, we apply loading stage by stage in accordance with calculated capacity and the load on each point is the same. By controlling loading speed, we use a dial indicator and displacement gauge to measure the deflection of reinforced concrete beam, recording corresponding load, while observing the beam cracks and destruction till the beam completely destroyed. Since reinforced concrete in the elastic phase have high strength and strong rigidity, the amount of change in mid-span of deflection is small in the beginning; after entering the plastic stage, the material property of reinforced concrete declines, and therefore the acceleration of the deflection of the beam speeds up, thereby forming an acceleration in the mid-span of load deflection curves.

Sahar Abouai et al (2019) made a Nonlinear simulation of reinforced concrete beams retrofitted by near surface mounted iron-based shape memory alloys. Three beams loaded monotonically in a four-point bending scheme were modeled: one un-strengthened beam serving as a reference beam (B1), one beam strengthened with unactivated Fe-SMA strips (B2), and one beam strengthened with activated Fe-SMA strips (B3). The proposed numerical model in ABAQUS can perfectly predict the behavior of NSM Fe-SMA strengthened reinforced concrete beams, and there is good correlation between the simulation and tests in terms of load deflection and load strain curves The numerical Fe-SMA strain results correlate highly with the experimental results, which confirms the validity of the perfect bond assumption between the Fe-SMA strip and grout. The comparison to a beam strengthened with CFRP strips with a similar axial stiffness revealed better ductile performance for the beam strengthened with Fe-SMA strips as a result of the excellent tensile behavior with large strains in tension of the Fe-SMA.

Boudjamaa Roudane et al (2019) analysed the Masonry Infilled Reinforced Concrete Building during Construction Stages using ABAQUS Software. This paper firstly presents a comparison with the ambient vibration surveys. An analysis model of different stages of construction of the reinforced concrete masonry wall was compared using the finite element software. In the second step, structural responses of the model were investigated by means of static analysis. The main construction stages of the buildings can be classified into three stages: Bare frame, brick-walled and coated brick with dimensions of 2.5 m length, 1.5 m width and 4.8 m height. Under the same static loading conditions, the model with masonry infill walls has significantly greater displacement compared to bare-frame and coated-brick cases. It is noticed that the maximum deflection becomes smaller in the middle corners of columns and larger in the connection columns-beams, while in the brick-walled case, the greater deflection is observed at the top left column edge above the infill wall. By comparing displacement for each stage of construction analysis, it can be concluded that the magnitudes of the displacements depend not only on the storey's level and masonry walls, but also on materials such as plaster coating in infield RC buildings.

Ali Ahmed et al (2014) analysed the dynamic behavior of a beam under impact load using a 3D finite element (FE) analysis technique , ABAQUS. In this paper Thirty analyses have been executed changing different parameters such as damping, tension and compression stiffness recovery, damage parameter-strain/displacement relations and friction coefficient to choose the best performing FE analysis model. FE model, FEA8-1 shows very good agreement of the midpoint displacements in the elastic region, but in the region where concrete material starts giving plastic deformation decreasing stiffness due to the formation of cracks. Although this model matches the maximum deflection limit of the beam with experimental results, it fails to give exact amplitudes of midpoint displacement waves of the beam in the plastic region.

2.2 Behaviour and Strength

Atthaphon Atichat et al (2017). analysed the Behavior of Concrete Beam to Column Connections under Static Load Using Finite Element Method. It lead to the development of nonlinear finite element model to analyze the behavior and strength of beam-column connections to reduce experiments. The damage plasticity model is applied to concrete and elastic-perfectly plastic model is applied to steel rebar and plate. The converge finite element results and test results show good correlation.

Venkatesan, B et al (2016) analysed the seismic performance of exterior beam-column joints strengthened with unconventional reinforcement detailing. Six specimens of external beam-column joints with cross sections for both beams and columns of 230 mm × 230 mm with a beam of 1.25 m span and a column 2 m high were casted. The reinforcement detailing for three of the specimens is according to IS456-2000 (non-ductile), and the remaining three specimens are per IS13920-1993 (ductile). A 500kN capacity hydraulic push and pull jack was used to produce the reverse cyclic load in the beam portion. Finite element analysis (FEA) for the beam-column joint subjected to cyclic loading was performed using ANSYS. The strength, initial stiffness and energy dissipation of ductile and non-ductile detailed beam-column joints DD-1 and ND-1 showed higher strengths of 16.67%, 8.30% respectively. The ferrocement for retrofitting increased the energy dissipation capacity and is more efficient for reinforced beam-column joints in seismic regions. Analytical modelling gives a close prediction of the experimental behaviour of beam-column joints.

S. S. Patil and S. S. Manekari (2013) Analysis of Reinforced Beam-Column Joint Subjected to Monotonic Loading.The Monotonic loading can be defined as very slowly applied loading in one direction it may be in upward or downward direction. From results it is concluded that, as load increases displacement, minimum stress and maximum stress also increases. For fixed support condition for corner and exterior joint the displacement, minimum stress and maximum stress values are minimum as compare to hinge support condition.

As stiffness of the structure changes the displacement, minimum stress and maximum stress changes Non-linearly. The behavior of corner beam column joint is different than that of the exterior beam column joint.

2.3 Bond-Slip effect

De-Cheng Feng et al (2018) developed a finite element modelling approach for the analysis of the cyclic behavior of precast beam-to-column connections. The bond-slip effect is an important factor that influences the behavior of the beam-to-column connections subjected to cyclic loadings. The concrete interface between the precast beam and column components and the post-cast concrete are also accounted for in the model. The overall anchorage slip of the bar is theoretically derived and validated through benchmarking with pull-out tests, and from there the M-P model is modified by defining an equivalent strain to encompass both the actual bar strain and the slip. The results indicate that the numerical model can capture the typical cyclic behavior, failure mode, stiffness degradation and energy dissipation of the connection. the developed numerical modelling scheme provides an effective and efficient way to modelling the cyclic behavior of precast beam-to-column connections with good accuracy.

2.4 Ductility

Anupoju Rajeev et al (2019) investigated the dynamic response of reinforced concrete (RC) external beam column sub-assembly subjected to shockwave. The internal connections are laterally confined in both directions by their neighboring joints, while the external beam-column joints are laterally confined only with two or three beams and are thereby less efficient in resisting lateral loads. The behavior of an external beam-column joint has been studied under quasi-static lateral loading. The enhancement of the reinforcement at the beam-column joint improves the ductility of the subassembly. Under high strain rate loading, the ductile subassembly exhibits high stiffness and ultimate strength and also the reinforcement in the beam column junctions offers enhanced resistance by increasing the shear strength, which thereby results in the arrest of shear cracks.

Hamed Dabiri et al (2020) investigated the Influence of reinforcement on the performance of non-seismically detailed RC beam-column joints. In this study four different parameters including longitudinal reinforcement of beam, transverse reinforcement of beam, the angle of beam stirrups and longitudinal reinforcement of column were changed in FE models. Results show that by increasing the longitudinal reinforcement of beam or decreasing the size of beam stirrup, both displacement ductility and curvature ductility decrease. And by decreasing the angle of beam stirrup or increasing the longitudinal reinforcement of a column, the curvature ductility and displacement ductility increases.

Tadesse G. et al (2015) made a study on the efficacy of a shear strengthening technique utilizing fabric reinforced cementitious matrix (FRCM) systems for beams with and without internal transverse shear reinforcement (ITSR) within the critical shear span (CSS). The results confirmed that the gain in the load carrying capacity of the beams increases with an increase in the FRCM reinforcement ratio. The beams with ITSR within the CSS experienced a more ductile behavior as compared to those of the ITSR free counterparts. The FRCM strengthening system has significantly increased the deflection of the strengthened beams relative to the corresponding reference specimens.

Ali A. Abbas et al (2013) numerically investigated the behaviour of steel fibre reinforced concrete beam-column joints under seismic action. The results show that the introduction of steel fibres led to an increase of load carrying capacity and stiffness whereas the increase of the spacing of the transverse reinforcement resulted in a decrease of load carrying capacity and ductility. The addition of fibres in optimum amounts led to significant enhancement to ductility. Nevertheless, fibres should not be provided in excessive amounts as this will lead to a less-ductile response. it can be concluded that steel fibres provided in optimum amounts can substitute for conventional transverse reinforcement and thus allow for a relaxation in stirrups congestion often experienced in seismic detailing of beam-column joints.

2.5 Shear Reinforcement

Constantin E. et al (2017) analysed the shear strength of reinforced concrete beam-column joints with crossed inclined reinforcement. The proposed approach has been applied to 26 RC beam-column joints subjected to cyclic loading with X-bars as the only shear reinforcement or in combination with stirrups or/and vertical bars in order to establish the validity of the model based on a broad range of parametric studies. The database of experimental information was compiled from 6 existing works of the literature. Comparisons between experimental data and predicted results derived from the proposed procedure showed a very good agreement.

Chris G Karayannis et al (2013) experimentally investigated the behaviour of reinforced concrete shear-critical beams with rectangular cross-section and continuous rectangular spiral reinforcement as transverse reinforcement under monotonous loading. The experimental program includes eight (8) beams with rectangular cross-section subjected to monotonic action of shear. Two beams have no shear reinforcement and they are used as control specimens. The transverse reinforcement of four specimens are continuous steel spirals with rectangular shape (rectangular spiral reinforcement), whereas two specimens have common closed stirrups. As the applied load increased, cracks spread out and gradually inclined cracks formed within the constant shear region at both shear spans of the beams. The results indicated that the use of continuous rectangular spiral reinforcement can provide enhanced bearing capacity and improved shear performance in shear-critical beams Beams with spiral reinforcement spacing at 120 mm and 80 mm exhibited 14.9% and 14.7% increased shear capacity with respect to the corresponding beams with stirrups respectively.

Henrik B. et al (2018) experimentally investigated the shear capacity of RC beams with curtailed reinforcement. All specimens is designed with four continuous longitudinal reinforcement bars placed in both the top and bottom with a concrete cover of 25 mm. Stirrups are placed in the beam-ends, above the middle support and under the middle load, for practical reasons. The load is applied from a deformation controlled hydraulic actuator. It has been concluded that the presence of curtailed reinforcement ends in the tension zone might decrease the ductility,when comparing the failure mechanisms for specimens with and without curtailed reinforcement. It appears that the diagonal shear crack develops at the same place, when failure occur in the same shear zone. Atlast It is found that the curtailed reinforcement slightly reduced shear capacity compared to similar beams without curtailed reinforcement.

Piero Colajanni et al (2014) estimated the shear capacity of Reinforced Concrete (RC) beams with web reinforcement by introducing a generalization of classical plastic Nielsen's model (based on the variable-inclination stress-field approach). In the test survey, all the specimens failed in shear with inclined cracks spreading after debonding, cracks between steel plate and concrete, and collapse of transversal reinforcement. It has been shown that the arrangement of stirrups, only in a vertical position, limits the shear capacity because of the high compression in the concrete stress field, while by introducing a second set of transverse reinforcement (as proposed in this study) it improves the shear capacity, even for extremely high values of the web-reinforcement mechanical ratio.. Adopting value of inclination of stirrups of 45° for the transversal reinforcement, the width of crack is limited, thus the mechanism of aggregate interlock allows the shear stress transfer.

Farid Abed et al (2019) made an experimental, analytical, and numerical results of deep concrete beams reinforced with basalt fiber-reinforced polymer (BFRP) bars without web reinforcement. . Three beams were reinforced with steel bars to act as controls while the other beams were reinforced with BFRP bars. Most of the tested beams failed by diagonal shear cracks that extended from the support to the nearest loading point. Ten beams of 2.0 m long and rectangular cross sections of 140 mm width with and variable heights were tested under four-point loading. Regardless of the reinforcement ratio, ρ, the BFRP-reinforced beams showed less stiffness compared to their steel counterparts. This was attributed to the low modulus of elasticity of the BFRP bars in comparison to that of the steel bars. It has been found out that increasing the longitudinal reinforcement ratio, ρ, increased the shear capacity of the BFRP-beams significantly without affecting their midspan deflections

2.6 Eurocode

K. Al Fakih et al (2017) performed study on the behavior of steel beam-to-column connections by using finite element analysis software Abaqus, Ansys, etc. from the theoretical and practical points of view. When designing steel structures, joints are usually assumed either pinned or totally rigid. This study comprises of two parts; Traditional method (Numerical method) and Finite Element (FE) method (modeling techniques) using software. It shows that extra considerations should be taken when designing bolted steel beam connections as per Eurocode.

Walter Salvatore et al (2005) Design, testing and analysis of high ductile partial-strength steel–concrete composite beam-to-column joints The beam-to-column joint has been designed to provide adequate structural performance under both monotonic and cyclic loading. The column stirrups, external to the central area of the joint but within the critical length, are arranged according to Eurocode 8. The parametric analyses conducted both on exterior and interior joints have revealed that the full activation of mechanisms 1 and 2 in the concrete slab causes stiffening and strengthening of joints. The reinforcing bars close to the column flange exhibit a strain level reduction when they are moved away from the inner column flange; and such reduction is not reflected in a reduction of stiffness and strength of a beam-to-column joint.

Claudio Amadio et al (2017) proposed a refined Finite-Element (FE) numerical approach to global and local behaviour of steel concrete composite welded joints subjected to seismic loads. The design approach adopted as per Eurocode 8 recommendations, shows a good dissipative behaviour of the composite connection. The analysis of the three FE deformation (i.e. the beam, column and column web panel contributions), confirmed that plastic damage was mainly reached in the beam only, while the column highlighted a fully elastic behaviour and the column web panel exhibited only negligible plastic deformations. This finding is in close agreement with the past experimental results.

2.7 Retrofitting

Suresh Kumar Paul and Pukhraj Sahu (2020) presented a Finite Element Analysis of retrofitting of RC beam with CFRP using ABAQUS. All beams have the same rectangular cross-section geometry and all beams are loaded under four point bending, but different in the length of the carbon fibre reinforced plastic (CFRP) plate. The pre-crack is modelled by providing 1 mm gap between CFRP plate and soffit of beam. The results showed that when the length of CFRP in flexural retrofitting increases, the load capacity of the beam increases as well. The load carrying capacity increases 37.03%, 33.49%, 7.31%. with the length 1560 mm, 1040 mm, and 520 mm of the CFRP respectively. The Cracks obtained in the experiments and in the simulations are similar, which indicates that the model can capture the mechanisms of fracture in the beams.The stiffness of the CFRP-retrofitted beams is increased compared to that of the control beams.

Lei Wang et al (2015) investigated the shear behavior of corroded reinforced concrete (RC) beams with stirrups and inclined bars. Fourteen RC beams with stirrups and inclined bars were designed and divided into two groups: Group A with corrosion just in stirrups, and Group B with corrosion both in stirrups and inclined bars. After the accelerated corrosion, the static loading test was conducted to study the effects of reinforcement corrosion on the shear behavior. The beams were simply supported and subjected to four-point loading. It is concluded that the slight corrosion loss less than 10% in stirrups and inclined bars has little effect on the degradation of shear strength. The further corroded stirrups and inclined bars, and the accompanied concrete section damage decreases the shear strength significantly. The Corrosion of Stirrups and inclined bars does not change the failure modes for the beams, but does early rupture shear reinforcement and does reduce the number of cracks at the ultimate state, especially for diagonal Cracks.

Ai-Lin Zhanga et al (2020) presented a new earthquake-resilient prefabricated column-flange beam-column joint (PCFBCJ) for the connection between column-flange and beam-column. The PCFBCJ consists of upper column with cantilever beam, lower column with ring flange, common beam and the connection devices. For the repair performance of PCFBCJ with different connection forms, four specimens were designed by changing the FCPs connection form, FCP thickness, bolts number, middle bolts interval, and bolt holes form and five low frequency cyclic loading tests have been conducted. To measure the displacement of common beam end and the relative slip of FCP, several displacement meters were arranged for the each specimen and strain gauges were arranged at the main deformation part of the specimens to measure strain. It can be found that the test results of all specimens are basically consistent with the results of FE analysis. The results shows that the positive and negative yield load and ultimate load of all specimens differ little, and all specimens have good bearing capacity and the slenderness ratio of unrestrained segment of FCP has a great impact on the bearing capacity and ductility of the joints.

III SUMMARY

(i) Bolted connection is a common design in steel beam connections; however, extra considerations should be taken when designing bolted steel beam connections in accordance with the Eurocode.
(ii) Beam-column joints being the lateral and vertical load resisting members in RC structures, are subjected to failure hence their confinement will strengthen the structure.
(iii) By analyzing the beam column joint using ABAQUS software It could able to prevent the failure of beam-column connection prior to failure of members and hence collapse of entire structure can be prevented.
(iv)There is no experimental analysis, the cost required for test specimen also gets eliminated.

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