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# Steel Tubes Filled by Concrete under Flexural and Compression: A Review

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**ABSTRACT**

This review examined the development and efficacy of steel-concrete composite structures, highlighting their use in contemporary building. Initially, composite beams depended on the bond between steel and non-structural concrete to provide fire resistance. Advancements in concrete characteristics and fire-resistant coatings enabled the creation of new designs, including partially encased beams and composite slabs with shear connectors, which markedly improved structural efficiency and flexibility. The analysis emphasized the enhanced flexural and axial performance of Steel Tube Filled and Enclosed by Concrete (STFEC) beams and columns relative to traditional reinforced concrete or hollow steel components. Crucial elements including steel yield strength, concrete strength, and confinement effects were recognized as essential for performance enhancement, with augmented steel tube thickness and concrete strength improving flexural capacity and ductility. The encasement offered by steel tubes was seen to enhance the mechanical properties of core concrete, diminishing local buckling and augmenting strength. Finite element analysis was confirmed as a dependable method for forecasting Steel Tube Filled by Concrete (STFC) behavior, augmenting design code recommendations, which were found to be conservative. The study emphasized technologies such as the utilization of recycled materials and self-stressing concrete to enhance sustainability and cost-effectiveness while maintaining performance standards. Failure mechanisms were mostly linked to material yielding, localized buckling, or a combination of compression and bending. The results validated the appropriateness of Steel Tube Filled and Enclosed by Concrete (STFEC) structures for applications requiring great strength and durability, such as high-rise edifices, bridges, and seismic regions.

## 1. Introduction

The application of steel and concrete in the construction of structural composite beams for edifices has progressed considerably over time. Initially, steel parts were enveloped in non-structural concrete to enhance fire resistance. As concrete with enhanced mechanical properties emerged, engineers acknowledged its potential to improve the flexural strength of beams, resulting in the creation of steel-concrete composite beams. Initially, the interaction between steel and concrete depended exclusively on the adhesion at their interface. Improvements in fire-resistant coatings ultimately rendered concrete encasement of steel profiles unnecessary, facilitating the development of innovative composite beam designs. A specific design incorporates a concrete slab, either solid or composite, positioned on a steel section, usually an I-beam. The composite action is accomplished by shear connectors, including headed stud connectors. A different variation, partially-encased beams, entails encasing the web of the steel profile in reinforced concrete while establishing shear connection between the steel and concrete elements. This beam type is prevalent in Europe and is regulated by the EN 1994-1-1:2004 [51] regulations. A concrete or composite slab may constitute a component of the composite beam's effective section,

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contingent upon its secure attachment to the steel section via shear connectors. [17]

### *1.1 Steel tubes filled by concrete (STFC)*

Steel Tubes Filled by Concrete (STFC) are composite structural components that integrate the advantages of steel and concrete, providing enhanced strength, flexibility, and streamlined building methods. The interaction between the steel tube and the concrete, referred to as bond behavior, is essential in assessing the overall performance of STFC. Research indicates that bond strength can fluctuate significantly based on variables such the materials utilized for steel and concrete, the dimensions of the tube's cross-section, and the concrete's age. For instance, STFC constructed with stainless steel typically exhibit inferior bonding compared to those fabricated with carbon steel. Moreover, increased cross-sectional dimensions and aged concrete generally diminish bond strength. To enhance this bond, methods such as welding internal rings or affixing shear studs to the steel tube are frequently utilized. [49]

### *1.2 Steel tube filled and enclosed by concrete (STFEC)*

Steel Tube Filled and Enclosed by Concrete (STFEC) represent a sophisticated advancement in composite structural systems. They proficiently integrate the benefits of concrete and steel to enhance overall structural performance. These systems are esteemed for their superior ability to manage both flexural and axial loads, rendering them adaptable for diverse structural applications. By combining concrete and steel, STFC utilize the complete plastic strength of thin-walled steel tubes while mitigating the risk of local buckling, as demonstrated by experimental research and finite-element analysis.

## 2. Previous research

This chapter reviews previous research on steel tubes filled and enclosed by concrete (STFEC) as well as steel tubes filled with concrete (STFC), focusing on their applications as beams and columns. [9] [50]

### *2.1 Steel Tube Filled and Enclosed by Concrete (STFEC) Beam and Steel Tube Filled by Concrete (STFC) Beam*

Elchalakani et al.(2001) [1] presented the experimental results of a study about the efficacy of circular tubes filled by concrete (TFC) exposed to substantial pure bending and deformation, with varying diameter to thickness (d/t) ratios ranging from (12-110). The study contrasts the performance of unfilled cold-formed circular hollow sections with those containing voids during pure plastic bending. Void filling substantially reduced local buckling for extremely high rotations within the $d/t \leq 40$ range. In contrast, within the inelastic range, many plastic ripples appeared in specimens with $74 \leq d/t \leq 110$. The steel tubes with vacancies filled typically improves its energy absorption, strength and ductility, particularly in sections with lower thickness. The assessed material characteristics revealed that the d/t threshold for plastic is 112. The maximum moment capacity of concrete-filled tubes is determined using the provided formula. The current design parameters for the ultimate moment capacity of tubes filled by concrete can be prudently applied to a new slenderness range of (100-188).

Gho and Liu (2004) [2] performed a research into the flexural behavior of twelve Rectangular hollow steel section specimens filled with high strength concrete, each measuring 160 cm in length. The specimens underwent pure bending until failure ensued. High strength concrete filled three steel hollow pieces of differing dimensions (15 x 15 cm, 20 x 15 cm, and 25 x 15 cm). The value of $f_c'$ spans from 56.3 to 90.9 MPa. The steel hollow sections demonstrated yield stresses of 438, 495, and 409 MPa, respectively. All tests demonstrated notable ductility in the material. Localized buckling was seen on the specimen’s compression zone. Comparing the moment capacities obtained from the codes' formulas with the experimental moment capacities values revealed that the flexural strengths of the specimens according to EC4 [51], ACI [52], and

AISC [53] were significantly underestimated by 11%, 15%, and 18%, respectively. The EC4 approach provided the most precise estimate of flexural strength, yielding a calculated-to-experimental moment capacity ($\frac{M_c}{M_e}$) ratio of 0.888 and a coefficient of variation of 0.051. The calculations in the codes were generated from data pertaining to normal-strength steel hollow sections and concrete.

$\text{Han, L. H.,}^{(2004)}$ [3] developed a mechanical model capable of predicting the performance of beams in concrete filled hollow structural sections (HSS). An analysis is performed utilizing a unified theory that integrates a confinement factor ($\xi$) to elucidate the composite interaction between the steel tube and the encased concrete. The experiment involved performing a sequence of tests on rectangular and square beams filled with concrete. The principal factors examined within the study were the ratio of (depth/width) β spanning from (1-2), and the ratio of (tube depth/wall thickness) ranging from (20-50). The relationship of load deflection for concrete filled hollow structural steel beams was established through experimental and theoretical approaches. The expected load versus mid-span deflection patterns closely align with the provided test results. The formulation of relevant equations for incorporation into building codes is conducted to ascertain the capacity of moment for the hollow structural section beams filled with concrete. A comparison analysis utilizes existing codes, specifically AIJ-1997 [54], BS5400-1979 [56], EC4-1994 [57], and LRFD-AISC-1999 [55], to evaluate the expected Beam capacity and flexural rigidity. The moment capacity reported by AIJ (1997) [54] and LRFD-AISC (1999) [55] was approximately 20% lower than the test results. Conversely, BS5400 (1979) [56] indicated a moment capacity that was roughly 12% lower than the experimental outcomes. The EC4 (1994) [57] and the proposed approach, both of which produced forecasts approximately 10% inferior to the test results, are regarded as the most precise predictors.

$\text{Han L. H. et al.}^{(2006)}$ [4] investigated the flexural performance of steel tubes filled by Self Consolidating concrete (SCC) by the testing of 36 composite beam specimens. The experiments encompassed several critical variables: (1) the types of sections employed (circular and square); (2) the yield strength of the steel, which varied from (235-282) MPa; (3) the tube diameter to wall thickness or tube width to wall thickness, represented as D to t, ranging from (47-105); and (4) the (span of shear/depth) ratio, which spanned from (1.25-6). The research indicated that the (span of shear/depth) ratio did not significantly affect the performance of Steel Tubes Filled by Concrete (STFC) beams with circular and square cross sections. The maximum capacity of STFC beams can be conservatively estimated utilizing the guidelines from (AIJ 1997 [54], AISC-LRFD-1999 [55], BS5400-1979 [56], EC4-1994 [57]), and the methodology suggested by Han [3]. It was determined that, overall, (EC4-1994) and the methodology presented by Han [3] constitute the most precise indicators. This paper further examined the initial section flexural stiffness ($K_i$) and serviceability-level section flexural stiffness ($K_s$) of composite beams. The expected beam flexural stiffness is evaluated against existing codes, specifically (AIJ-1997, AISC LRFD-1999, BS5400-1979, and EC4-1994), along with the methodology suggested within this study.

$\text{Lu, H., et al.}^{(2009)}$ [5] employed Finite Element Analysis (FEA) modeling to examine the flexural performance of circular thin walled Steel Tube Filled by Concrete (STFC) beams. The FEA modeling was validated with a series of test data, yielding a generally acceptable degree of concordance. An FEA model was employed to examine the stress and strain patterns within the composite portion during the process of loading. An examination was performed on the interaction between the steel tube and its concrete core. A model was developed to elucidate the force transmission mechanism of a circular composite part under pure bending conditions. The modelling results lead to the conclusion that the flexural performance of STFC beams is analyzed by FEA modeling. A link was established between projected load and deformation curves, failure modes, bending capacities, and experimental results. An investigation utilizing FEA modeling was performed to examine the strain and stress patterns in a composite portion subjected to loading conditions. The interaction of concrete and steel in composite beams facilitates the redistribution of stress, resulting in a substantial enhancement of flexural capacity and ductility. A study was performed on the mechanism concerning load transfer of a circular composite element under bending, employing a strut-tie model. This model was developed by a comprehensive analysis of stress distribution. The examination of the mechanism indicates that the (span of shear/depth) ratio does not have a statistically considerable impact on the structural characteristics of steel tubes filled by concrete (STFC) beams with circular cross-sections.

Chitawadagi and Narasimhan $^{(2009)}$ [6] exhibited the mechanical behavior of circular steel tubes filled with different concrete grades under flexural forces. This investigation examines the influence of steel tube thickness, concrete cross-sectional area, inner concrete strength, and concrete confinement on the curvature and moment capacity and of steel tubes filled by concrete (STFC). The acquired flexural strengths are juxtaposed with the values forecasted by the code requirements (EC4-1994 and LRFD-AISC-1999). Ninety-nine specimens, each measuring one meter in length, were examined and filled with concrete varying in characteristic strengths (20, 30, and 40 N/mm²) and (diameter/thickness) ratios ranging from (22.3-50.8). A predictive interaction model for the moment and curvature of the STFC sample is constructed according to the findings of the experiment. Several overall findings may be derived: (1) The experimental study demonstrated that infilling the empty parts with concrete led to a substantial enhancement in both the moment of resistance and the corresponding curvature. Furthermore, the Tube Filled by Concrete (TFC) specimens exhibited superior ductility relative to the empty sections. Augmenting the steel tube wall thickness improves the ductility and moment of resistance of both the Tube Filled by Concrete and Hollow Tube (TFCHT) specimens. Regression models developed from a restricted number of trials utilizing Taguchi's Design of Experiments (DOE) methodology may be employed for the essential design of tubes filled by concrete (TFC) beams under flexural stresses. Increasing the strength of the concrete filling in a TFC specimen does not substantially enhance its moment-carrying capacity, even with consistent wall thickness. The term "Strength Increasing Factor," as developed in this work, quantifies the impact of concrete on the moment capacity of Tubes Filled by Concrete (TFC) beams. The confinement of concrete improves performance when utilizing higher strength concrete alongside a steel tube with increased wall thickness. Four EC4-1994 offers a conservative estimation of the moment capacity of test specimens, allowing for a margin ranging from 30 to 35%. AISC-LRFD is excessively modest in forecasting the moment capacity of Tubes Filled by Concrete (TFC) sections as it neglects the impact of concrete infill.

Ali, A. A., et al. $^{(2012)}$ [7] analyzed the structural efficacy of composite beams encased in concrete. Tests were performed on specimens exposed to lateral loading. The test results indicate that the steel beam core substantially affects the structural integrity and failure mechanism of the beam. The beams demonstrated a significant level of ductility. The objective of the study is to ascertain the design flexural strength of concrete beams by analyzing the distribution of elastic and plastic stress inside the composite section. The linear elastic theory fails to accurately anticipate the mid-span deflection of the beam.

Li, X., et al. $^{(2012)}$ [8] performed an investigation on the flexural performance of GFRP-reinforced concrete-encased steel composite beams. A novel composite beam, designated FRP-RCS, was engineered to improve ductility and corrosion resistance. This beam comprises ductile structural steel elements integrated with corrosion-resistant FRP-reinforced concrete. An experimental investigation was conducted to examine the flexural behavior of the proposed FRP-RCS beams. The research entailed the examination of seven beam specimens that were simply supported and subjected to four-point bending loads. The test specimens comprised one beam constructed from fiber-reinforced polymer (FRP)-reinforced concrete (RC), solely reinforced with glass fiber-reinforced polymer (GFRP) bars, and six beams fabricated from FRP-RCS, reinforced with both GFRP bars and enclosed in structural steel forms. This investigation primarily studied The strength under compression of concrete, the amount of GFRP reinforcement, and the configuration and ratio of enclosed structural steel forms. The investigation results indicated that the use of enclosed steel forms significantly enhances the capacity of load bearing, rigidity, energy absorption, and ductility potential of the examined sections. The tested FRP-RC beam exhibited a brittle failure resulting from the sudden fracture of the tensile GFRP bars. Conversely, the suggested FRP-RCS beams demonstrated ductile behavior principally due to the beneficial residual strength of the enclosed steel forms following the compression of the concrete. Additionally, a suggested method was put out to predict the capacity of load bearing for the FRP-RCS beams.

$\mathrm{An, Y - F\ et\ al.}^{(2014)}$ [9] employed numerical analysis to assess the flexural behavior of Steel Tubes Filled and Enclosed by Concrete (STFC). A model was developed using Finite Element Analysis (FEA) to investigate the bending properties of the composite sections, and a collection of test data is utilized to validate the FEA model. A thorough analysis was performed to investigate the full spectrum of the moment curvature relationship, stress patterns across the composite section, and the interlinkage between steel and concrete. Thin-walled steel tubes have been found to be appropriate for application in concrete-enclosed STFC. These tubes can attain maximum plastic strength without undergoing local buckling prior to attaining the ultimate condition. A strut and tie model is suggested to elucidate the force transmission mechanism of Steel Tubes Filled and Enclosed by Concrete (STFEC) member under bending conditions. The flexural capacity of Steel Tubes Filled and Enclosed by Concrete (STFEC) was found to exceed that of a reinforced concrete beam with a comparable quantity of longitudinal steel. A parametric approach is ultimately employed to obtain simplified equations for forecasting the behavior of flexural strength of Steel Tubes Filled by Concrete (STFC) sections.

$\mathrm{Ren, Q - X.\ et\ al.}^{(2014)}$ [10] conducted a study were twenty-six sections were investigated. This comprised eight beam sections experiencing pure bending and eighteen column sections subjected to a series of bending and compression. The study aimed to explore The characteristics of elliptical steel tubes containing concrete in beams and columns. The principal parameters evaluated were the (span of shear/depth) ratio for beams, the slenderness ratio, and the load eccentricity for columns. The results of the examination demonstrated that Steel Tubes Filled by Concrete (STFC) beams and columns featuring elliptical cross-sections displayed ductile behavior, akin to that of STFC members featuring round cross-sections. The ratio of shear span-depth $(\frac{a}{B})$ significantly influences the behavior of elliptical STFC beams. As the $(\frac{a}{B})$ value escalates from 1.56 to 2.60 and subsequently to 3.65, the bending strength diminishes by 12.5% and 22.3%, respectively. The inclusion of concrete infill markedly enhances the efficacy of elliptical Steel Tubes Filled by Concrete (STFC) beams, yielding a bending strength that is 1.41 times superior to that of hollow steel tube beams. In the context of columns subjected to axial compression, it is noted that the compressive strength exhibits a substantial rise of 19.0% and 63.6% as the slenderness ratio diminishes from 75 to 56 and subsequently to 38, respectively. Moreover, the compressive strength of these columns is 2.47 times superior to that of the hollow steel tube columns. In instances of columns subjected to eccentric compression, the compressive strength markedly increases with variations in eccentricity and slenderness ratios. As the eccentricity rises from 0 mm to 48 mm and subsequently to 144 mm, the compressive strength escalates by 44.1% and 70.7%, respectively. Correspondingly, as the slenderness ratio diminishes from 75 to 56 and subsequently to 38, the compressive strength escalates by 22.9% and 51.9%, respectively. Moreover, the compressive strength of these columns is determined to be 2.19 times greater than that of hollow tube columns. This work presents simplified methods for estimating the characteristics of elliptical STFC beams and composite columns. These variables encompass bending strength, initial and serviceability-level section bending stiffness, axial compressive strength, and eccentric compressive strength.

$\mathrm{Wang, R. et\ al.}^{(2014)}$ [11] created a FEA (Finite Element Analysis) model to examine the flexural characteristics of rectangular shaped Steel Tubes Filled by Concrete (STFC) samples with compact, non-compact, or thin cross-sections. The validation of the FEA modeling relies on seventy test outcomes. The experimental results and Finite Element Analysis (FEA) exhibited satisfactory agreement about the ultimate capacity of bending and the curvilinear trends of the moment against deflection at the middle span relations of the composite component. FEA (Finite Element Analysis) modeling is utilized to examine the core concrete remnant failure patterns, the distinctive outer steel tube residual deformations, and distribution of stress and strain throughout the composite section during the entire loading process. The study's outcome of the composite beam demonstrates that the interlinkage between the concrete and steel causes stress redistribution inside both the concrete and steel components. This redistribution of stress in the rectangular Steel Tube Filled by Concrete (STFC) improves the ductility and flexural capacity. The reliability analysis method is utilized to adjust the current design equations for composite beams in (EC4 (2004), AISC (2010), and DBJ/T13-51-2010 [58]).

$\mathrm{Han, L-H. et\ al.}^{(2015)}$ [12] conducted a sequence of Finite Element Analysis (FEA) models as well as experiments on large scale box members composed of Steel Tubes Enclosed and Filled by Concrete (STEFC) exposed to bending. The research encompassed the examination of eight complete specimens, comprising six box members composed of Steel Tubes Enclosed and Filled by Concrete (STEFC) and two comparable box members composed of Reinforced Concrete (RC). The study aimed to examine the impact of variety of the steel tubes diameter (74.9 mm-102.2 mm) and the height of the section (840 mm-1260 mm) on the box members composed of Steel Tubes Enclosed and Filled with Concrete (STEFC) performance under bending pressures. A study was performed to investigate and compare the failure processes and the box members composed of Steel Tubes Enclosed and Filled by Concrete (STEFC) performance under bending with those of similar box members composed of Reinforced Concrete (RC). A Finite Element Analysis (FEA) model was created to investigate the bending behavior of box members composed of Steel Tubes Enclosed and Filled with Concrete (STEFC). This analysis encompassed a comprehensive examination of the moment-curvature connection, load transmission, and the impact of the (span of shear/depth) ratio. A thorough examination of Finite Element Analysis (FEA) modeling was performed, and a simplified model was proposed to predict the bending strength of concrete-enclosed STFC box elements.

$\mathrm{Xu, W. et\ al.}^{(2016)}$ [13] analyzed the compressive and flexural performance of members shaped as hexagonal steel tubes filled by concrete (STFC). Specimens are subjected to tests for axial compression and bending. The experimental effort focuses on adjusting the cross-section’s steel ratio while evaluating the design of hollow tube members. The research examines failure modes, the correlation between load and deformation, and the progression of strains. A FEA (Finite Element Analysis) model is developed as well as corroborated with the empirical findings. The FEA (Finite Element Analysis) model is utilized to carry out a thorough examination of the load-deformation connection, distribution of internal force, and development of stress. A parametric analysis is applied to examine the effects of several parameters, including ratio of steel, yield strength of steel, and strength of concrete, on compressive and flexural behavior. The suggested streamlined models for determining the maximum flexural and compressive strengths are presented. The DBJ/T13-51-2010 [58] and EC4 formulae are able to accurately determine the maximum strength of compression for hexagonal Steel Tubes Filled by Concrete (STFC) stub columns. The distribution of plastic stress approach and the model fiber method yield accurate forecasts of the maximum flexural strength of hexagonal Steel Tubes Filled by Concrete (STFC) beams. Several comprehensive conclusions might be inferred: In hexagonal STFC stub columns, the steel tube exhibited outward local buckling upon collapse, attributed to the support from the concrete. Conversely, both inward and outward local buckling were detected in the case of hollow tubular columns. The concrete-filled specimens demonstrated improved the strength of compressive and ductility. The enhancement of the ratio of steel led to a reduction in local buckling of the steel tube. Subsequent to the failure, the hexagonal Steel Tubes Filled by Concrete (STFC) beams demonstrated local buckling of the external tube of steel as well as pulverizing of the concrete in the compressive region. Tube fractures occurred more frequently in beams with a reduced steel ratio. The concrete's resistance to compression and the tube's buckling capacity were improved with a higher steel ratio. The Finite Element Analysis (FEA) model was developed as well as validated for both column and beam specimens. The constitutive model for concrete confined in rectangular Steel Tubes Filled by Concrete (STFC) is applicable to the concrete core in hexagonal Steel Tubes Filled by Concrete (STFC). The proposed model precisely forecasted the failure processes and load-deformation curves for both stub column and beam specimens. In the case of stub column specimens, augmenting the ratio of steel and strength of yielding enhanced both the ductility and the strength of compression. Conversely, enhancing the concrete strength augmented the strength of compression while diminishing ductility. The flexural strength of beam elements was markedly affected by the steel ratio and steel yield strength, while the impact of concrete strength was negligible.

$\text{Li, G. et al.}^{(2017)}$ [14] investigated the mechanical properties of high strength square shaped steel tubes filled by high strength concrete (HSTHFC) exposed to pure bending loads. Six examples with various ratios of steel were examined. Analyzing the mechanical properties necessitated the establishment of appropriate nonlinear finite-element models. The load-displacement curves derived using mathematical calculations correspond along with the experiment's results. This article analyzes the effects of various materials. The correlation between moment and curvature may be categorized into three distinct phases: elastic, yield, and hardening. The maximum bearing capacity augmented with enhancements in the ratio of steel, yielding strength of steel, and compressive strength of concrete. The experiment's maximum bearing capacity is compared to the specifications of several codes, including AISC LRFD (1999), AIJ (1997), EC4 (1994), and GB50936 2014 (2014). The experimental as well as finite element analysis results closely corresponded with the computed outcome of Eurocode 4 (1994). The results of this investigation closely correspond with the EC4 (1994) code.

$\text{Xiong, M} - \text{X. et al.}^{(2017)}$ [15] evaluated the efficacy of high tensile steel tubes filled by ultra-high strength concrete under normal cooling conditions. This project experimental results presented a new perspective on the structural effectiveness of steel tubes filled by concrete (STFC) members exposed to flexural stresses. The research employed steel with high tensile strength exhibiting a yield strength of up to 780 MPa and concrete with ultra-high strength with a cylinder compression strength of up to 180 MPa. The objective of the experimental findings is to ascertain if specimens composed of steel tubes with ultra-high tensile strength filled with ultra-high strength concrete can attain the requisite resistance to cross-section plastic moments. The experimental results of the ultimate moment resistance were juxtaposed with the analytical forecasts derived from the Eurocode 4 methodology. To guarantee the secure application of the Eurocode 4 method for assessing the flexural resistance of STFC members utilizing high tensile steel tubes and ultra-high strength concrete, design guidelines were provided.

$\mathrm{Lu, Y.}^{(2017)}$ [16] conducted an experimental study on members composed of steel tubes filled by concrete, self-stressed and compacted as well as reinforced by steel fiber under bending moment. This experimental study focused on evaluating the influence of self-stress and fibers of steel on the performance of members self-compacted and composed of steel tubes filled by concrete. A sum of 27 specimens, reinforced with steel fibers and self-stressors, underwent bending testing. The assessment considered the factors of self-stress, thickness of steel tube, strength of concrete, also the proportion of fiber volume. The experimental study findings demonstrated that the test members had a degree of ductility. The incorporation of fibers of steel and self-stress did not modify the member’s mechanism of failure. Self-stressing may somewhat improve flexural capacity and increase flexural stiffness. The incorporation of steel fibers in beam specimens may prolong the elastic phase and improve the flexural strength. The rise in steel tube thickness decreased the fibers of steel beneficial effect. An equation was presented to find and predict the flexural capacity of members composed of steel tubes filled with concrete, self-stressed and compacted. The formula's correctness was validated by a comparison of predictions and experimental data.

$\mathrm{Flor\ et\ al.}^{(2017)}$ [17] examined the Steel Tube Filled by Concrete (STFC) in two segments. The initial section addressed the imperfections of concrete within the steel tube due to the concrete pouring process, whereas the subsequent section examined the performance of STFC beam specimens subjected to flexural forces. Two samples, each measuring 12 meters in length and 250 x 150 mm with a thickness of 6.3 mm, were utilized to examine concrete faults. The sample preparation involved longitudinally cutting the tube to create U-shaped sections, followed by welding two angles at the top and bottom of each specimen to reestablish the closed configuration of the tube segments. The angles recur every meter along the sample's length. The sample ends were sealed by welding a steel plate, and two holes with a diameter of 100 mm were created above the steel tube at the sample ends to facilitate concrete pouring. The concrete utilized in this investigation is self-compacting concrete. During the concrete casting process, the specimens were positioned horizontally. The concrete was poured into the steel tube of the first specimen without pressure, but the second specimen was subjected to pressure during the process. Both specimens were examined after a duration of eight months. Numerous voids of varying forms and depths were seen on the upper surface of the steel tube, with an average depth of 2.99 mm for the specimen subjected to pressure and 1.97 mm for the specimen without pressure. The second phase of this project involved examining six beam specimens possessing identical properties to those utilized in the initial phase, albeit with a length of six meters. Four specimens were STFC, while the other two were unfilled to investigate the impact of concrete infill on the steel tube and to determine the maximum moment based on plastic theory for this category of STFC beams. The findings indicated that STFC exhibited a maximum flexural moment 15% greater than that of the empty steel tube, along with enhanced ductility. Furthermore, the maximum moment capacity observed in the practical test was 2% lower than the value derived from plastic theory calculations.

$\mathrm{Cho, J.\ et\ al.}^{(2018)}$ [18] assessed the composite girder flexural strength constructed from a Steel Tube Filled by Concrete (STFC). The flexural strength of the STFC composite girder subjected to positive and negative bending moments was assessed utilizing the plastic stress distribution method (PSDM). Simultaneous equations were formulated for this objective. Subsequently, a sequence of experiments was applied to examine the effect of internal shear connections between the tube of steel and the infill of concrete and to authenticate the accuracy of the proposed equation. A Finite Element Analysis (FEA) non-linear model was performed on each member tested to exhibit the failure process as well as validate the Finite Element Analysis (FEA) model. The findings demonstrate that the suggested equations effectively forecast the STFC composite girder flexural strength under both positive and negative bending forces. The effect on flexural strength was negligible when internal shear connectors between the tube of steel and concrete infill was used. An analysis was undertaken to assess the influence of the diameter to thickness (D/t) ratio, the concrete infill compressive strength, as well as the local buckling of the tube of steel on the STFC composite girder flexural strength through a series of parametric models. The findings of the parametric analysis underscore several design difficulties.

$\text{Shallal, M. A.}^{(2018)}$ [19] examined the flexural performance of quadrilateral and circular Steel Tube Filled by Concrete (STFC) under bending conditions. The composite material, comprising concrete and steel, integrates the advantages of both substances. Steel exhibits exceptional tensile strength and ductility, whereas concrete demonstrates significant stiffness and compressive strength. The samples underwent multiple tests to evaluate their performance. This experimental study entailed the examination of twelve specimens of beams, comprising six square parts S1 to S6 and six circular sections C1 to C6. The portions, both square and round, were categorized into two groups, with each section's size being changeable. The original group's section size was 100 mm with a thickness of 3 mm, whereas the second group's section size was 75 mm with a thickness of 2 mm. The concrete's strength differed over each portion. Two separate varieties of concrete compositions were utilized, with a single model in each area deliberately kept un-encased in concrete. The reference beams were utilized for comparison with the alternative models. Samples (S1-S3) are square with dimensions of 100x100 and a thickness of 3 mm, resulting in a diameter to thickness ratio (D/t) of 33.34. Likewise, samples (S4-S6) are square, measuring 75x75 mm with a thickness of 2 mm, yielding a (D/t) ratio of 37.5. Conversely, examples C1 to C3 are circular, possessing a diameter of 100 mm and a thickness of 3 mm, yielding a diameter to thickness ratio (D/t) of 33.34. Samples (C4-C6) are circular, possessing a diameter (D:75 mm) and a thickness (t:2 mm), yielding a diameter to thickness ratio (D/t) of 37.5. Each sample measures 850 mm in length. The primary aim of this investigation is to ascertain the maximum load capacity of beams made of steel, specifically tubular square and circular varieties, when filled with different types of concrete and exposed to bending stresses in construction applications. The depth to thickness ratios (D/t) employed in the investigation are 33.34 and 37.5. Two specific compressive strengths of concrete, 22.9 MPa and 31.9 MPa, were employed to fill the steel sections. The examination results indicate that the maximum moment strength of the STFC frequently exceeds that of the similar hollow beams. The increases in the initial series of square beams S1-S3 vary from 47.15% to 87.07%. The augmentations within the initial series of circular beams C1-C3 vary from 63.94% to 104.96%. The enhancements resulted from the application of steel confinement to the concrete core, which augmented the composite beam's ductility and moment capacity.

$\text{Hou, C} - \text{C. et al.}^{(2019)}$ [20] examined the lateral impact performance of Steel Tube Filled and Enclosed by Concrete (STFEC) box beams and columns through experimental and numerical approaches. Twenty specimens were evaluated utilizing a drop-hammer impact equipment. The test parameters were impact energy, boundary conditions, and axial load magnitude. An analysis of the experimental results is performed, encompassing modes of failure, the chronological record of the impact force, mid-span deflection, and the comprehensive impact process. The findings demonstrate that the samples exhibit a flexural shear failure mode under impact conditions. An analysis summarizes the principal properties of the impact force and mid-span deflection curves. The paper examines the impact behavior of the specimens, encompassing the maximum impact power, impact time frame, and remaining middle span deflection, as well as the influence of these factors. An FEA model is created for examining the mixture of interactions between the reinforced concrete (RC) and STFC elements. The examination determined that the reinforced concrete (RC) element substantially enhances the structure's resistance to impact. Nevertheless, the RC element efficiently protects the STFC elements, averting substantial harm. The amalgamation of impacts improves structural safety under impact loading and aids in post-impact recovery.

Gunawardena, et al.(2019) [21] conducted a detailed research of current literature on the flexural strength of circular steel tubes filled by concrete (STFC). This work utilized a significantly larger database of published flexural tests compared to prior review studies, demonstrating that four frequently employed design criteria are suitable and should be applied cautiously when assessing the flexural strength of circular STFC. This observation was validated regardless of the particular variety of concrete utilized for infilling the steel tubes of the circular STFC. The reliability evaluation was conducted on a sample of 219 circular STFC flexural tests, as described in The body of written works, has proven that the capacity coefficients specified for concrete and steel in AS/NZS 2327 offer a reasonable level of dependability for purposes of structural design. The capacity coefficients calibrated for the goal dependability index exceeded the thresholds specified in the standard, hence validating the code's conservatism. Moreover, it was concluded that the specified slenderness limits for compact behavior in the design requirements were excessively restrictive. To ascertain the exact constraints, additional bending tests must be performed on tubes with larger diameters, thinner walls, and greater steel strengths. Further testing is necessary to assess the influence of the steel tube building method on the flexural strength of circular STFC.

A recent study by Chen, J – Y. et al.(2020) [22], the structural integrity of twelve Steel Tube Filled and Enclosed by Concrete (STFEC) box beams was analyzed. The research aimed to assess the impact of section dimensions, tube of steel diameter, and bending orientation on beam performance. The test findings were examined, encompassing the identified failure modes and the progression of concrete fissures during the entire loading process. A computational model was subsequently created to analyze the flexural characteristics of the beams made from composite materials. An investigation was performed to examine the whole array of elements, encompassing load transfer mechanisms and stress distribution. Following parametric investigations were performed with FEA modeling. This investigation introduced a technique for forecasting The rigidity and flexural strength of concrete enclosed STFC box beams. Based on the limited investigation, the subsequent conclusions can be drawn: All specimens demonstrated flexural failure mechanisms. The external Reinforced Concrete (RC) element exhibited significant damage in the upper section, whilst the internal Steel Tube Filled by Concrete (STFC) components remained largely intact in the middle section. The flexural fissures were evenly dispersed across the pure bending zone. The maximum width (w) of vertical concrete cracks decreased as the diameter (D) of the internal components of STFC increased. Simultaneously, ultimate moment Mu increased from 27.6% to 30.3%. The verified Finite Element Analysis (FEA) model was employed to comprehensively examine the flexural behavior. The M-ϕ connection was classified into five stages over the complete loading history. The RC component attained its load-bearing capacity, whereas the STFC components reached 82% of their full strength at $\phi_u$ . The stress redistribution observed during the descent phase illustrated the synergistic effect of the Reinforced Concrete and STFC elements. The load transfer mechanism was elucidated utilizing the established strut-tie model, grounded in the analysis of stress distributions. Three The parametric analysis indicated that $M_u$ (the investigated parameter) increased as the values of $f_{ys}$, $\alpha_s$, $f_{yl}$, $f_{cu,out}$, and $\alpha_l$ climbed. Nevertheless, $f_{cu,out}$ did not exert a substantial influence on $M_u$. The increases in $f_{ys}$, $\alpha_s$, $f_{yl}$, and $\alpha_l$ may lead to an enhancement in the residual moment. Techniques with less complexity were employed to predict the initial stiffness and the final bending strength.

AlZand, A. W. et al (2019) [23] implemented novel empirical methodologies for precisely predicting the bending moment capacity ($M_u$) and flexural stiffness values of steel tube filled by concrete (STFC) composite beams at both initial and serviceability stages ($K_i$ and $K_s$). To develop these empirical methodologies, it is essential to get a broad dataset for $M_u$, $K_i$, and $K_s$, encompassing various properties of STFC beams. As a result, this analytical study entailed the creation of 144 numerical STFC models employing finite element software. The efficacy of the newly invented empirical techniques was confirmed by juxtaposing them with the outcomes of previously documented numerical and experimental investigations undertaken by various other investigators in the field. Employing the novel methodologies, the average values derived by juxtaposing the anticipated $M_u$ values with the previously published figures for square and round STFC beams were 0.967 and 0.996, respectively. The mean values derived from the anticipated $K_i$ and $K_s$ values were 1.074 and 1.050, respectively. The results of these novel procedures were juxtaposed with those obtained from the established criteria and techniques in this domain, including EC4, AISC, AIJ, BS5400, and other analogous approaches.

AlZand, A. W. et al. (2021) [24] analyzed the flexural performance of a narrow steel tubular beam. The beam was constructed by joining two C-sections and subsequently filled with concrete made with recycled aggregate, resulting in a Steel Tube Filled by Concrete (STFC) beam. The lips of the C-section functioned as internal reinforcements for the cross section of the STFC beam. A flexural evaluation was performed on five large-scale samples, comprising one hollow sample devoid of concrete material. The ABAQUS program was employed to run and analyze twenty supplementary STFC models. This was conducted to assess the effects of numerous variables that were not examined in the research. The mathematical representation effectively confirmed the flexural characteristics and the failure mechanism of the specimen examined, marginally overestimating the capacity for flexural strength by about 3.1%. The research validated the efficacy of employing tubular C-sections within the STFC beam framework. The incorporation of internal stiffeners, or lips, resulted in substantial enhancements in flexural strength, rigidity, and absorption of energy coefficient. An innovative analytical technique was established to accurately forecast the flexural strength capability of internally stiffened STFC beams with steel stiffeners. This method aligned with the results of the present study and other research conducted by various researchers. The results from the examined STFC beams are encapsulated in the following order: The Investigative study validated that the proposed prefabricated skinny STFC beams, manufactured with two C-sections, exhibited a bending capacity roughly 3.7 times greater, regardless of whether comprised of 70% recycled concrete aggregate. (2) Under static bending stress, the prefabricated tubular steel beams (double C sections) filled with 0%, 30%, 50%, and 70% recycled concrete exhibited behavior analogous to that of traditional STFC beams. Furthermore, the lips of these C-sections were firmly affixed to the concrete, functioning as internal reinforcements for the narrow STFC beam's cross section. This mitigated the outward bending of the beam's upper flanges, postponing eventual failure. The use of up to 70% recycled aggregate in place of raw aggregate resulted in somewhat reduced values of flexural rigidity as well as strength capacity compared to conventional concrete, with reductions ranging from 7.2% to 10.7%. The weight of the proposed fabricated steel tube beams was markedly increased by the inclusion of concrete filler materials. The flexural strength of these beams was markedly enhanced, exhibiting increases of around 409% and 363% when employing regular concrete and a mixture of 70% recycled concrete, respectively. These results have considerable ramifications for structural engineering. They illustrate that regardless of the increase in beam mass, they may be employed to precisely forecast the circumstances under which this composite system would be dependable for construction projects. The expense was a crucial element throughout the planning and construction phase, as exhibited by our analysis of the pricing of concrete and steel components in the local market. The bending characteristics of the STFC beam were precisely recreated utilizing the ABAQUS algorithm. The outcomes of the non-linear evaluations of FE STFC models indicate that augmenting the thickness of the tubes significantly influences their flexural strengths and stiffness's more than altering other parameters. Nonetheless, augmenting the strength of compression associated with the concrete infill material and/or the yield strengths of the steel tubes yielded minimal impact.

*2.2 Steel Tube Filled and Enclosed by Concrete (STFEC) Column and Steel Tube Filled by Concrete (STFC) Column*

Giakoumelis, G. and Lam, D$^{(2004)}$ [25] examined the axial load characteristics of circular shaped Steel Tubes Filled by Concrete (STFC) with varying compressive stress. An analysis was conducted on the impact of concrete confinement, the concrete and steel tube adhesion strength, additionally the thickness of the steel tube. The assessed column strengths are juxtaposed with those anticipated by Australian Standards, American Codes, and Eurocode 4. Fifteen specimens were assessed for concrete strengths of 30, 60, and 100 N/mm2 at D/t ratios between 22.9 and 30.5. Each column measured 300 mm in length and 114 mm in diameter. The impact of shrinkage is significant for high-strength concrete, whereas it is less for normal-strength concrete. All three programs projected values exceeding those reported in the experimental findings. Eurocode 4 offers the most precise assessment for both standard and high stress concrete.

Han, L – H. et al.$^{(2005)}$ [26] evaluated 50 specimens to assess the behavior of Self Consolidating Concrete (SCC) filled Hollow Structural Steel (HSS) stub columns under axial loading. The primary modifications in the studies included (1) the sectional configuration (circular or square), (2) the range of steel yielding strength from (282 to 404) MPa, and (3) the ratio of tube diameter or width to wall thickness ($\frac{D}{t}$ or $\frac{B}{t}$), which ranged from 30 to 134. This project introduces the formulation of a mechanical model for concrete-filled hollow structural steel stub columns. This analytical research proposes a complete theoretical framework that incorporates a confinement coefficient (ξ) to define the steel tube as well as the encased concrete joint behavior. The observed load and deformation correlation demonstrated a strong correlation with the experimental results. The research employed a theoretical model to analyze the impact of key elements that ascertain the maximum strength of composite columns. The parametric and empirical investigations yield significant insights for developing mathematical equations that ascertain the maximum strength and the correlations between axial load and axial strain in composite columns. The research study compares estimated stub column strengths with established codes, including ACI 1999, AISC-LRFD-1999, AIJ-1997, BS5400-1979, and EC4-1994.

Tao, Z. et al.$^{(2009)}$ [27] employed longitudinal stiffeners to enhance the comprehensive efficacy of quadrilateral or rectangular shaped steel tube columns with thin walls and filled by concrete. The following research examines the nonlinear design and analysis of quadrilateral stub columns subjected to axial compression. ABAQUS, a software employing Finite Element Analysis (FEA), performs the nonlinear analysis. The ultimate strength and load-deformation curves from the test align closely with the anticipated results. This model is employed to analyze and elucidate column behavior. The stipulations for the rigidity of the stiffeners and the (width/thickness) ratio constraints for the sub-panels are addressed. This analytical study examines the feasibility of forecasting the load-bearing capacity of stiffened composite columns in accordance with existing design rules.

$\text{Huang, H. et al.}^{(2010)}$ [28] conducted a finite element study of compression performance of Double Skin Steel Tube Filled by Concrete (DSTFC) stub columns including a Circular Hollow Section (CHS) inner tube and either a Square Hollow Section (SHS) or CHS outer tube. The finite element modeling was validated using a compilation of test data published by several scholars. Mean stress in relation to longitudinal strain curves, stress distributions within concrete, interactions between concrete and steel tubes, and the consequences of hollow ratios on the behavior of DSTFC stub columns were illustrated. The significant variables influencing the sectional capacities of composite columns were analyzed for their effects. This paper's short study permits the following conclusions to be drawn: This analytical study employs the finite element method to examine DSTFC stub columns. The results derived from this modeling demonstrate a strong alignment with the test outcomes. The analysis examines standard curves that illustrate the correlation between average stress and longitudinal strain. An study is performed to assess the stress distributions of concrete at several characteristic locations. The stress-strain relationship for the average longitudinal strain demonstrates either strain hardening or elastic, totally plastic behavior, contingent upon the confinement factor (ξ). A greater confinement factor (ξ) indicates strain hardening in the connection. In contrast, for composite sections with a lower confinement factor (ξ), the relationship demonstrates strain softening. The analysis examines the interaction between the concrete and steel tubes within the composite columns. The influence of the hollow ratio on concrete stress is more significant in stub columns with circular cross-sections compared to those with square cross-sections. The study investigates the critical parameters that affect the relationship between axial load (N) and longitudinal strain (Ɛ) in stub columns. The stiffness during the elastic-plastic phase of (N-Ɛ) relations is observed to increase with a higher hollow ratio. Stub columns with circular sections demonstrate greater residual strength than those with square sections following substantial deformation.

$\text{Yang and Han}^{(2012)}$ [29] examined the behavior of steel tube with thin walls filled by concrete (STFC) columns under concentrated partial compression. A number of studies were performed to examine the influence of sectional configuration, (length/diameter) ratio, partial compression area ratio, and upper endplate thickness on the performance as well as load-carrying capacity of a partially loaded STFC column. The research involved the evaluation of twenty-six STFC specimens to ascertain their bearing capacity, load-deformation relationship, and failure mechanism. The STFC columns demonstrated adequate bearing capacity and ductility under concentrically applied partial compression. A Finite Element Analysis (FEA) model was developed to mimic the behavior of a Steel Tube Filled by Concrete (STFC) column under concentrated applied partial compression. The model's predictions were juxtaposed with the test results, and the outcomes were generally in remarkable concordance. Subsequently, the Finite Element Analysis (FEA) model was employed to investigate the mechanism of a STFC column subjected to concentrated partial compression. The authors provide a straightforward model for predicting the bearing capacity of a composite column under concentrically applied partial compression. The findings of the present investigation yield the subsequent conclusions: STFC columns with thin walls subjected to partially concentric Compression typically demonstrates ductile behavior. Typically, the failure mechanisms of partially loaded steel tubes filled by concrete (STFC) columns with an $\frac{L}{D}$ ratio ranging from 4.5 to 6 are analogous to those of stub columns with an $\frac{L}{D}$ ratio of 3. A finite element analysis (FEA) model was created to examine the behavior of STFC columns with thin walls under concentric partial compression. The Finite Element Analysis (FEA) model well anticipated the failure mechanisms, load-deformation correlations, and behaviors of partly loaded STFC columns. A more straightforward model was suggested to predict the load-bearing capability of partially laden STFC columns with $\frac{L}{D}$ ratios below 6. The predictions generated by this basic model are relatively conservative and adequately acceptable.

$\mathrm{Wang, Y. et\ al.}^{(2012)}$ [30] analyzed the immutable characteristics of square shaped Steel Tube Filled by Concrete (STFC) columns with reinforcement. This analytical study analyzes the performance of four square shaped STFC welded with multiple reinforcing stiffeners, beside one reference STFC. A theoretical analysis was performed to forecast and delineate the whole characteristics of the specimens, encompassing mechanical properties including strength, ductility, as well as modes of failure. The investigations have been conducted during the test. The researchers created and verified a numerical analysis instrument utilizing experimental data from pertinent scholars. A complete parametric study had been undertaken to examine the factors affecting mechanical characteristics. Recommendations for cross-sectional strength design have been formulated based on test outcomes and other academic investigations.

$\mathrm{Abed, F. et\ al.}^{(2013)}$ [31] conducted an experimental investigation to analyze sixteen Steel Tube Filled by Concrete (STFC) specimens and their behavior under pure axial loads at a low rate of 0.6 kN/s. This project analyzes three distinct STFC with (diameter/thickness) ($\frac{D}{t}$) ratios of 54, 32, and 20. Two varieties of concrete, possessing compressive strengths of 44 MPa and 60 MPa, occupy these STFC. The assessed compressive axial capabilities are juxtaposed with the theoretical values forecasted by four distinct international codes and standards: The American Institute of Steel Construction (AISC), the American Concrete Institute (ACI 318), the Australian Standard (AS), and Eurocode 4. The comparative results also included proposed formulas obtained from the literature. The investigation indicated that the $\frac{D}{t}$ ratio significantly influences the compressive behavior of the STFC specimens more than the other factors. The experimental findings indicate that an increase in the $\frac{D}{t}$ ratio correlates with a reduction in the underestimating of axial capacities, as calculated by the majority of programs. Moreover, when the $\frac{D}{t}$ ratios increase, the ductility of the column diminishes with the enhancement of the concrete infill's strength. Conversely, the reverse applies at smaller $\frac{D}{t}$ ratios. An increase in the $\frac{D}{t}$ ratio leads to a drop in both the stiffness and axial strength of the STFC component due to diminished confinement. A nonlinear finite element numerical model is developed and validated with the available experimental data, employing the ABAQUS commercial software package.

$\mathrm{Han, L-H. and\ An, Y-F}^{\ (2014)}$ [32] examined the response of steel tube enclosed and filled by concrete (STFC) stub columns subjected to axial compression. A Finite Element Analysis (FEA) model is designed to investigate the performance for the composite columns. The research considers the substance's nonlinearity and the relationship between concrete and steel tubes. The FEA modeling is validated through a compilation of test data. This paper provides a thorough analysis of the load-deformation relationships of concrete-enclosed STFC stub columns. The research examines the relationships between the outside concrete and steel tube of STFC, together with the central concrete and steel tube of STFC. An analysis is performed on the distinctions among concrete-enclosed STFC columns, traditional STFC columns, and Reinforced Concrete (RC) columns. A parametric analysis is subsequently performed using Finite Element Analysis (FEA) modeling. Simplified equations are ultimately proposed to predict the maximum strength of composite stub columns. The restricted findings of this investigation indicate the subsequent conclusion: circular shaped Concrete-enclosed STFC stub columns with quadrilateral cross-sections are modeled using finite element analysis under axial compression. Nonlinear material behavior and the interplay between concrete and steel tubes are taken into account. The predicted and measured outcomes are in strong concordance. The load (N) vs axial strain (ε) curve of the concrete-enclosed STFC column has five stages. The external RC element restrains the steel tube after the composite column attains maximum strength. Prior to the concrete-encased CFST column attaining maximum strength, the load (N) vs axial strain (ε) curves of the inner CFST are essentially indistinguishable. The dual enclosures of the steel tube and external concrete result in the internal CFST load exceeding the column load. As D to B increases, the intensity disparity between the inner STFC and the associated column diminishes. Increased outer concrete strength ($f_{cu,out}$), central concrete strength ($f_{cu,core}$), longitudinal bar ratio ($\alpha_l$), steel ratio of STFC ($\alpha_s$), and D to B enhance ultimate strength, while stirrup spacing (s) diminishes it. At the peak strength of the concrete-enclosed STFC column, ($\frac{N_{cfst}}{N_{cecfst}}$ ) increases with the augmentation of ($f_{cu,core}$), ($\alpha_s$), and (D/B). Augmenting ($f_{cu,out}$) and ($\alpha_l$) results in a decline of ($\frac{N_{cfst}}{N_{cecfst}}$) at peak strength. At maximum strength, the impact of (s) on ($\frac{N_{cfst}}{N_{cecfst}}$) is negligible.

$\mathrm{An, Y-F. et\ al.}^{(2014)}$ [33] conducted a theoretical analysis of the behavior of steel tube enclosed and filled by concrete (STFC) box columns under eccentric axial loading. The authors employed Finite Element Analysis (FEA) to investigate the composite columns as well as corroborated the FEA modeling with previously published experimental results. The authors examined the behavior of the composite material, considering the correlation between the exerted force and the resultant deflection at the midpoint of the structure, the stress distribution, the failure mechanisms in the columns, and the interrelations among the steel and concrete elements. A comparison was conducted between the performance of concrete-enclosed STFC box columns, RC columns, and STFC built-up columns. A comprehensive examination was performed, utilizing parametric analysis and the moment magnification method, to provide accurate design formulas for concrete-enclosed STFC box columns under eccentric loading. The inquiries detailed in this document culminate in the subsequent conclusions: Concrete-enclosed STFC box columns may fail owing to material failure, which can manifest as either compression-controlled or tension-controlled failure, in addition to stability failure. Composite columns with a slenderness ratio (λ) below 60 are classified as members that fail owing to material characteristics. In these instances, the moment magnification approach is appropriate and yields a cautious approximation. As the ($\frac{e}{B}$) ratio increases, the load contribution of the central STFC elements diminishes, however the moment contribution escalates at the maximum load of the composite columns. The concrete-enclosed STFC box column demonstrates superior ultimate strength and stiffness relative to both a comparable RC box column and a STFC built-up column. The strength and stiffness of composite columns exhibiting failure governed by compression are profoundly affected by the concrete strength, concrete area, and steel area. In columns subjected to tension-controlled failure, the steel area is the primary determinant of strength and stiffness. The distinct sectional properties do not significantly influence the failure mechanisms, encompassing compression controlled and tensile controlled failure. The principal factors exerting the greatest influence on the failure mechanisms are the ratio of e to B and the parameter (λ).

$\mathrm{An, Y-F. and\ Han, L-H. et\ al.}^{(2014)}$ [34] conducted an investigation to analyze the conduct of a concrete-enclosed STFC column under combined compression and bending. A Finite Element Analysis (FEA) model is developed to investigate the performance of the composite column. The observed and anticipated results provide a significant concordance regarding the failure mode, load-deformation relationship, and ultimate load. An examination examines the standard failure modes, the comprehensive response range of the load lateral deflection relationship, the Loading distributions of the internal STFC and external Reinforced Concrete (RC) elements, and the contact stress between the steel tube and the concrete in the composite columns. The research additionally investigates the impact of the Slenderness ratio and loading trajectories in composite columns. An examination of the sectional capacity of concrete-enclosed STFC columns is performed utilizing a finite element analysis model. The analysis examines the impact of factors including the compressive strength of concrete and tensile strength of steel, the steel ratio of Steel Tubes Filled by Concrete (STFC), the longitudinal reinforcement ratio, and the diameter of STFC. A streamlined model is presented to calculate the sectional capacity of concrete-enclosed STFC columns under combined compression and bending. The limited findings of this inquiry yield the subsequent conclusions: The Finite Element Analysis (FEA) model presented is suitable for an in-depth examination of concrete-enclosed STFC columns under compression and bending forces. Composite columns may undergo either outer concrete failure (compression-controlled or tension-controlled) or stability failure. If the slenderness ratio (λ) of a concrete-enclosed STFC column is below 22, second order effects may be neglected. The failure mode of the composite column with a λ value below 60 is categorized as an exterior concrete failure. (2) Under loading path II, the flexural strength ($M_U$) is generally superior compared to loading path I, despite the ultimate axial load ($N_U$) being constant. (3) An increased value of ($\frac{e}{B}$) leads to a greater value of ($\frac{M_{cfst}}{M_U}$) for the column that fails under compression, whereas the impact of $\frac{e}{B}$ on ($\frac{M_{cfst}}{M_U}$) for the column that fails under tension is negligible. The influence of the $\frac{e}{B}$ ratio on the load ratio of $\frac{N_{cfst}}{N_U}$ (where $N_{cfst}$ denotes the load of the CFST component at the maximum load $N_U$) is negligible when the e to B ratio is less than or equal to 0.2. When the e to B ratio surpasses 0.2, an elevation in the e to B ratio leads to a decline in the $\frac{N_{cfst}}{N_U}$ ratio for the column. A simpler model was introduced to forecast the sectional capacity of a concrete-enclosed STFC column subjected to simultaneous compression and bending forces. Nevertheless, the system exhibits a prudent approach in its predictions.

$\mathrm{Cai, J.\ et\ al.}^{(2015)}$ [35] performed a numerical analysis to analyze the mechanical properties and failure causes of Steel Tube Filled by Concrete and Reinforced by Steel (STFCRS) columns. The study was conducted with the ABAQUS solver program. The finite element models of SRCFST columns were validated using established experimental results. The study conducted a numerical analysis of 22 specimens to analyze the effects of the ratio of steel tubes ($\alpha_t$), ratio of section steel ($\alpha_s$), strength of concrete ($f_c'$), yield strength of the steel tube ($f_y^t$), and yield strength of section steel ($f_y^s$) on the mechanical properties and maximum resistance of STFCRS columns under axial compression. The Eurocode 4 model Considerably underestimates the load-bearing capacity of STFCRS columns, leading to the creation of a new model designed to anticipate their strength. The comparative examination of the computational outcomes derived from the proposed model and the research data indicates that the model demonstrates a high level of dependability in forecasting the maximum load-bearing capacity of STFCRS columns. The calculation results demonstrate that the peak strength and starting stiffness of steel tube filled by concrete (STFC) columns are positively correlated with all factors. Nonetheless, the fluctuations in the section steel ratio ($\alpha_s$), yield strengths of steel tubes ($f_y^t$), and section steel ($f_y^s$) exert negligible influence on the axial compression properties of STFC columns when their maximum strength is attained. Conversely, the STFCRS columns typically transition from demonstrating strength softening behavior to strength hardening behavior with an increase in the steel tube ratio ($\alpha_t$). The research indicates that Eurocode 4 significantly under appraises the performance of the steel tube filled by concrete and reinforced by steel (STFCRS), as it neglects the strength augmentation of the central concrete and section steel attributed to the containment phenomenon. This research presents a novel model for precisely forecasting the bearing capacity of STFCRS columns. The model's validity was substantiated by simulations and experiments performed on STFCRS column specimens.

$\mathrm{Wang, Y.\ et\ al.}^{(2015)}$ [36] performed tests on thirty-nine stub columns till failure. The study aimed to examine the compressive behavior of regular strength steel tube filled by concrete with recycled aggregate (STFCRA) stub columns subjected to axial loading. The research analyzed various features, including the degree of substitution of Recycled Coarse Aggregate (RCA), the origin of the RCA, the strength of compression of RAC cores, as well as the (steel area/concrete area) ratio. The research findings indicated that the fluctuation in the mechanical characteristics of STFCRA stub columns is inferior to that of RACs, mostly due to the incorporation of steel tubes. The origin of Recycled Coarse Aggregate (RCA) did not influence the compressive performance of axially loaded reinforced Steel Tube Filled by Concrete with Recycled Aggregate (STFCRA) stub columns within the defined parameter range of the examined specimens. The incorporation of RCA led to a reduction of under 10% in the compressive strength of STFCRA, which is less significant than the decline noted in RAC samples during material testing. The research investigated the influence of steel tubes on the RAC cores Throughout the complete loading process by evaluating strain gauge data. Subsequently, mathematical equations were developed to forecast the longitudinal stress-strain correlations for both steel tubes and RAC cores. The existing Steel Tube Filled by Concrete (STFC) design is evaluated against the test outcomes of STFCRA stub columns, as well as design suggestions are provided.

A. Gbabar $^{(2016)}$ [37] examined columns fabricated from Steel Tube Filled by Concrete (TFC) with the finite element software ANSYS 15.0. An analysis has been performed on four various column geometries: circular, square, hexagonal, and octagonal. The analytical solutions for circular and quadrilateral geometries have been juxtaposed with the research data presented by Alwash et al. (2013). The comparative failure load results indicate a 4% deviation between the experimental data and ANSYS 15.0 results. Additionally, parametric calculations were performed to assess the influence of various shapes of steel tube filled by concrete columns (namely hexagonal and octagonal) on their load-bearing capacity. An innovative equation is presented to predict the maximum strength of Tubes Filled by Concrete (TFC) by employing empirical data from 148 TFC columns of diverse cross-sections, with side lengths varying from 20 to 400 cm. To evaluate the precision of the suggested formula, the loads derived from various design methodologies (American Concrete Institute (ACI 318M) [52], Eurocode (EC4) [57], New Zealand Standard of Concrete Structures (NZS) [59], and American Institute of Steel Construction (AISC) [53]) are juxtaposed with it. The analysis indicates the minimal convergence rate for the proposed equation.

Ekmekyapar, T. et al. $^{(2016)}$ [38] conducted 18 trials on circular steel tube filled by concrete (STFC) columns of differing lengths, encompassing short, medium, and long categories. To examine the impact of column characteristics and the containment phenomenon, it was essential to employ three $\frac{L}{D}$ ratios, two $\frac{D}{t}$ ratios, two steel grades, and three concrete classes. A few specimens possess characteristics that conform to the accepted application limitations of EC4 [57] and AISC 360-10 [53], whilst others display traits that surpass these limits. Due to the demand for high-strength materials in contemporary, large-scale, and efficient structures, it is essential to surpass existing design criteria. Evidence indicates that concretes with compressive strengths of 56 MPa and 66 MPa exhibit exceptionally smooth and malleable load shortening curves. This indicates that various varieties of concrete can undergo significant deformation. The fragility of 107 MPa concrete is demonstrated by its sudden shifts from the pre-peak to the post-peak region and the rapid dissipation of stress in load shortening curves. Furthermore, a total of 239 research data points have been obtained from literature sources to assess the precision of EC4 [57] and AISC 360-10 [53] predictions, both within and beyond the scope of their applicability. This study analyzes the effectiveness of prediction techniques on short, medium, and long STFC columns, rather than concentrating on a limited spectrum of configurations. The forecasts of EC4 [57] exhibit a significantly greater concordance with the test results. The predictions provided by AISC 360-10 demonstrate a conservative tendency across all parameter combinations. The application scope of EC4 can be broadened to encompass solutions for columns with enhanced functionality. A thorough examination of the confinement effect is essential in the formulations of AISC 360–10. The $\frac{L}{D}$ ratio and relative slenderness are critical characteristics that directly affect column behavior. Nonetheless, the $\frac{D}{t}$ ratio does not directly influence the column's behavior. Several inferences to infer: Column SI diminishes with increasing central concrete strength. Enhanced confinement performance is noted in columns with reduced concrete strength. In comparison to 107 MPa concrete, both 56 MPa and 66 MPa concrete demonstrate superior deformation capacity and malleability. Moreover, 107 MPa concrete advantages from more robust steel tubes with elevated yield strength confinement. To improve ductility and surface smoothness, employ thicker steel tubes within this concrete. A greater contribution of 107 MPa concrete to compressive load capacity was noted in columns featuring thinner steel tubes. EC4 projections were often inaccurate for columns with relative slenderness ratios under 0.4. Exceeding the 0.4 relative slenderness criteria, EC4 produces conservative outcomes. Nonetheless, AISC 360-10 forecasts are conservative for all test data except five instances. Predictions of EC4 and AISC 360-10 enhance with more column slenderness. Although both codes provide cautious estimates above a slenderness ratio of 1.0, AISC 360-10 demonstrates superior performance and more precisely forecasts the specimens test results analyzed in this research paper. The length-to-diameter $(\frac{L}{D})$ ratio and relative slenderness $(\lambda')$ of steel tube filled by concrete (STFC) columns significantly influence column capacity. Nonetheless, the $\frac{D}{t}$ and containment factors do not directly influence the behavior of STFC columns. The predictions of EC4 are more consistent with test findings and effectively forecast the characteristics of STFC columns beyond the limitations of application. EC4 application limitations can be modified to facilitate more extensive column arrangements. AISC 360-10 offers cautious outcomes for STFC columns with characteristics both in and outside the application limitations. This indicates the need to amend the containment phenomenon of circular tubes in AISC 360-10 calculations.

Lu, Y. et al.(2018) [39] investigated the bonding properties of steel fibers utilized to reinforce a steel tube filled by concrete that are self-stressing and self-compacting (FSTFCSS) columns. This study conducted experiments on ninety steel tube filled by concrete (CFST) columns. The experiment examines four factors: (a) the specific type of concrete (self-stressing self-compacting concrete reinforced with steel fibers as well as self-compacting concrete); (b) the steel tube thickness ranging from (2.5 to 4.25) mm; (c) the compressive strength of concrete (C40, C50, as well as C60); and (d) the steel fiber content in the concrete (0%, 0.6%, as well as 1.2%). The research findings indicate that the bonding strength properties of members with steel fibers utilized to reinforce a steel tube filled by concrete that are self-stressing and self-compacting ranges from (0.50 to 2.51) MPa, surpassing that of self-compacting steel tube filled by concrete members. Self-stress considerably enhances the steel tube filled by concrete (STFC) members bond strength, with a mean increase of 42.7%. The binding strength initially diminishes and subsequently escalates as the volume percentage of steel fiber rises. Ultimately, proposed methods are presented to forecast the bonding strength properties of steel fibers utilized to reinforce a steel tube filled by concrete that are self-stressing and self-compacting columns, offering more accurate predictions than current design codes. From the preceding analysis, the subsequent conclusions may be deduced: The bonding strength properties of steel fibers utilized to reinforce a steel tube filled by concrete that are self-stressing and self-compacting varies between (0.50 to 2.51) MPa. The bonding strength properties of Steel Tube Filled by Concrete that is self-consolidated (STFCSC) specimens frequently surpasses that of alternative materials. In STFCSC and FSTFCSS members, increased concrete strength or a thicker steel tube leads to enhanced bond strength. The implementation of self-stress considerably enhances the bonding strength properties of STFC members. The mean degree of enhancement is 42.7%. Self-stress amplifies the chemical adhesive force, mechanical contact force, and frictional resistance between the steel tube and central concrete. The bonding strength properties initially diminishes with an escalation in the volume percentage of steel fibers, followed by an increase. Consequently, there exists an ideal percentage of steel fiber volume that can improve the bonding characteristics of FSTFCSS members. Formulas are suggested for forecasting the bonding strength properties of FSTFCSS columns. The test findings, in contrast to the forecasts, indicate that the new formulas yield a more precise prediction compared to the current design codes.

$\text{Yuan, H. et al.}^{(2018)}$ [40] conducted a study on the ST-RC column, a composite structure incorporating a concrete-filled steel tube within reinforced concrete. The ST-RC columns, or staged construction-steel tube-reinforced concrete (SC-ST-RC) columns, represent an innovative composite structure. Currently, there is inadequate evidence concerning their behavior and ductility. This study analyzed the operating principles of two distinct types of shear wall-reinforced concrete (ST-RC) columns in a 15-story building. A finite element model was suggested for SC-ST-RC columns subjected to axial compressive force and lateral loading. The model integrated a suitable material-constitutional relationship. The analysis considered the existence of material nonlinearity and their interplay between steel tubes and concrete. The suggested finite element model precisely forecasted the lateral stiffness, strength, and deformation capacities of SC-ST-RC columns. A thorough investigation was performed to assess the influence of several factors on displacement ductility. The parametric investigation ultimately yielded a simpler equation for calculating the displacement ductility of SC-ST-RC columns. The predictions of the proposed formula demonstrate a robust association with a substantial quantity of test outcomes. The suggested formula indicates the required displacement ductility for different seismic design classifications in the present ST-RC specification. It can serve as a significant resource for the seismic design of SC-ST-RC structures.

$\text{Hassanein, M. F. et al.}^{(2018)}$ [41] performed a study on the finite element analysis of short columns constructed from high-strength octagonal steel tube filled by concrete with substantial diameters. The research sought to assess the aesthetic appearance of the columns as well as their capacity to endure substantial loads. At now, Steel Tube Filled by Concrete (STFC) columns are employed to bear substantial loads. There has been an increasing trend in the utilization of High-Strength Concrete (HSC) for the construction of STFC columns. This is executed to optimize the available floor space in diverse structures, taking into account the limited land areas globally. This work investigates octagonal STFC short columns by finite element (FE) modeling to analyze the architectural specifications of the octagonal column form and the benefits of STFC columns. Validated finite element (FE) models are utilized to conduct a parametric analysis on octagonal steel tube filled by concrete (STFC) short columns to enhance our comprehension of their behavior. The research primarily examines large-diameter columns utilizing a diverse array of (diameter/thickness) ratios, spanning from (40 to 200). The bulk of these columns are composed of high-strength concrete (HSC) capable of withstanding pressures up to 100 MPa. The maximal strengths, as established by literature trials and current finite element analysis, are juxtaposed with the prevailing design models. This contrast reveals the current design models demonstrate caution, with the D/t ratios affecting their accuracy. Consequently, a novel design methodology is given, utilizing the D/t ratios of the columns as a pivotal element. This proposed design paradigm has been corroborated by existing experimental data and has been found to produce outstanding results. This study offers a thorough examination of the principal variables influencing the structural integrity and performance of octagonal steel tube filled by concrete (STFC) short columns constructed using high-strength concrete (HSC).

$\mathrm{Ding, F-x., et\ al.}^{(2018)}$ [42] performed an extensive analysis of the mechanical characteristics of two column types: traditional Quadrilateral shaped Steel Tube Filled by Concrete stub columns (QSTFC) as well as Steel Tube Filled by Concrete Confined by Stirrups stub columns (STFCS). The research incorporated tests, numerical simulations, and theoretical analysis to examine the conduct of these columns subjected to compressive load. Sixteen QSTFC stub columns as well as sixteen STFCS stub columns were evaluated, considering several features like internal stirrups, concrete strength, as well as the cross-sectional aspect ratio (B to D). An study was performed on the failure patterns, bearing capacity, stiffness, and ductility of the specimens utilizing the experimental results. An FE model was created to numerically imitate and examine the composite interaction within the steel tube, stirrups, and core concrete. The enhancement of the core concrete's energy dissipation capacity due to stirrup confinement is also analyzed. A comprehensive theoretical equation was developed to predict the maximum load-bearing capacity of STFCS and QSTFC stub columns subjected to compressive loads. This equation was derived using the superposition principle and a method of rational simplification. Evidence indicates that the proposed equation for these columns exhibits greater precision than the formulas already available in the literature and codes.

$\mathrm{Chen, J-Y. et\ al.}^{(2019)}$ [43] analyzed the axial efficacy of a particular type of Steel Tube Filled as well as Enclosed by Concrete (STFEC) box stub column. The column comprises an external Reinforced Concrete (RC) box column and six integrated steel tube filled by concrete (STFC) components. Eight axial compression experiments were performed on the STFEC box members. A Finite Element Analysis (FEA) model was created to investigate the structural properties of the composite columns. The simulation considered the consequences of material nonlinearity as well as the interaction characteristics between the concrete and steel tubes. The verified Finite Element Analysis (FEA) model was subsequently utilized to conduct a thorough investigation of the load-deformation responses. The research additionally analyzed the outcomes of common failure modes, the distribution of internal loads and stresses, as well as the contact stresses between the concrete and steel tubes. Parametric analyses investigated the compressive characteristics of STFEC box specimens, emphasizing the influence of geometry and materials characteristics. A streamlined model was suggested to forecast the maximum strength and early stiffness of STFEC box stub columns during axial compression.

$\mathrm{Yang, Y-F. et\ al.}^{(2020)}$ [44] performed an investigation on the evaluation as well as a quantitative simulation of quadrilateral shaped Steel Tube Filled by Recycled Aggregate Concrete (STFRAC) stub columns subjected to concentric compression. A total of eighteen members are assessed, comprising twelve specimens constructed from STFRAC and six specimens produced of Steel Tube Filled by Concrete (STFC) as a reference. The specimens exhibit varying (width/thickness) ratios B to t, (depth/width) ratios $\beta$, In addition to the substitution of recycled coarse aggregate ratios (r). The research findings demonstrate that quadrilateral STFRAC stub column members display an analogous failure mode to their equivalents. Nonetheless, the load-bearing capacity and composite elastic modulus of STFRAC members are inferior to those of STFC specimens, both diminishing as the value of (r) increases. Moreover, specimens exhibiting a larger (B/t) ratio and ($\beta$) value demonstrate a diminished ductility index. A Finite Element Analysis (FEA) model, created with ABAQUS software, is employed to numerically simulate the behavior of rectangular STFRAC stub columns subjected to concentric compression. The precision of the expected outcomes is subsequently validated through a comparison with experimental observations. The Finite Element Analysis (FEA) model offers enhanced understanding of the behavior of concentrically loaded rectangular Reinforced Concrete-Filled

Steel Tube (STFRAC) stub columns. This work offers streamlined equations for calculating the load-bearing capacity of rectangular reinforced alkali-activated fly ash slag concrete-filled steel tube (STFRAC) stub columns. The comparison of the reduced equations with actual data indicates that the simplified model accurately forecasts load-bearing capability.

$\text{Abbas, N. J. et al.}^{(2021)}$ [45] introduced a novel method for precisely forecasting the maximum load-bearing capacity of hexagonal Steel Tube Filled by Concrete (STFC) columns. The novel method had been corroborated utilizing experimental data sourced from the literature. Furthermore, it was utilized to build a constitutive model for the core concrete applicable in Finite Element Analysis (FEA). This makes it possible for the model to be evaluated using the current research data regarding how hexagonal columns behave when subjected to a concentrated load. A thorough parametric investigation had been performed to examine the influence of various factors on how the columns behave and their maximum strength. An examination was undertaken to assess the influence of concrete compressive strength, the yield strength ratio of steel, and the ratio of depth to thickness of the tube. The investigation demonstrated that these parameters significantly affected the behavior of the columns. Reducing the (depth/thickness) ratio ranging from (33-17) yielded a 100% enhancement in maximum strength.

$\text{Ali, A. A. and Abbas, N. J.}^{(2021)}$ [46] conducted a study around the behavior of box steel tube filled by concrete (STFC) columns, with a specific focus on the confinement effect. The impact of confining pressures complicates the assessment of the ultimate strength of STFC columns. A database of 188 evaluated columns has been employed to produce two types of formulas: modified and simplified. These calculations can be utilized to predict the ultimate strength of box STFC columns with diverse geometrical and material characteristics. Multiple coding procedures and prior formulas from other authors were employed for validation and to illustrate the reliability of the outcomes. The proposed restricted concrete model was employed in a finite element examination to illustrate the axial load-shortening characteristics of composite columns. The results were subsequently compared with the experimental findings. The existing formulas and concrete model yielded results that closely corresponded with the outcomes of the experimental tests.

$\text{Ye, Y. et al.}^{(2021)}$ [47] examined a novel particular kind of steel tube filled by concrete (STFC) structural element by substituting the middle segment using a stone prism instead of the concrete infill. A study was performed to examine The mechanical characteristics of steel tube filled by concrete and enclosed by stone prism (STFCS) specimens subjected to compressive axial load. The study comprised twenty-four stub columns, comprising eighteen members of STFCS and six specimens of STFC. Axial compression was applied to the columns until they failed. The main considerations included The stone prism's dimensions (7.5 cm, 10 cm, or 12.5 cm), the steel tube thickness (6.0 mm, 8.0 mm, or 12.0 mm), and the compressive strength ($f_{cu}$) of the concrete ranging from 62.3 MPa to 107.0 MPa. The experiment's findings showed the synergistic effects among the three components of the specimen, resulting in a significant enhancement of the load-bearing capacity of the STFCS column. A study had been undertaken to examine the influence of various characteristics of the failure modes, load-carrying capacity, load-deformation response, and ductility of the STFCS members. Simultaneously, the empirically assessed each member's axial compressive strength of STFCS was juxtaposed with the anticipated values derived from the formulas in established design codes for conventional STFC columns. The current design algorithms failed to accurately forecast the load-bearing capacity of STFCS stub columns, leading to the suggestion of an improved model. From the experimental data, the subsequent conclusions can be derived: The principal factor affecting the failure mechanism of STFCS stub columns is the manifestation of outward local buckling in the steel tube and the compression of the concrete infill and stone prism. When STFCS columns break, shear collapse of the infilled concrete may also transpire. A Strength factor (SI) exceeding 1.0 signifies that composite action occurs among the different components of the STFCS member. As the ratio of confinement (ξ) rises, the value of SI generally diminishes. The strength of the axial compression of a STFCS component generally increases linearly with both the tube wall thickness (t) and the stone ratio (β). The concrete strength ($f_{cu}$) does not significantly affect the strength of STFCS components in this test.

Ci, J. et al.$^{(2022)}$ [48] performed both experimental as well as numerical analyses regarding the behavior of axial compression of quadrilateral steel tube filled and enclosed by concrete (STFEC) short columns featuring a circular shaped inner steel tube. Experiments were performed on six large-scale short columns constructed from Circular steel tube filled and enclosed by concrete (STFEC). The columns exhibited diverse inner circular tube sizes, spanning from (320-500) mm. The study aimed to examine the influence of the diameter and thickness of circular steel tube filled by concrete (STFC) columns regarding their axial performance. A conceptual model is created using the fiber analysis method and confirmed in comparison to a comprehensive test database. An evaluation is performed to ascertain the precision of several standardized design models, and a basic model is suggested for estimating their maximum strengths. The test findings demonstrate that STFEC columns have enhanced load-bearing capacity and are able to endure considerable axial loads in the absence of notable decline in strength. Augmenting the diameter of the steel tube enhances the synergy between steel and concrete within the inner STFC column, resulting in a significant 27.3% improvement in the strength of compression of STFEC columns. It has been demonstrated that the increasing rate of compressive strength in the core concrete of the STFC column is higher for columns with a reduced local slenderness ratio. The ductility of STFEC columns is affected by the compressive strength of the concrete and the configuration of the stirrups. Additionally, the design model presented in this research study is able to provide a more precise assessment than conventional design methods. The inquiry produces the subsequent conclusions: The principal failure modes seen in the tested STFEC short columns, under concentric loading, were the crushing and spalling of the exterior concrete. The failures were accompanied by the distortion of stirrups and longitudinal bars. The external concrete effectively inhibited local buckling in the internal steel tube. The incorporation of encased STFC columns led to an improvement in the maximum strength of the STFEC columns. The computed enhancement in maximum strength ranged from (6 to 12) % relative to the maximum load of the STFEC columns derived from the superposition approach. The stub columns exhibited ductile failure, maintaining residual strengths between (85% to 95%) of their maximum loads. Substantially augmenting the thickness of the steel tube markedly improved their ultimate strengths. This is attributable to the improved synergy between the steel and concrete elements of the inner STFC columns. The increment in the strength of compression of the core concrete in the STFC column was determined to be more pronounced in the column exhibiting a lower local slenderness ratio. The outcome of the parameter analysis results demonstrates that the compressive strength of the external concrete and the stirrup spacing significantly influence the ductility of STFEC columns. The increased longitudinal bar ratio correlates with enhanced maximum strength of the columns. Nevertheless, the longitudinal bar ratio exerts no substantial impact on the ductility of the columns.

## 3. Conclusions

1. Improved Flexural and Axial Performance: Steel tube filled and enclosed by concrete (STFEC) beams and columns exhibit enhanced flexural and axial characteristics relative to traditional reinforced concrete (RC) or hollow steel structures, attributable to the composite interaction between concrete and steel.

2. Ductility and Energy Absorption: Steel Tube Filled by Concrete (STFC) constructions, particularly those with circular cross-sections, provide considerable ductility and energy

absorption, making them suitable for high-load, high-performance applications.

3. Influence of key parameters: The performance of Steel Tube Filled by Concrete (STFC) structures is affected by key parameters like the D/t ratio, steel yield strength, concrete strength, and confinement effects. Augmenting steel tube thickness and concrete strength improves flexural capacity and ductility.

4. Design Code Predictions: Although numerous design codes (EC4, AISC, AIJ, etc.) offer conservative estimations for Steel Tube Filled by Concrete (STFC) structures, improvements are necessary to accommodate contemporary materials, geometries, and loading scenarios.

5. Finite Element Analysis (FEA) Validations: Numerical modeling through FEA has been rigorously tested against experimental outcomes, providing dependable instruments for forecasting Steel Tube Filled by Concrete (STFC) behavior under diverse stress and failure scenarios.

6. Impact of Confinement: The confinement offered by steel tubes enhances the mechanical properties of core concrete, leading to augmented strength and diminished local buckling tendencies.

7. Innovative Combinations: The incorporation of novel combinations, including recycled aggregate concrete, self-stressing concrete, and steel fibers, significantly improves the flexural and axial performance of Steel Tube Filled by Concrete (STFC) structures.

8. Failure Mechanisms: Steel Tube Filled by Concrete (STFC) members typically fail due to material yielding, local buckling, or a combination of compression and bending, exhibiting unique failure patterns based on varying section geometries and material combinations.

9. Sustainability and Cost Efficiency: Employing recycled components or enhancing steel-concrete combinations can diminish expenses and environmental repercussions without substantially affecting performance.

10. Practical Applications: These results validate the appropriateness of Steel Tube Filled and Enclosed by Concrete (STFEC) structures for high-rise edifices, bridges, and seismic regions, where elevated strength, rigidity, and durability are essential.

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