Journal of Civil Engineering and Technology (JCIET)
Volume 10, Issue 1, January– June 2024, pp. 18-29, Article ID: JCIET_10_01_003
Available online at https://iaeme.com/Home/issue/JCIET?Volume=10&Issue=1
ISSN Print: 2347-4203 and ISSN Online: 2347-4211
Impact Factor (2024): 14.98 (Based on Google Scholar Citation)

USING THE FINITE ELEMENT METHOD TO ANALYSIS THE EFFECT OF ECCENTRICITY LOADS

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ABSTRACT

Since it transmits the loads from the slabs and beams to the foundation, the column is typically thought of as the fundamental structural component of the building. Building columns may be constructed to antiquated requirements, making them susceptible to damage from natural calamities like storms or earthquakes. Numerous experimental investigations on typical damaged and undamaged concrete columns have demonstrated the benefits of the strengthening methods mentioned above.

ABAQUS 2022 software was utilized for modeling in this numerical study, which simulates an experimental operation with nine columns, one of which was loaded to failure and is regarded as a control column. Each specimen in the finite element model is made up of an upper and lower end plate, a concrete core, a stainless steel pipe, and reinforcement in between the pipe and the end plates. S4R elements from ABAQUS imitate the stainless steel pipe and stiffeners, whereas C3D8R elements simulate the concrete core and end plates. When simulating the interaction between concrete and stainless steel pipe, the primary surface is described as the interior of the stainless steel pipe, with core concrete serving as a representation of the secondary surface. The discretization of the primary surface network is configured to be the same as that of the secondary surface, and the nodes of the primary and secondary surfaces coincide, reducing the likelihood of node intersection and ensuring good computational accuracy and model convergence. Based on the convergence study, the unit grid discretization is adjusted to 16 mm to balance calculation efficiency and accuracy.

Keywords: Non-Symmetric Loading, Moment Distribution, Numerical Simulation, Structural Analysis, Eccentricity Loads, ABAQUS 2022.

Cite this Article: Noor Alhuda Abdulrheam and Prof. Dr. Hussam Ali Mohammed, Using the Finite Element Method to Analysis the Effect of Eccentricity Loads, Journal of Civil Engineering and Technology (JCIET). 10(1), 2024. pp. 18-29.
https://iaeme.com/MasterAdmin/Journal_uploads/JCIET/VOLUME_10_ISSUE_1/JCIET_10_01_003.pdf

LITERATURE REVIEW

Pawel wysmulski (2017) to investigate a carbon fiber reinforced polymer (CFRP) thin-walled C-column. Eccentric pressure was applied to the column in a predetermined direction. The computer simulation made the assumption that the column cross-sections' hinge support served as a boundary condition. An examination of the impact of eccentricity on the critical force value was done in individual investigations. Numerical and experimental research methods were the two distinct research methodologies used in the study. Using the sophisticated Abaqus® technology, the finite element approach was utilized to conduct the numerical simulations. It was demonstrated that the eccentricity of the load had a significant impact on the critical force value that corresponded to the local buckling of the channel cross section.

The study's focus is an eccentrically compressed short, thin-walled C-section. The samples were created using an autoclave and contained a polymer reinforced with carbon fiber. Eight layers make up the composite lay-up, which is symmetrical with respect to the central plane. The composite layers are arranged as follows: [0/-45/+45/90]s. The axially-compressed C-section scheme and the direction of the eccentric load measurement are indicated by the "e" axis in Figure 1. The shift distance of the compressive force along the central axis of inertia, measured from the center of mass in the cross-section, was characterized as eccentric. The overall parameters of the channel-section profile were w = 80mm, h, with the assumption that the distance might vary within the range of $0<e<10$mm.

In accordance with the applicable ISO standard, experimental testing was used to evaluate the mechanical properties of a single layer of the composite material. Table 1 displays the mechanical characteristics of the CFRP laminate.

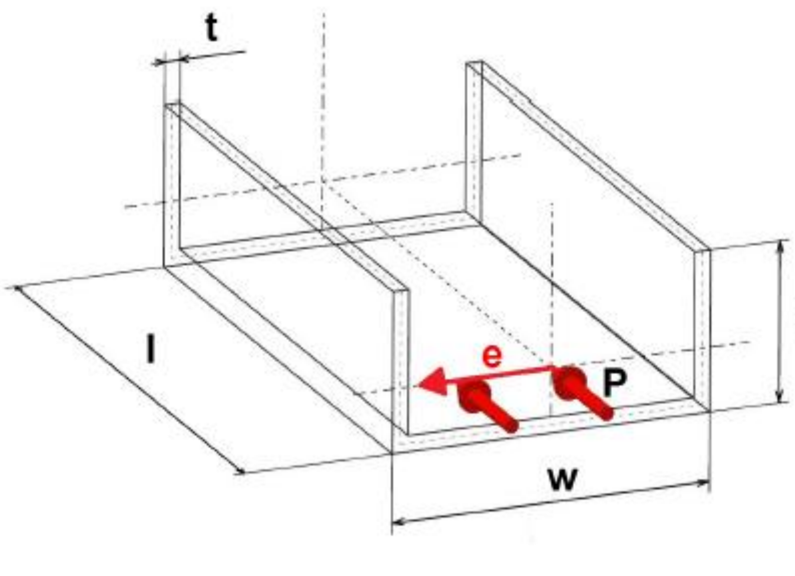

Figure 1 shows a schematic of the study item with a predetermined eccentricity axis (Pawel Wysmulski)

Table 1: CFRP Composite Mechanical Characteristics

Young's modulus [MPa]		Kirchhoff's modulus [MPa]	Poisson's ratio v_{12}
0° (E_1)	90° (E_2)	±45° ($G_{12}/G_{23}/G_{13}$)	0.32
130710	6360	4180	

Using the finite element approach, a thorough analysis of thin-walled C-sections under eccentric pressure was conducted. Experimental tests were used to verify the finite element model [2, 4, 5, 6, 7, 16, 17, 18]. Figure 2 displays the C-section profile that was utilized in both the discrete model and the experimental testing.

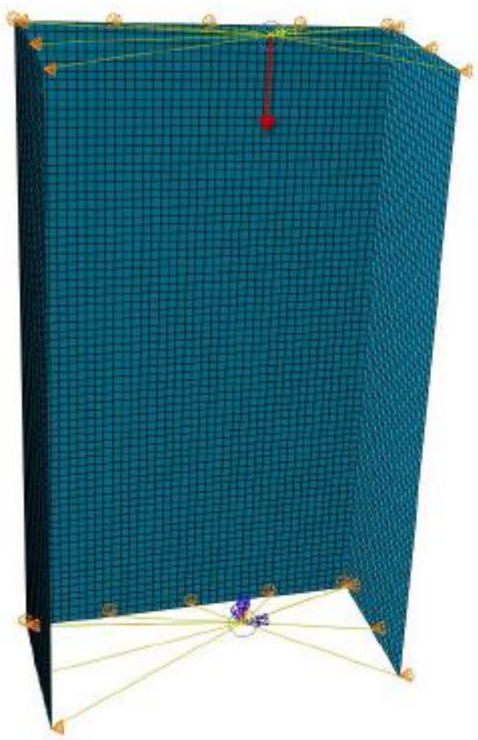

Figure 2. (Pawel Wysmulski) Numerical model FEM during an eccentric compressive load analysis e = 10mm

For the two compression variants of cross-section C, the investigation made it possible to determine the deformation modes and the associated values of critical forces. While the second step looked into compression by eccentric loading, the first stage contained an analysis reflecting axial compression conditions. The experimental results of the compression of cross-section C, taking into account the eccentricity of the compression, validated the numerical solution of the eigenvalue problems for the presented specimens. This information was vital in enabling the analysis of the effects of the load's eccentricity on the structure's critical state. Figure 3 displays both the numerical model and the physical specimen's lowest buckling mode with an eccentricity value of e = 10 mm.

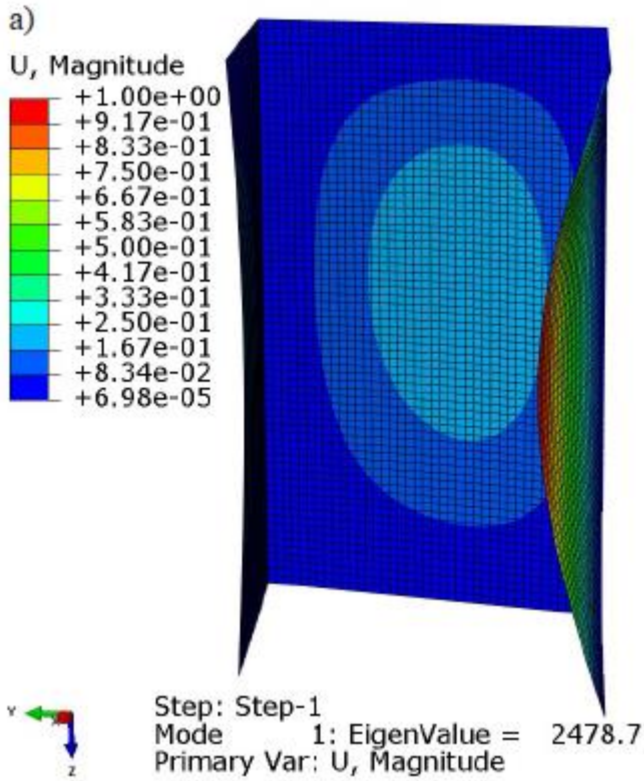

Fig. 3. The findings of the pre-set eccentricity analysis (e = 10 mm) for compression (Pawel Wysmulski)

Ihsan A. S. Al- Shaarbaf (2018) Under axial compression load and uniaxial bending, the behavior of thin reinforced concrete columns with longitudinal holes was examined. One of the research specimens is an investigation of eight thin columns measuring 150 x 150 x 1300 mm. The ANSYS computer program (version 16.1) was used to do the nonlinear finite element analysis and simulate the behavior of reinforced concrete thin columns with longitudinal holes. The longitudinal steel ratio of the column's longitudinal bars and the grade of the longitudinal steel reinforcement (fy) are the two characteristics taken into account.

The findings demonstrated that there is a noticeable rise in the ultimate load in hollow reinforced concrete slender columns when the steel ratio is raised. In the numerical study, four distinct steel ratio values—1.6%,2.3%,3.2%, and 4.2%—were used; as a result, the final load rose by 0.00%,7.14%, 17.59%, and 35.51 percent, respectively. Additionally, the rise in steel Deflections and levels of tensile stress were different for the numerical columns under consideration at stages nearing the ultimate load.

It was observed that the final load increased by roughly (0.00%, 19.98%, 31.97%, and 41.12%) for each of the four steel grades (350, 450, 550, and 650 MPa) that were chosen. Due to the high eccentricity value, which raised the bending moment value, cracking at the tension face first emerged at low loading values. The initial fissure was observed at Pu (0.15 - 0.2). As a result, the moment rather than the axial stress had the dominant influence. The initial crack's appearance at a low applied load value caused the cracked moment of inertia to diminish in value. As a result, at low imposed load values, the column failed. The numerical column (CF1) fracture pattern obtained at the ultimate load stage is displayed in Fig. (4).

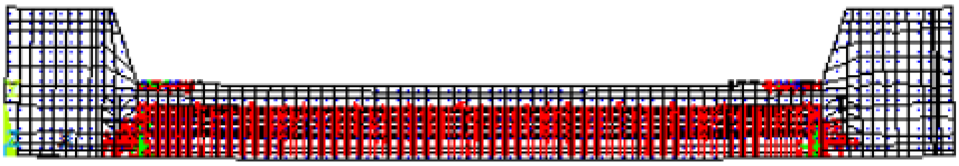

Fig. (4) Numerical column crack pattern at maximum load level (Ihsan A. S. Al- Shaarbaf)

Krzysztof Gromysz (2018) To eliminate deflections in a building, temporary supports—a stack of repetitive elements—are employed. The building is also forced to shift vertically using hydraulic jacks. A portion or all of the building's weight is supported by the temporary supports, depending on the stage of deflection elimination. The building's weight is eccentrically transferred to the supports as a result of errors in the assembling of the piling pieces. Furthermore, horizontal forces load the supports. The kinematic excitations of non-axial mounted jacks, wind loads, deformations of the second order supports, and exceptional loads are the causes of these forces. The eccentric loads and horizontal forces acting on the supports are what cause the deformations in the vertical direction that have a positive sign. Tensile stresses, however, cannot be transmitted by the chimney's unconfined hexagonal parts. As such, the load determines how rigid the supports are. Analysis was done on the temporary supports' horizontal stiffness in relation to the presence of unintentional eccentricity and horizontal stresses.

In order to do this, a support model whose material does not transmit tensile stresses was established. It was demonstrated that the support plan changes based on the value of the horizontal load and the eccentricity of the imposed vertical load. There are eight distinct schemes that the support can execute. It was discovered that the support's rigidity decreases as the eccentricity and horizontal load value rise. If the support system is a pendulum, this stiffness ranges from zero to a maximum value that represents the stiffness of the cantilever bar. Because it is assumed that the load is significantly less than the critical load, the study is restricted to standing supports. Furthermore, the impact of the top of the support's displacement on eccentricity has not been taken into account.

A rod with length l and a cross section with height h and width b makes up a model of the support. The direction perpendicular to the road axis is indicated with x, while the rod axis is shown with z. The point where the rod is supported is where the coordinate system (x, z) starts. The rod's vertex is free to travel in the direction of x. The rod's supported end's boundary conditions prohibit it from moving. The distribution of strains in the base determines whether the entire rod section or a portion of it can rotate in the coordinate z = 0. he vertical force Qz applied in the distance ea to the road axis (unintentional eccentricity) and the horizontal force Qx load the vertex of the rod (z = l) (Fig. 5). The unwanted eccentricity ea takes on a positive value in the opposite scenario, or a negative value if the force Qz is applied on the left side of the axis z. In this work, the force Qx, pointing in the right direction, is examined; thus, Qx takes on positive values.

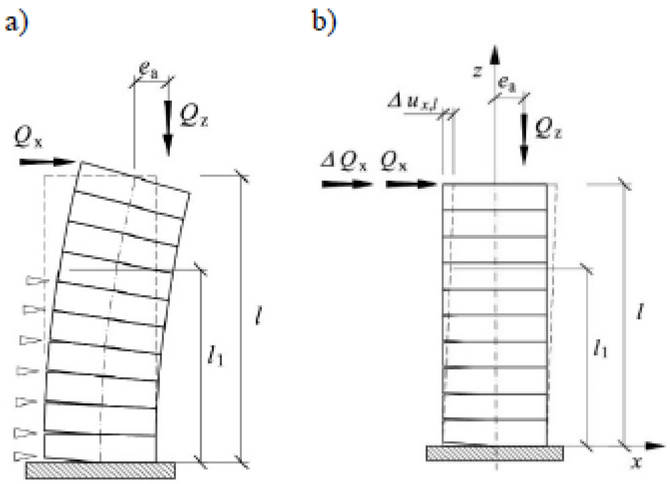

Fig. 5. A stack of components serving as temporary support plan for determining the stiffness kx,l; a position where contact points between pieces are opened is indicated with arrows. scheme of deformations induced by the unintentional eccentricity ea and by the horizontal load Qx.

Bashar A. Mahmood (2019) The impact of load eccentricity on deep beam failure load and failure mechanism is examined in this study utilizing the ANSYS is a nonlinear finite element program. Three RC deep beams are modeled, with shear span to depth ratios between 0.91 and 1.67. When the experimental and numerical results were compared under medium loading, they were found to be roughly in perfect agreement. This was carried out to provide an accurate model depiction. A notable decrease in the failure load was seen under eccentric loading, according to the model that was used to examine how RC deep beams behaved at various beam heights. There was a noticeable decrease in the failure load because of eccentricity, but there is also a (gradual) increase in failure load with increasing beam height. All beams, regardless of height, exhibited the identical failure load at a 50 mm eccentricity load value, and their failure was caused by the concrete crushing at the compression face of the beam.

In both compression and tension, concrete behaves differently, making it a quasi-fragile material. An element called SOLID65 from ANSYS is useful for modeling concrete. In compression, this element can crush and crack. There are eight nodes in the element, and each node has three degrees of freedom. For every beam, a straight line connecting multiple locations creates a simplified stress-strain curve. We utilize a Poisson's ratio of 0.2. For closed cracks, a shear restraint factor of 0.7 is considered, whereas for open fractures, a value of 0.3. It is assumed that the tensile stiffness coefficient (TC) is 0.6. The load, support, and a typical finite element mesh are displayed in Figure (6). The mesh size was selected to replicate the eccentricity of the load, with 50 mm in the X-Y direction and 15-20 mm in the Z direction. The simulation of load eccentricity and support is displayed in Figure (7). It was expected that the nodes of the bar element and the nodes of the concrete element were fully bonded. In order to replicate the real boundary conditions of the experimental investigation, the modeling benefit of symmetry was disregarded.

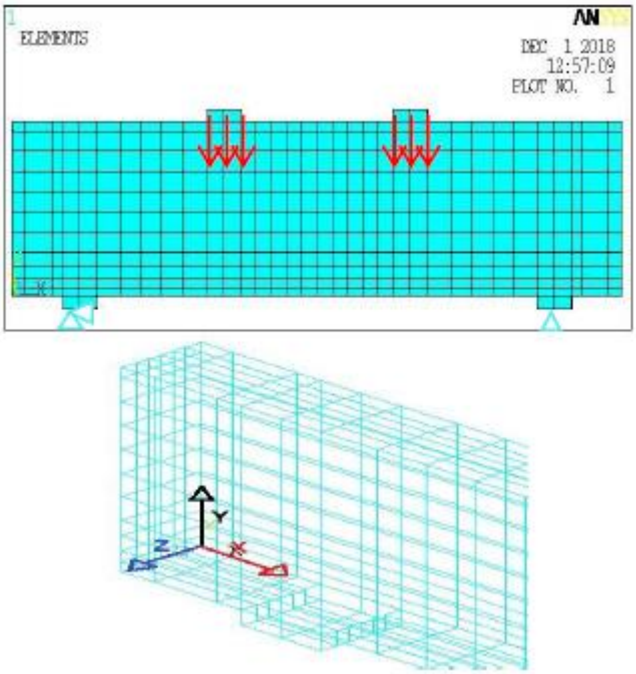

Fig. (6) Axes directions, loading, support simulation, and finite element mesh (Bashar A. Mahmood).

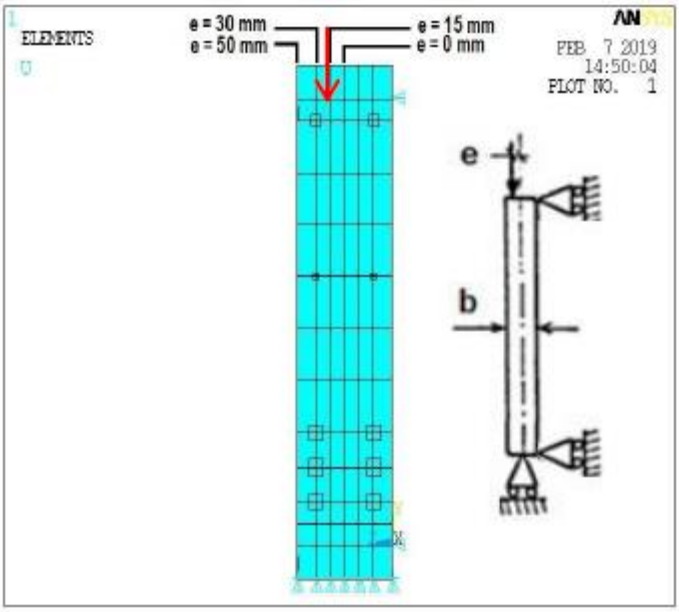

Fig. (7) The G2 beam under eccentric load and support conditions in three dimensions and from the side (Bashar A. Mahmood).

C. Claeson (2020) A he behavior of reinforced concrete columns tested under eccentric monotonic loading is examined using a nonlinear finite element analysis, which is provided. The test findings and the finite element analysis results show good correlation. To look at the variations in failure modes for various concrete strengths, length-to-width ratios, and loading eccentricity, a parametric research was conducted. Concrete with a higher compressive strength was advantageous, particularly at low load eccentricity. The strength of high strength concrete columns declined more quickly than that of columns of conventional strength as the eccentricity rose. The load-bearing capability of the high-strength concrete columns was nevertheless greater than that of the normal-strength columns.

Creating nonlinear finite element models that could replicate the columns' failure mechanism and, in conjunction with testing, improve our understanding of the mechanical behavior up until the point of ultimate failure was one of the study's goals. With the aid of the nonlinear finite element program ABAQUS, these models were created. It was decided to build a model using three-dimensional hybrid beam elements with three nodes. The beam element model has the benefit of being able to be executed in a fair amount of time.

Sadjad A. Hemzah (2021) Examine and validate the ABAQUS numerical model of the partially loaded square high-strength reinforced concrete (HSC) columns with an eccentricity of 50 mm from the center (e/h = 0.5). In order to achieve this goal, nine short HSC columns that had been reinforced using carbon fiber reinforced polymer (CFRP) plates in various configurations were employed. These columns were then experimentally tested for their ultimate strengths and full load response, with the vertical deflections from a previously published research paper being utilized to verify the accuracy of the equations.He verified model was subsequently used to evaluate additional parameters, including the impact of additional CFRP layers, various load eccentricities (e/h), and beginning load ratios. The numerical analysis demonstrated good agreement with the experimental results since the final load and deflection values converged. Additionally, the results demonstrated that the ultimate capacity was greatly increased for complicated specimens reinforced with CFRP laminates when the number of CFRP plates was increased in both transverse and longitudinal directions. Concurrently, for all specimens, whether fully or partially reinforced with CFRP plates, the ultimate strength and deflections increased with the decrease in the eccentricity ratio (e/h). In fact, the findings demonstrated that a decrease in the final load was the outcome of the reinforced specimens' increased beginning load ratios.Using several mesh sizes in ABAQUS was done in order to conduct a convergence study and identify the ideal volume that would yield the required respectively. The mesh size of 20 mm was selected for this paper. The impact of element size on the vertical load and deflection curves is depicted in Figure 8.

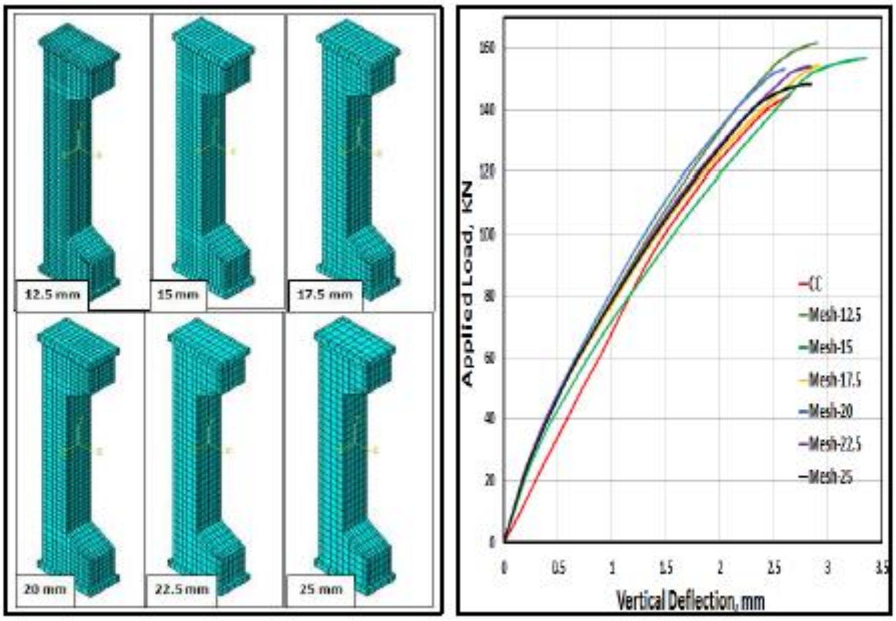

Fig. (8) mesh density with finite elements. (B) How element size affects load-deflection curves vertically (Sadjad A. Hemzah).

Dara A. Mawlood (2022) Because composite columns can increase the useable area in the floor plan while reducing the size of the building columns, they are frequently employed in the construction of high-rise buildings. The goal of this study was to create a nonlinear 3D finite element analysis model for solid and hollow columns subjected to various eccentric loads (90, 180 mm) using ABAQUS, version 6.13-4. The model included several circular composite column designs with various multi-clad tubes. Using a numerical approach and six reference experimental data sets for composite columns, the data was extended to 12 more composite column specimens. According to the ABAQUS data used in this study, a drop in the load to failure for composite columns is caused by an increase in eccentricity for applied loads. At varying eccentric loads, the ultimate capacity of solid composite sections is greater than that of hollow composite sections at eccentricity. The same outcomes are seen with loads that have eccentricity. The greater number of steel layers suggests the same outcomes. The strength of concrete has a major impact on how stiff it is. The composite column's stiffness increases in tandem with an increase in concrete strength. For the specimen (CC1S00) with fc'=31.96 MPa, the ratios of concrete compressive strength values were (-4.4, 3.1, and 6.5) percent as per the reference column. The finite element results are in good agreement with the experimental results, and the method used is in the nonlinear analysis.

Results from ABAQUS 6.13 in terms of numbers that illustrate the failure modes of composite columns tested under eccentric stress. All specimens collapsed as a result of local buckling, which is comparable to Al-Khekany et al.'s laboratory experiments. Concrete is poured into the tube, increasing the section's strength and ductility. Consequently, the steel pipe's local buckling failure is postponed. Furthermore, the concrete is contained within the steel pipe. The concrete prevents the hollow steel pipe from bowing locally because of its restraining action. Figure (9) depicts the specimen's (CC2H) model failure at eccentricity.

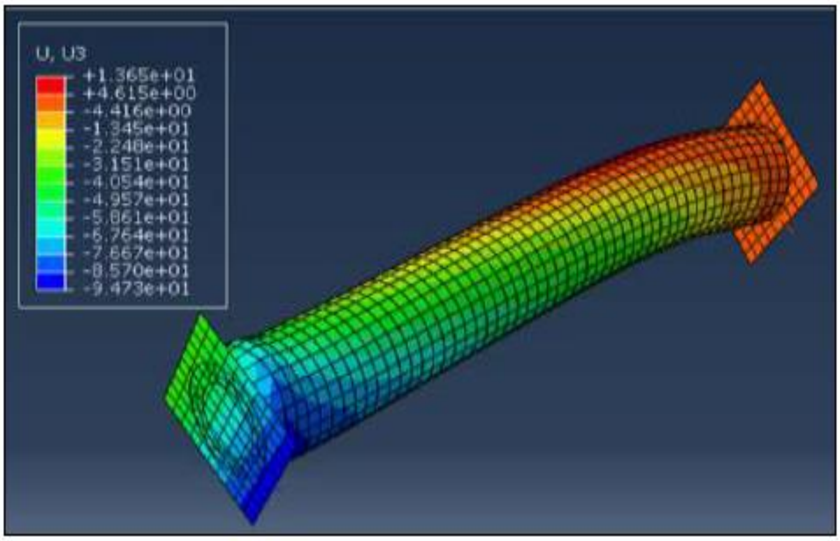

Fig. (9) Column failure under 180 mm eccentricity. (Dara A. Mawlood).

Wen-Chao Xie (2023) In settings where corrosion is a risk, concrete-filled stainless steel tubes (CFSST) could be employed as structural components. This work presents a thorough numerical analysis of the mechanical characteristics and calculation technique of CFSST members under eccentric loading. Three-dimensional elements are utilized to create a finite element analysis (FEA) model, which is then validated using related experimental data of conventional carbon steel filled concrete tubes (CFST) under tension and CFSST.

The characteristics of eccentrically generated CFSST components are next examined using the calibrated finite element model, in the load carrying capability of the composite member is largely dependent on the laws of composite action and the stress distribution between the concrete core and the stainless steel tube. To calculate the impact of different parameters on the tensile strength of CFSST components, a comprehensive parametric analysis is performed. The ultimate tensile strength of CFSST members subjected to eccentric tension is finally predicted using a computational model that is proposed and used; the values predicted by the model correlate well with the finite element method calculations.

Figure 10 displays the derived finite element model of CFFST members under eccentric loading. At the top face plate's load line, eccentric loading takes place. Furthermore, every degree of freedom is limited, with the exception of z- and x-axis translation and rotation. With the exception of x-axis rotation, all degrees of freedom are restricted by a fixed line that is placed on the lower outer side of the lower end plate. With the exception of x-axis rotation, all degrees of freedom are limited by a fixed line that is placed on the bottom of the lower end-plate.

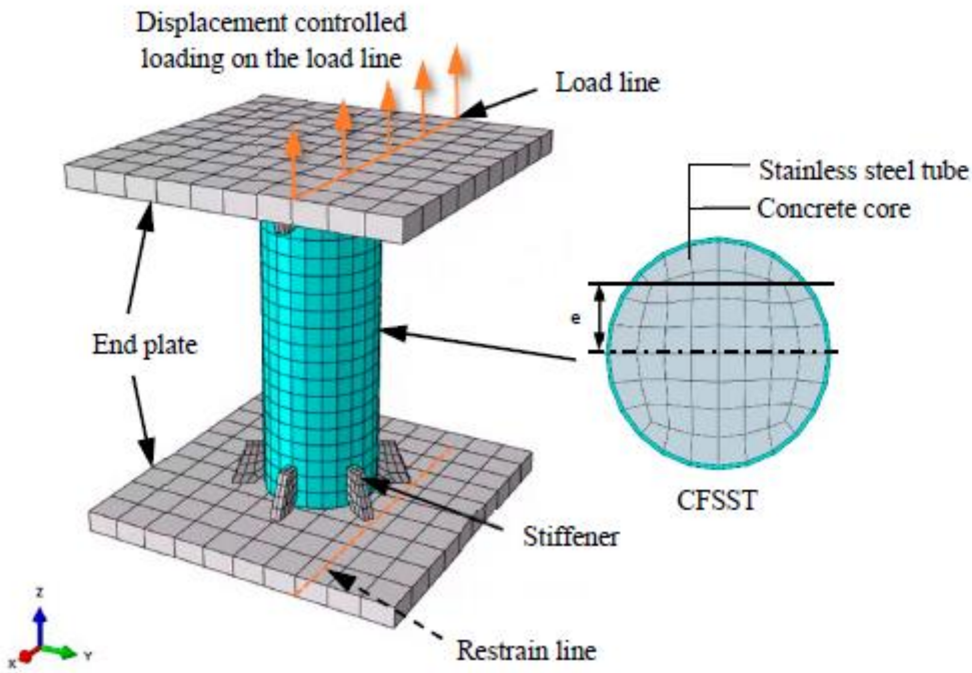

Fig. (10) FEA model of the eccentrically tensioned CFSST member. (Wen-Chao Xie).

Nasim Shakouri Mahmoudabadi (2024) Examine When subjected to axial and eccentric loads, glass fiber reinforced polymer (GFRP) reinforcements outperform typical steel members in concrete buildings, particularly in vertical components like columns. They also offer a number of other advantages over standard steel members. Nevertheless, numerical and experimental studies on the behavior of here are restricted GFRP-reinforced concrete (RC) columns that can withstand eccentric loading and differ in stirrup spacing. Six examples were cast in this study with two groups of stirrup spacing (50 mm and 100 mm) and three distinct eccentricity values (25 mm, 50 mm, and 75 mm). The experimental findings demonstrated that when the eccentricity value increased, the specimens' ability to support a load reduced. The software utilized for the numerical analysis in this work was ABAQUS finite element. The results of the finite element analysis (FEA) were within an acceptable range and closely matched the experimental results. For axial load and strain, the greatest deviation between the finite element findings and the experimental values was 12.06% and 3.61%, respectively.

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CONCLUSIONS

1- The column's buckling mode and the lowest buckling mode determined by numerical modeling are in agreement. There is a strong correlation between the critical forces determined through experimentation and the calculated critical forces. The outcomes produced by using the created FEM models support this. The findings indicate that the critical force corresponding to a local buckling of the column is significantly impacted by load eccentricity. It has been discovered that the critical load is significantly reduced when load eccentricity is applied in a direction away from the column's web. Conversely, an eccentric load applied to the web of the column causes a small increase in the stiffness of the structure.

2- The study's suggested ABAQUS 6.13-4 models are appropriate for forecasting the behavior of composite column specimens. The numerical results agreed well with the experimental load-buckling curve over the complete behavior range.

3- he results of the suggested model demonstrate that when eccentricity increases for applied loads from 90 mm to 180 mm, the strength of the composite columns decreases with the applied loads. The column's stiffness decreases as the load's eccentricity is transferred away from it, hastening the structure's loss of stability.

4- Nonlinear finite element models that were predicted demonstrate that hollow composite sections have lower ultimate loads than solid composite sections because One factor that helps the section resist the imposed load is an increase in the concrete core's cross-section area.

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