Civil and Environmental Engineering
Vol. 0, Issue 0, DOI: 10.2478/cee-2026-0061

Experimental Investigation of Eccentric Composite Hollow Steel-Concrete Tensioned Column

Wameedh Issa BRAIDI [1], Rasool Dakhil MOHSIN[1], Nasser Hakeem TU'MA[1,*], Haider Abdul-Kareem RAHEEM[1]

[1] College of Engineering, University of Misan, Misan, Iraq
* corresponding author: naserhakeem@uomisan.edu.iq

Date of Submission: 31 August 2025
Revision Date: 01 November 2025
Date of Acceptance: 20 November 2025

Civil and Environmental Engineering
Journal of the Faculty of Civil Engineering | University of Žilina

Abstract

The current research offers scientific originality due to the lack of studies related to composite columns in enhancing tensile resistance as a result of the presence of non-axial tensile forces in many civil engineering applications. The research gap lies in using a composite section of hollow steel and concrete to produce a column that resists eccentric tensile forces. Five short composite columns as well as two reference columns were casted to study the effect of the existing of hollow steel section and different types of the eccentricities on the tensile strength of the composite short column. The designs were prepared to accommodate all the variables mentioned for calculating net forces and internal resisting moments of the section. The main conclusion of the current study confirmed the possibility of using the composite column in places that are exposed to eccentric tensile forces with a high efficiency of up to 17%. Also**,** laboratory tests showed that the optimal eccentric loading distance is the distance that is 15% greater or less than the balanced eccentric distance in order to maintain the tensile strengths at the highest level.

Keywords

Tensioned Column; Composite Column; Hollow Steel Section; Eccentric Loading Distance; Short Column.

1. Introduction

A very important aspect of structural engineering and reinforced concrete elements is the presence of direct tension in the section. Since the tensile strength of concrete is relatively weak, reaching 10% of the compressive strength, it has become imperative to seek reinforcement within the concrete section to enhance this resistance. When designing a concrete section, the tensile strength of the concrete is neglected, relying solely on the tensile strength of the reinforcing steel. Furthermore, the strengthening systems may be external, using different materials or multiple strengthening methods, or internal, as is the case in our current research. The use of hollow steel sections gives the initial impression of eliminating the needing of the concrete of low tensile strength and therefore, enhance it with a strong one to maximize tensile strength. So, the research concept focuses on this content, with an emphasis on providing a strong bond between the steel section and the concrete to ensure a good bonding as a single element. One of the structural elements that is exposed to either direct tension or with uniaxial or even biaxial bending the tensioned column, which is sometimes called floating columns (Ubani,2022).

Figure 1: Reinforced Concrete Tensioned Column

Waleed et al. (2012) investigated the combined effect of axial load and bending moment on reinforced concrete type either normal and self- compacted concrete columns reinforced by Carbon-Fiber-Reinforced Polymer (CFRP). The main parameters were as well as a concrete type, the layer's thickness, fiber orientations with respect to perpendicular axis of the column and the ratios of eccentricity to column depth. In general, the results demonstrated that a significant improvement in performance of strengthened columns than the unstrengthened ones.

Aparna et al. (2017) conducted an experimental works for columns of steel tubes filling by either waste material or steel reinforcing mesh. Waste material in term of Lathe waste was utilized as a fiber. The fibers played a bridging in the force transmitting tensile forces along the cracks. The steel mesh of 1 mm in thickness was used, and then pouring the concrete inside the steel tube. Results showed that, there was no considerable improvement in the axial loaded by using lathe waste filling concrete but offered more ductility than the steel mesh filled columns.

Vigneshvar et al. (2017) focused on the determination the tensile strength of the column and the range of failure of the tension type under combined loading consisting of compressive axial load and bending in term of balanced axial load factor (λ). A numerical study covered several parameters such as distribution of steel inside the column's section (equally and unequally spaced) , different cross-section's dimensions, percentage of reinforcement, strains in longitudinal steel and the orientation of the column. Noticed were tabulated that the column sections containing of unequally spaced longitudinal reinforcement gave a higher moment resisting than the another spaced, i.e. more tensile capacity will occur in the column section.

Mansi (2018) studied various configurations of floating columns that were early studied by many authors. the plan irregularity key parameter included torsion irregularity, re-entrant corners, diaphragm discontinuity, out-of-plane offsets, and non-parallel systems. The vertical irregularity of stiffness irregularity, mass irregularity, vertical geometric irregularity, discontinuity in capacity, and in-plane discontinuity were also investigated. As well as the configurations, the study contained analysis, structural performance against lateral load, and effect of existing columns on multistory buildings. The study proved that failure is most likely to occur when the column is floating during earthquake. So, such column should be avoided and strengthening system should be adopted such as infill, shear wall , bracing, etc.

Muhammad et al. (2018) carried out an experimental investigation to study the behaviour of hollow core of Reactive Powder Concrete (RPC) columns. It externally warped with a circular tube manufactured by Carbon-Fiber-Reinforced polymer (CFRP). The laboratory program consisted of four groups of sixteen sample of dimensions of diameter equal to 206 mm. The height and the overall hole were 800 mm 90 mm; respectively. The different loading conditions were applied and were concentric, eccentric of two distances of 25 mm and 50 mm. as well as four-point bending. Experimented noticed the CFRP tube gave a slight increasing in confinement of the strength.

Binglin (2020) used the experimental research on composite column of fully steel H-section and high strength concrete. Also, an analytical model was proposed to extract the whole range of axial load-displacement behaviour for different concrete strength up to 130 MPa and many steel section's grade up to S690. Experimental showing stated the confinement due to interaction of the steel section and surrounding concrete was not activated before spalling the concrete cover. The stirrups-potential for induced confining pressure started at the beginning of applying the compressive load up to the failure. In the proposed model, the steel section's enhancement of confinement was derived based upon the state of biaxial stress of the steel web where the lateral tensile stress was expected to initiation due to the expansion of the concrete. The longitudinal compression stress was developed due to the applied axial load.

Hubert et al. (2021) presented an experimental study about using eccentric compressive short columns of open cross section manufacturing by Carbon Fiber Reinforced Polymer (CFRP) thin-walled composite profiles. All columns were made by autoclaving and consisted of 8 plies of unidirectional CFRP laminate. The main key parameters that exanimated were the effect of laminate layup and cross-sectional shape to verify their effects on the buckling, post-buckling and failure load. The results showed that the same level of losing in stability of compressive carrying capacity were recorded. The study was also demonstrated that the negative effect on the stability and strength was occurred in the direction parallel to the web.

Alaa and Mohammed (2021) introduced a general description about the reinforced concrete slender columns eccentrically loaded and containing different longitudinal hollow cross section of rectangular and circular. Seven groups were erected to accomplish the study's goal. All column were the same dimensions and had symmetrical reinforced bars with rectangular cross section. Half of ten specimens were warped by CFRP sheet to study buckling's effect. Tests were showed that the ultimate load was inversely proportional to eccentricity. Also, the results stated that the circular hollow cross section enhanced the capacity better than rectangular one.

Paolino et al. (2021) introduced a jacketing system as external strengthening technique by using of High-Performance Fiber Reinforced Concrete (HPFRC) around the existing column subjected to axial compressive force and uniaxial bending moment. The experimental program consisting four reduced- scale columns. The first one was RC of reference columns without any jacketing while the others three specimens were coating by HPFRC. The design of reference column's specimens was based upon Italian code for representation the existing RC buildings as poor-detailed in term of dimensions and reinforcement , from authors' point of view. The scaling of 1:2 was adopted. The adoption was based on two considerations for modelling of real columns and limitations of laboratory. Finally, an analytical design aids for retrofitting the using of the HPFRC jacket was proposed.

A recommended design equation was illustrated as pure axial tensile action of reinforced concrete columns neglecting the tensile capacity of concrete and the entire stress will be carried by the steel reinforcements only . So, the area of steel required to resist the tensile axial force will be given by (Ubani ,2022) in addition to skin reinforcement for controlling the crack problem:

$$A_{st,req} = N_{t,Ed}/0.87f_{yk} \quad (1)$$

Where:
$A_{st,req}$ = Area of steel required
$N_{t,Ed}$ = Ultimate axial tensile force
f_{yk} = Characteristic yield strength of the reinforcement

The research on strengthening structural elements of column with hollows strengthening by Carbon Fiber Reinforced Polymer (CFRP) strip was presented by (Sri,2024). The main objective was the effect of high shear force intensity on the strain behavior of longitudinal reinforcement and CFRP strips. Nine samples with hollow cross-section of 1.5", 2.5", and 3.5" and three samples of solid cross section were utilized to study the effect of voids on the strain profile. Numerical analysis was used using a fiber element model. Then, an equation was proposed for calculating the tensile force in CFRP strips. The proposed equation approximated the test results with an accuracy level of 90%.

In summary of the above, there is almost no study covering the use of hollow steel sections embedded within the reinforced concrete body of a column under the influence of a tensile load with a uniaxial moment.

2. Methodology

2.1. Research Design

Generally, all specimens were designed as short columns of 0.2 m and 0.125 m in width and depth of cross-section; respectively. The slenderness ratio (k L/ r) was 13 for specimens of 0.5 in height as per ACI-318-19. The design forces were based upon the yielding force of the longitudinal reinforcements, yielding of the composite of steel box section and the contribution of the tensile force of concrete (0.62 $\sqrt{fc'}$ times the concrete area). In addition, the interface surface between the steel box and the surrounding concrete were enhanced by steel studs of 0.9 cm in diameter and 1.5 cm in height that welded from four sides at 10 cm intervals. The dimensions of steel boxes are 75mm × 50mm × 2 mm. The tied reinforcements were selected as Φ 10 mm at 100 mm in middle-height region while three ties were used through 100 mm from both ends. The first symbols of the specimens " C" refers to the column. The second letter (E) refers to eccentric load condition. The "S" and "H" letters refer to the solid and hollow cross-section; respectively. The " B" letter refers to composite action and the integer number indicated the sample number. Seven samples were prepared to perform the study in two groups. The first group was organized to study the effect of the types of longitudinal core on the tensile loading carrying capacity. The second group was used to study the effect of column's height.

The eccentric load columns were designed to be failed in balanced and tensile yielding of steel on the side nearest from the load. The steel boxes were extended in the corbel region for continuity of composite action as well as the welded studs between the steel box and the surrounding concrete area. The both ended corbel were reinforced in such a case to ensure the rigid eccentricity distance. The steel tied at the connected region of column- corbel were provided to avoid the stress concentration. The two groups were planned to get the experimental findings. The first group of balanced failure were prepared as solid, hollow and steel box section with constant balanced eccentricity (eb) for all. The second group were focused on the tensile failure's investigation by decreasing the eccentricity by ± 15 % for specimen C-E-B-4 and accumulative increasing of 15%, 30 % and 45 % over balanced eccentricity for specimens C-E-B-5, C-E-B-6 and C-E-B-5 ; respectively. The characteristics of the column are listed in Table 1 and Figure 2. Also, the steps for theoretical design are shown in Figure3. The corbel is designed to withstand the forces and is reinforced as shown in Figure 3.

Table 1: The details of Tested Beams

Group	Beam ID	Loaded Type	Failure Type	Eccent. (e) [mm]	Section Type	Length [mm]	Steel Box No.
Group-1	C-E-S-1	Eccentric	Balance	210	Solid	500	---
	C-E-H-2	Eccentric	Balance	210	Hollow	500	---
	C-E-B-3	Eccentric	Balance	210	Composite	500	1
Group-2	C-E-B-4	Eccentric	e < eb	190	Composite	500	1
	C-E-B-5	Eccentric	e1 > eb	242	Composite	500	1
	C-E-B-6	Eccentric	e2 > eb	273	Composite	500	1
	C-E-B-7	Eccentric	e3 > eb	305	Composite	500	1

The wooden mold was made from a square piece with the overall dimensions of the sample, which served as the mold's floor. The remaining parts were cut to fit the dimensions and secured to the floor with iron bars, allowing the sample to be opened easily and supporting the mold during pouring. The transparent silicon was used to fill the undesirable openings among wooden pieces. The longitudinal opening of the hollow cross-section was made by cork material. All concrete covers were selected as 20 mm.

All specimens were poured in the same time. The batching plant were weighted all materials and provided the fresh concrete by truck mixer of 1.5 cubic meter. The quality control plan was carried out under supervision of one member of the authors' team. Then, the fresh concrete was transport inside the laboratory by box type single wheel barrow trolley. The small machine vibrator was used along the pouring process. Finally, the top surface of the specimens was levelled by trowel.

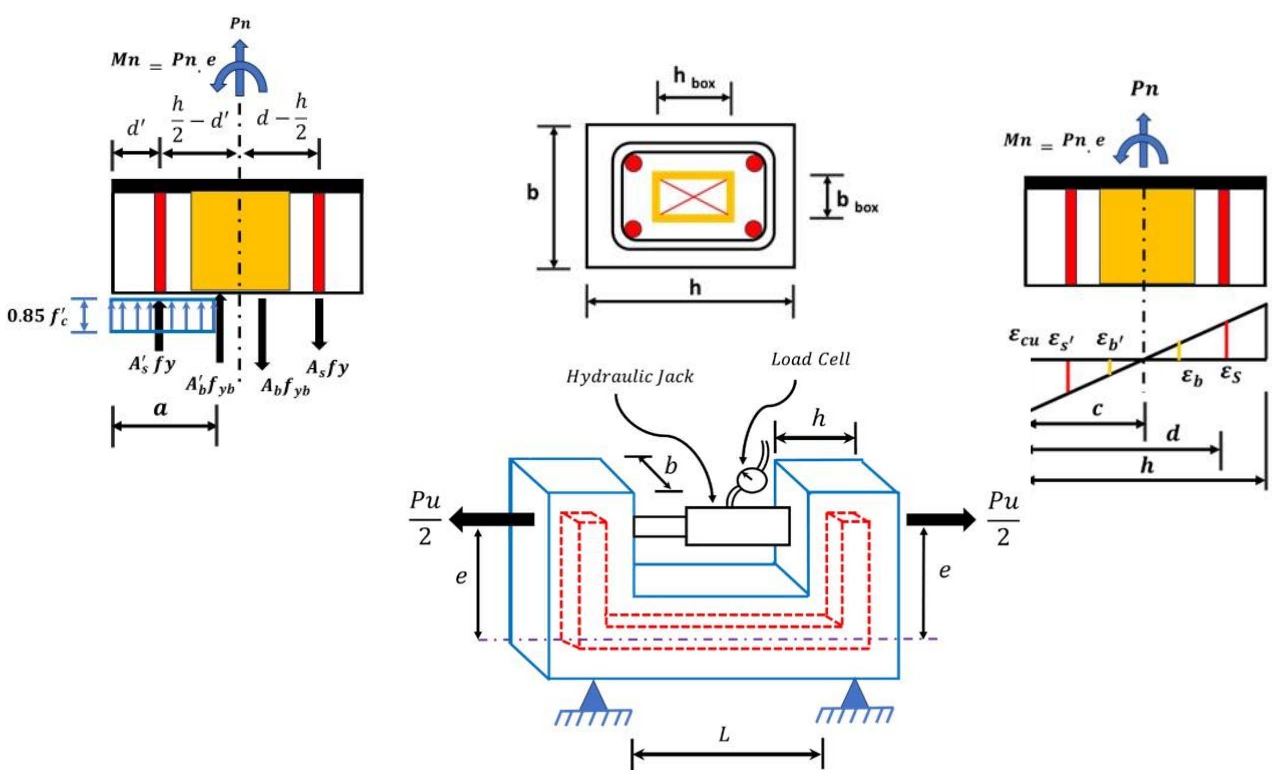


Figure 2: Geometry and Details of Tested Column

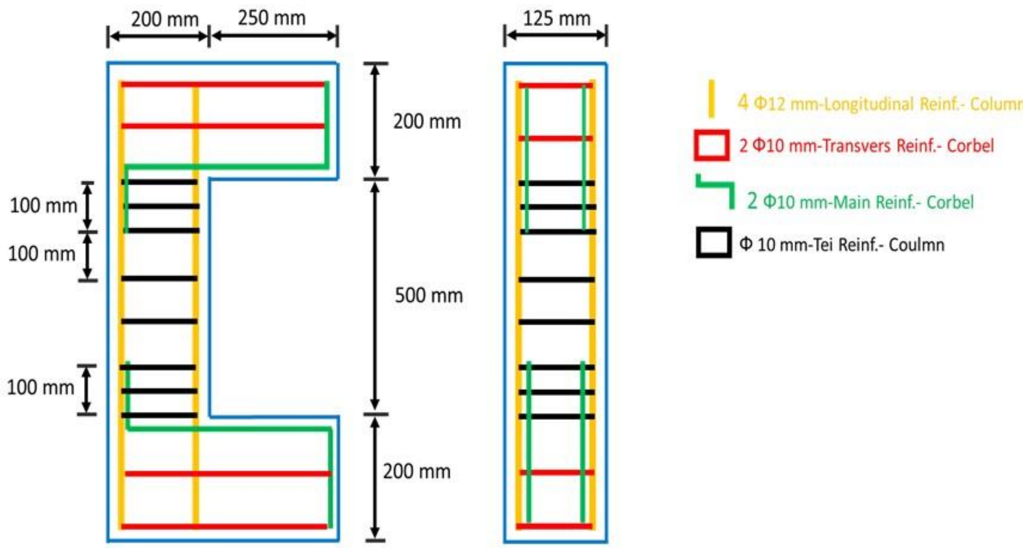


Figure 3: Reinforcement Details of Tested eccentric column

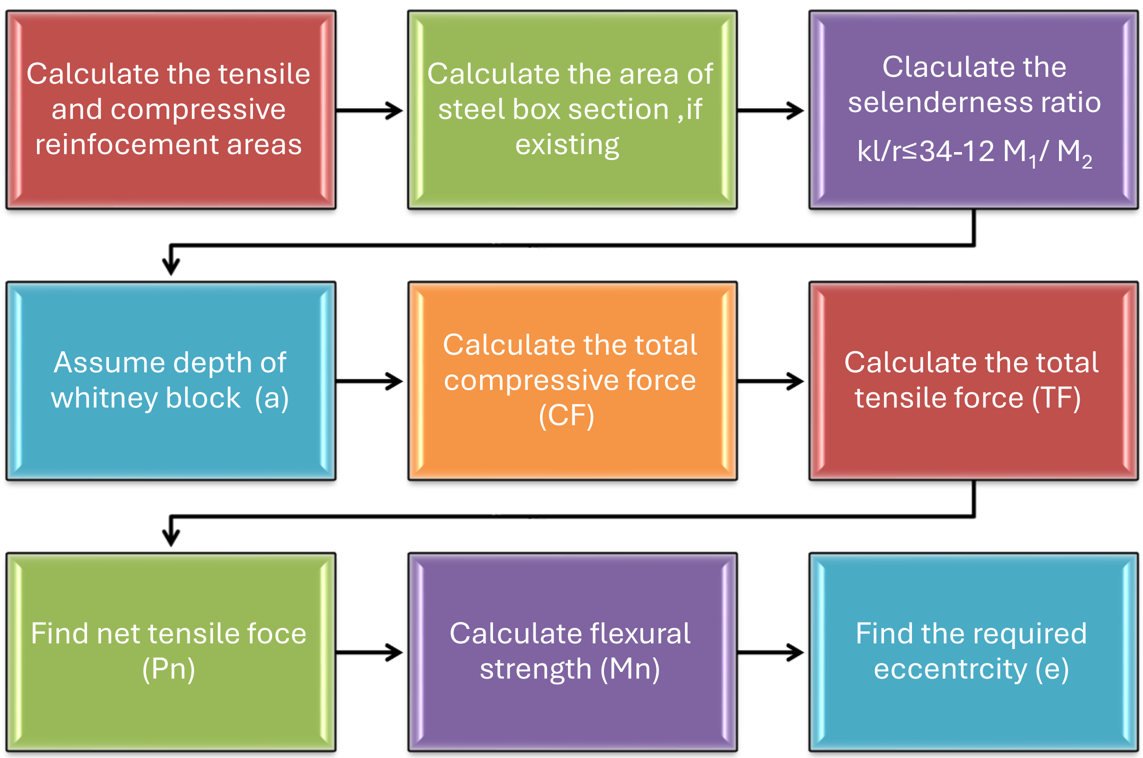


Figure 4: Steps for theorical design

Figure 5: Fabrication the Specimens

2.2. Materials and Procedures

All materials used in the manufacture of the specimens are the same materials used in other studies that fall within a research program adopted by the same researchers. Ordinary Portland cement type (I) was used. The test was carried out according to the Iraqi specification No.5/2019 at the laboratory of material and construction – Technical Institute of Amarah. The natural sand was used as a fine aggregate. The sand was tested according to Iraqi specification No. 45/1984, Zone II. The maximum size of coarse aggregate is 20 mm and the required tests were carried out according to Iraqi specification No. 45/1984. All the hollow steel sections were tested following the American specification for steel materials testing ASTM A370-10 ,as shown in Table 2.

Table 2: Properties of Steel Box

Test Indication	Average Value	ASTM-A 370-10 [14]
Yield Tensile Strength [MPa]	325	250 Min.
Ultimate Tensile Strength [MPa]	436	400- 500

All reinforced bars that utilized were Van Steel Plant in Iraq. The results of tests were based upon the manufacturing certificate of each bar's diameter. The results were carried out per ASTM (A615/A615-22), Table 3.

Table 3: Properties of reinforced Bars

Test Results				ASTM A 615/A615-22 Grade 60 limits		
Bar size [mm]	Yield strength [N/mm^2]	Ultimate strength [N/mm^2]	Elongation [%]	Yield strength Min. [N/mm^2]	Ultimate strength Min. [N/mm^2]	Elongation [%]
10	619	638	24	420	550	9
12	577.6	653	11.6	350	550	7

The quantity of all materials of fresh concrete was based on the field of experience. All materials were mixed together by batching concrete plant. The materials per one cubic meter of fresh concrete shown in the Table 4. The mechanical properties of the used concrete were shown in the Table 5. Three cylinders of 150 mm in diameter and 300 mm in length for compressive strength were used and test was carried out per ASTM C 39/C 39M -05 . The tensile strength was estimated by three cylinders of 100 mm in diameter and 200 mm in length where testing was done per ASTM C 496/C 496M and as well as three prisms of (500 mm) in length and (100 x 100) mm cross-section and testing was also carried out per ASTM C78-08.

Table 4: Mix Proportions for Fresh Concrete

Cement [kg/m^3]	Sand [kg/m^3]	Gravel [kg/m^3]	Water [kg/m^3]
410	813	955	196

Table 5: Mechanical Properties of the concrete

Sample No.	Cylinderical Compressive strength (fc') [MPa]	Tensile Strength	
		Splitting [MPa]	Modulus of Rupture [MPa]
1	24.2	2.5	3.31
2	24. 1	2.2	3.45
3	23.6	2.6	3.67
Average	24.00	2.43	3.48

After completeness the curing process, the beams were transferred to the testing machine. The column is placed horizontally due to the difficulty of maintaining its verticality when placed lengthwise on two supports on both sides. A piece of rubber was placed on each support to prevent bearing stress. The hydraulic jack was lifted by a 3-Ton load carrier to equilibrate the weight of the jack until the two edges of the jack were locked in their designated places. The first reading was recorded and considered the zero reading. Then, a manual piston was used to gradually apply the load until the failure strength was reached. The device has a load cell certified by the Central Agency for Standardization and Quality Control. The device's capacity is 60 tons. The dial gauges were INSIZE typed with a maximum measuring of 30 mm and a precision of 0.01 mm, Figure 6.

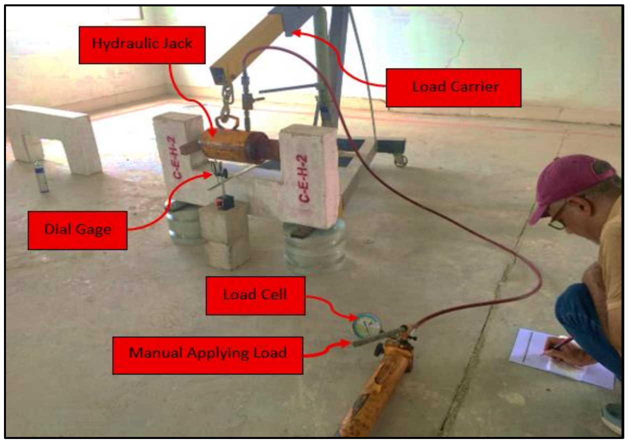
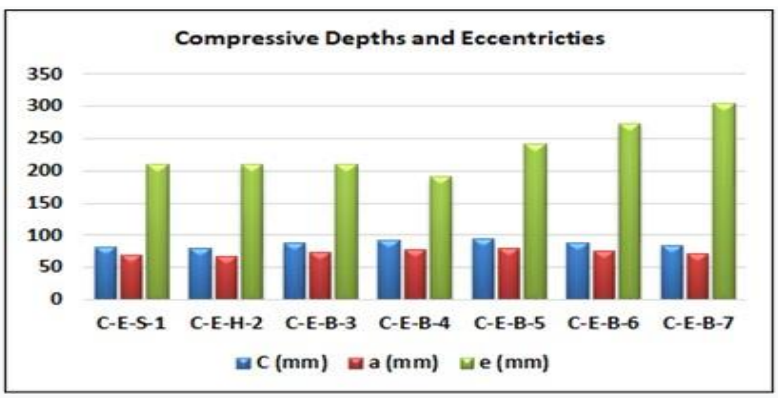


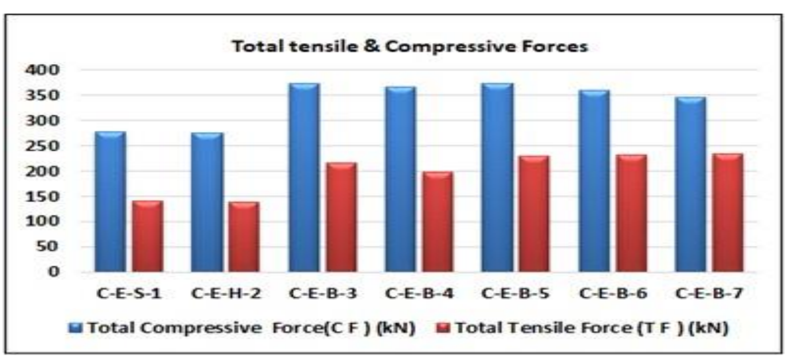
Figure 6: Testing layout

3. Results

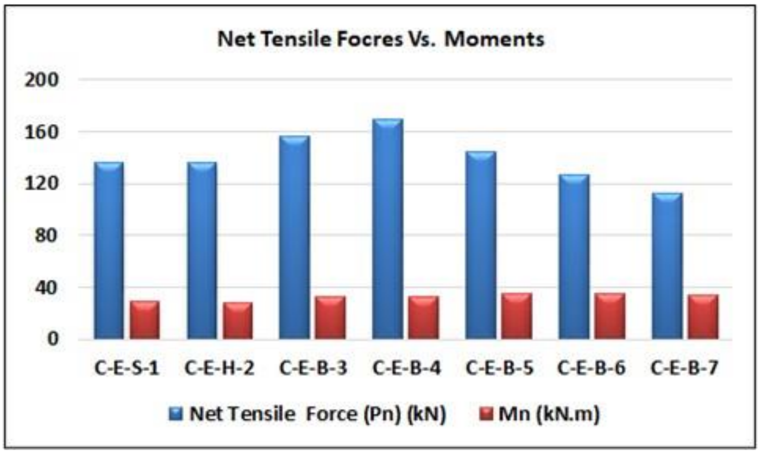
By analyzing the obtained results, when comparing the samples in the first group, the designed tensile strength of the hollow reference sample C-E-H-2 is less than that of the solid reference sample C-E-S-1 by 4% (120/125). The reason for this is very clear, which is the presence of the longitudinal cavity, which contributes to a decrease in the tensile force of the concrete and thus a decrease in the total tension in the section. When comparing the C-E-B-3 specimen with the hollow reference specimen C-E-H-2, the practical tensile force increases by 13% (135/120) due to the presence of the steel box which provides enhancement to the tensioning components and thus increases the total tensile force. Laboratory results showed an underestimation of 10% compared to the design values, which means that there is at least a safety factor of (1/10) capacity as shown in Table 6, Figure 7 and Figure 8.



a- Theoretical Compressive depth, Whitney block depth and eccentricities



b- Theoretical total tensile and compressive forces



c- Theoretical net tensile forces and flexural strengths

Figure 7: Theorical Design Information

Table 6: Theoretical and Experimental Tensile Loads, Moments and Eccentricities

G. ID	Beam	Theoretical Results			Experimental Results			(Pu/Pn) ×100%	(Mu/Mn) ×100%
		Force (P_n) [kN]	Moment (M_n) [kN.m]	Eccent. (e) [mm]	Force (P_u) [kN]	Moment (M_u) [kN.m]	Eccent. (e) [kN.m]		
G- 1	C-E-S-1	136.77	28.80	211	125	26.25	210	91.39	91.16
	C-E-H-2	136.02	28.58	210	120	25.2	210	88.22	88.16
	C-E-B-3	156.92	32.96	210	135	27.3	210	86.03	82.84
G-2	C-E-B-4	169.34	32.24	190	140	26.6	190	82.67	82.50
	C-E-B-5	144.27	34.86	242	125	30.25	242	86.64	86.77
	C-E-B-6	126.48	34.62	274	115	31.51	274	90.93	91.00
	C-E-B-7	112.75	34.39	305	100	30.5	305	88.69	88.68
Average								88 %	89 %

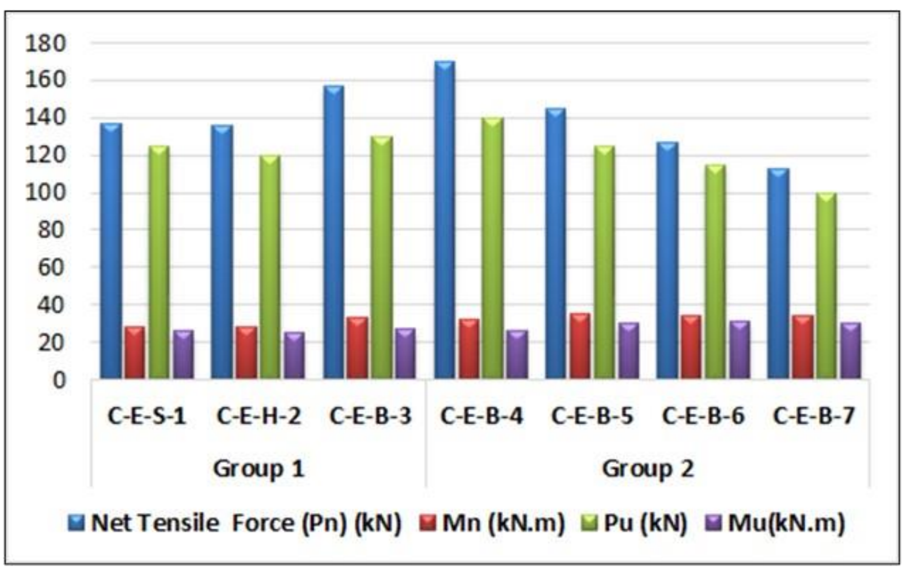


Figure 8: Theoretical and Experimental Tensile Forces and Moments

The C-E-B-4 model is designed to have an eccentricity by 15% less than of the balanced eccentricity. When compared to the hollow reference, the tensile force increases by 17% (140/120). This is due to the increase in the depth of neutral axis (C), which leads to an increase in the depth of compressive stress block (a) , which in turn leads to an increase in the compressive strength and a decrease in the total tensile force, which leads to a decrease in the eccentricity with a similar moment. Specimens C-E-B-56, C-E-B-5 and C-E-B-7 recorded the lowest tensile strength. This could be due to the fact that as the eccentricity will be larger than the balanced eccentricity that led to decrease, the depth of the neutral axis , which in turn leads to a decrease in the stress block depth. This results in a decrease in the compressive force, and semi-constat tensile force in the section which in turn leads to a decrease in the net tensile strength. This also agrees with the lower part of the column's interaction diagram, where the forces decreases when e > eb. Also, laboratory results showed an underestimation of 10% compared to the design values, which means that there is at least a safety factor of (1/10) capacity as shown in Table 6 , Figure 7 and Figure 8 .

Almost all samples showed that the concrete started to crack at the same value (45 kN) and at an average of 40% of the maximum tensile failure ultimate value. This increase may be due to the presence of tied reinforcement, as well as the presence of shear studs that acted as barriers to restrict tensile width, which led to the development of better resistance, as shown in Figure 9.

When observing the cracks and their formation mechanism, it was noted that the cracks started in the upper part (the part exposed to the resultant tension) and then with increasing load application, it continues to descend towards the opposite part. However, it was noted that the width of the cracks was small (hair crack). This was in the middle of the column space, while the corbel area suffered from multiple cracks and concrete collapse in the final loading stages, and then the test was stopped. Although the column was placed horizontally instead of vertically due to laboratory difficulties as mentioned previously, the upward deflection was recorded, but it remains relatively small because the column is short and is not affected by lateral displacement to a large extent as shown in Table (7).

Table 7: First Crack Load and Deflection

Group ID	Beam	P_{cr} [kN]	P_u [kN]	(P_{cr}/P_u) ×100%	Crack Type	Mid-Span Deflection [mm]
Group 1	C-E-S-1	45	125	36 %	Direct	6
	C-E-H-2	46	120	38 %	Direct	6.1
	C-E-B-3	50	135	37%	Direct	6.5
Group 2	C-E-B-4	47	140	34 %	Direct	5.7
	C-E-B-5	50	125	40 %	Direct	6.3
	C-E-B-6	48	115	42 %	Direct	6.8
	C-E-B-7	43	100	43 %	Direct	7

Figure 9: Modes of failure

4. Conclusion

Laboratory results showed that the composite columns made of concrete and hollow steel sections had a significantly better tensile response compared to solid counterparts, after ensuring higher bonding by providing the required connection of the shear studs. The possibility of using the specific type of short column to resist the eccentric tensile forces was clearly indicated in increasing tensile strength by 17%. For the same balance eccentricity, the ultimate tensile strength can be increased by 12% rather than the hollow core column. Based on the specimens' failure, the tensile strength may be increased even further than current levels if crushing of concrete was prevented by many means such as tapered corbels. The methodology used in analyzing and designing the models also provided a minimum factor of safety of (1/10). The hair cracks appeared in the middle of the column span and longitudinally extended along the column's width with small crack width despite the presence of tied reinforcement. The specific failure's pattern of columns was the crushing of concrete in the corbel area and the wide cracks had also appeared. The optimum condition for columns was when used e = eb ± 15 %, as it gave the highest three tensile strengths.

Acknowledgements

The authors are in debt to the laboratory of Material and Construction – Technical Institute of Amarah and the Laboratory of Higher Studies of Civil Engineering Department of Misan University who contributed to the development of the experimental investigation.

Disclosure of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

Ubani, O. (2022). On the Design of RC Tension Columns. https://structville.com/2022/03/on-the-design-of-rc-tension-columns.html.

Waleed, A. W., Mohammed, M. R. & Alaa, H. (2012). Experimental Study of Reinforced concrete Columns Strengthened with CFRP under Eccentric Loading, Journal of Engineering and Development, 16, No.3.

V. Aparna, D. Vivek, Kancharla N. and B. Karthikeyan. (2017). Experimental Investigations On Steel-Concrete Composite Columns For Varying Parameters. IOP Conf. Series: Earth and Environmental Science 80. https://doi.org/10.1088/1755-1315/80/1/012029 .

Vigneshvar, R. , Hareesh, M., & Sekar, S. K. (2017). Analysis Of Tensile Capacity of Reinforced Concrete Columns and Its Ductility Performance Towards Seismic Behavior. International Journal of Civil Engineering and Technology, Volume 8, Issue 8, pp. 798–806.

Mansi, J., Rupali, G.(2018). Study On Configurations Of Floating Columns In An Asymmetrical Irregular RC Framed Building Under Earthquake Loading. International Journal of Advanced in Management, Technology and Engineering Sciences, Volume 8, Issue II.

Muhammad, N. S., Hussamaldeen, G. & Tao, Y. (2018). Experimental investigation of CFRP confined hollow core Reactive Powder Concrete columns, Faculty of Engineering and Information Sciences- Papers: Part B. 1328, University of Wollongong.

Binglin, L. & Richard, L. (2021). Investigation on Axial Load-Shorting Behaviour of High Strength Concrete Encased Steel Composite Section. Engineering Structures. https://doi.org/10.1016/j.engstruct.2020.111401.

Hubert, D., Patryk, R., Pawel, W., Katarzyna, F., & Miroslaw, F. (2021). Experimental study on the effect of eccentric compressive load on the stability and load-carrying capacity of thin-walled composite profiles. Composites Part B 226, Elsevier Ltd. https://doi.org/10.1016/j.compositesb.2021.109346.

Alaa, M. S., & Mohammed, S. (2021). Experimental Study Of Hollow Slender Reinforced Concrete Columns Subjected To Eccentric Loads. Civil and Environmental Engineering, 17, 303-317. https://doi.org/10.2478/cee-2021-0032.

Paolino, C., Costantino, M., Antonio, O., & Domenico A. (2021). Experimental Behavior of Existing RC Columns Strengthened with HPFRC Jacket under Concentric and Eccentric Compressive Load. Buildings, MDPI. https://doi.org/10.3390/buildings11110521.

Sri, H. D., Rendy, T., Sabril, H., & Febi P. Y. (2024). Tensile Forces Behavior On Longitudinal Reinforcement And CFRP Strips On Circular Hollow Reinforced Concrete Columns, Civil and Environmental Engineering, 20, 86-97. https://doi.org/10.2478/cee-2024-0008.

IQS 5/2019 .Portland cement Central Organization for Standardization and Quality Control Iraq (in Arabic).

IQS 45/1980 . Aggregates from Natural Sources for Concrete and Building Construction. Central Organization for Standardization and Quality Control. Iraq (in Arabic).

ASTM A370 / ASME SA-370. Standard Test Methods and Definitions for Mechanical Testing of Steel Products. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States.

ASTM, C39.(2005). Standard specification for testing method for compressive strength of cylindrical concrete specimens. American Society for Testing and Materials, Philadelphia, PA., USA.

ASTM C 496/C 496M.(2004). Standard Test Method for Splitting Tensile Strength of Cylindrical concrete Specimens, American Society for Testing and Materials. West Conshohocken, USA.

ASTM C78-08 .(2008). Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading). American Society for Testing and Materials. West Conshohocken. USA.

ACI 318-19 (22). (2019). Building Code Requirements for Structural Concrete. American Concrete Institute, Reapproved 2022.

How to Cite This Article

Braidi, I. W., Mohsin, D. R., Tu'ma, H. N., & Raheem, A. K. H. (2026). Experimental Investigation of Eccentric Composite Hollow Steel-Concrete Tensioned Column. Civil and Environmental Engineering, 0 (0). https://doi.org/10.2478/cee-2026-0061