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Research Article

A Finite Element Analysis to Investigate Tee Concrete Beam Specifications

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Abstract:

Tee beam section represent an important structural component due to its significant application in many construction fields. Determining the optimal sectional sizes for a beam is a challenging task, as it involves identifying the dimensions that will enable the beam to withstand the most intense shear forces. For that in this thesis, the tee section investigated base on different sizes and conditions using ANSYS software program. The methodology involves three stages; the first stage is the validation conditions which compare with previous studies. The second stage was by changing the beam section dimensions based on 1900mm length. Finally, the third stage is by changing the length to 3000mm span. The results observed that the perforated beams with deeper size surpassed all other typical beam kinds. The deflection reduced from 8.454 mm to 3.280 mm. This result supported by the results of second group with observed as the best case due to beam depth. The deflection in this stage reduced from 24.748 mm to 23.001 mm.

1. Introduction

The construction of reinforced concrete structures is marred by serious problems that undermine the structural integrity and long-term durability of the structures. Poor workmanship and absence of quality control during the construction process, normally caused by inexperienced personnel, are among the serious issues. Common issues such as the absence of adequate vibration of concrete lead to honeycombing, while inadequate protection from external environmental conditions speeds up structural deterioration. In addition, insufficient maintenance and deficient soil exploration in many instances end up causing unsuitable foundations that create differential settlement and corrode reinforcing bars. All these aggravating circumstances ultimately lead to various forms of structural defects, such as cracking and loss of strength, which are reflective of more training and regulatory measures in the construction industry [1]. All these problems must be addressed for ensuring reinforced concrete structures are long-lasting and safe, particularly with proper use of tee beams for efficient operation.

The tee beam, being a crucial part of reinforced concrete structures, is characterized by its tee cross-section that enables it to resist gigantic loads in an efficient manner. The upper flange of the tee beam is a compression member and is capable of resisting compressive stresses, while the web directly underneath it serves excellently to resist shear stresses. This unique configuration allows tee beams to play a very important role in most uses, particularly in building highway bridges, where they are reinforced with bars to absorb tensile forces resulting from bending [2]. While they have their advantages, tee beams are limited compared to I-beams, particularly with respect to resistance against tensile loads due to the absence of a bottom flange. In this article, we analyze the performance and structural safety of tee beams based on bending strength, failure ultimate moment, toughness, rigidity, malleability, and load deflection [3]. We aim to review empirical tests and compare with design code equations so that we can analyze the adequacy of current methods in estimating cracking moments and flexural strength.

The paper also delves into the collaborative behavior of tee beams in floor slabs, with proper focus on proper alignment and incorporation in monolithic structures. Since tee beams are found ubiquitously in residential as well as commercial structures, knowledge regarding their behavior under a variety of loading conditions becomes imperative. The paper addresses issues related to determining optimal sectional sizes for tee beams, more particularly in the context of shear resistance and the error implications of design. As the number of concrete buildings has increased, there has been a growing need for effective methods of reinforcement. The study aims to enhance current knowledge regarding tee beams with various reinforcement strategies and performance when subjected to different stress conditions. Table 1 presents a literature review of studies on the characteristics of tee beams.

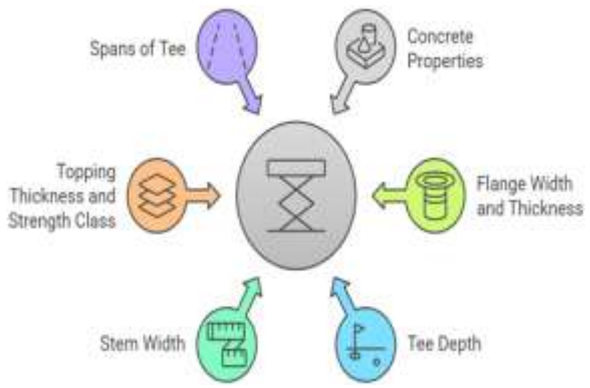

Figure 1. *Factors influencing tee beam section design*

1.1 Effective factors for designing the tee beam section

Several parameters are very important in the design of sections in tee beams. Concrete characteristics vary according to prestressing patterns and loading requirements, whereas atmospheric conditions decide more thick tops or diameters. Flange widths vary from 1.2 m to 4.8 m with typical specifications of 2.4 m and 3 m and thickness of 50 mm to 100 mm. The total depth of double tees, taking into account flange thickness, varies from 300 mm to 812 mm, with each producer offering depths for availability. Stem widths also vary, where the standard chamfer sizes are 50 mm or 76 mm, with deeper elements being thinner in stem thickness. Topping strength and thickness recommendations suggest normal weight concrete at 3000 psi (21 MPa) for composite sections, with some manufacturers suggesting stronger strengths, as much as 4000 psi (27 MPa). Load capacity and spans for double tee sections are finally given in charts, where one notices that longer spans (18 m to 20.5 m) have lower eigen frequencies (3 Hz), and shorter spans have higher eigen frequencies, showing an inverse proportionality [4-13]. Figure 1 illustrated the factors influencing tee beam section design.

2. Research Methodology

The research methodology uses the Finite Element Method (FEM) on ANSYS software to analyze the performance of concrete pillars with focus on their mechanical properties and seismic response under changing loading conditions. ANSYS is an extensive finite element software tool designed for multiple applications and encompasses over 180 types. Both static and dynamic analysis fall within its capabilities. For more than twenty years, it has been recognized as the premier program for finite element analysis. It is a distinctive and resilient tool that can be employed in engineering to address diverse challenges [14]. The approach initiates with the preprocessing steps involved in meshing the problem in terms of nodes and elements, developing governing equations, and finding the global stiffness matrix. A cylindrical storage beam is simulated with the SHELL63 element, having membrane and bending capabilities. Modal analysis checks assembly of stiffness and mass matrices, and governing equations of motion are derived in terms of determining mode shapes and natural frequencies. Meshing is important to achieve accuracy, and the loads are applied to the model either before or after meshing. The solution is launched using ANSYS commands, with the possibility of modifying the parameters of analysis. The parameters of the cement and steel reinforcement material are defined to achieve structural performance at its optimum, and the model is validated by comparing with experimental data to confirm the accuracy of the model in predicting the structural behavior. Fig. 2 presents a flowchart illustrating the methodology adopted for this analysis.

3. Results and Discussion

Validation of a simulation model involved a comparison of computational results from the current study with those obtained from ANSYS 2020 testing under similar conditions, focusing on the model's ability to forecast the concrete beam behavior correctly. The results showed that the model could accurately portray intermediate displacement deformation behavior, notably illustrating that central stiffness plays an important role in load-carrying capacity. The model displayed another type of bending that would support additional loads while maintaining the alignment of certain nodes. Figure 3 and 4 illustrate the directional and total deformation results, respectively, showcasing the model's performance compared to previous experimental data. The error percentages for various load conditions are summarized in Table 2, indicating a high level of accuracy in the model's predictions. The validation process ensured that the simulation model is a good predictor of structural concrete beam behavior, with percentage errors remaining in acceptable ranges for use as desired. The short tee beam displacement response analysis in four cases (G1-CASE 1 to G1-CASE 4) reveals that all the cases experience growing deflection with higher loads, with the maximum deflections ranging from 3.280 mm to 8.454 mm at the loads of up to 135 kN. G1-CASE 2 experiences the maximum deformation, demonstrating a high response to loading conditions. All the specimens possess serviceability limits ranging between 90 kN and 105 kN, highlighting the need for in-depth structural analysis to realize the beams' performance under varying loads. The outcomes highlight the need for beam characteristics in civil engineering applications. Figure 5 shows the comparison of load-displacement curves from this study and reference study for different cases of G1 group. The results of the second group cases' displacement response for long tee beam under load indicate that vertical displacement is load dependent, as noted by a surface-mounted laser displacement sensor. The mid-span deflection in G2-CASE 1 was 23.615 mm at 155 kN, and for G2-CASE 2, it was a maximum of 24.748 mm at the same load. Maximum deflections for G2-CASE 3 and G2-CASE 4 were 23.155 mm and 23.001 mm, respectively. Serviceability limits were maintained between 80 kN and 110 kN in all the samples, and initial evidence of shear fracture occurred in all the samples at 80 kN. These outcomes demonstrate the powerful impact of tee beam properties on engineering design and analysis. Figure 6 shows the comparison of load-displacement curves from this study and reference study for different cases of G2 group.

Table 1. *Summary of the literature review*

Reference	Objective	Key Findings
[4]	Develop a computational model for analyzing rectangular concrete beams with HFRP reinforcements.	Established a correlation between torque and twist; the relationship is linear until the first torsional crack. Investigated torsion induced by loading eccentricities and curved plans.
[5]	Present a mathematical model for efficient design of rectangular beams with haunches.	Non-prismatic beams are more cost-effective than prismatic ones, showing lower cost, volume, and weight under various loading conditions.
[6]	Evaluate shear performance of tee hybrid reinforced concrete beams with openings.	Analyzed 13 tee hybrid beams under varying loads; findings on the impact of CFRP reinforcement and aperture size on structural behavior.
[7]	Assess structural integrity of multi-tee precast concrete slabs.	Recommended clip-type shear reinforcement at dapped ends; experimental results showed significant flexural strength improvements during construction.
[8]	Optimize double-tee bridge beams using ultra-high-performance concrete.	Noted reduced weight and increased span capacity with ultra-high-performance concrete, proving competitive in life-cycle costs.
[9]	Develop CFRP-prestressed concrete sections.	Created a mechanical anchoring system for CFRP tendons; flexibility in tensioning recognized, facilitating easier construction.
[10]	Study flexural strengthening of RC tee beams using Ferro cement.	Found that Ferro cement significantly enhances flexural strength in pre-damaged Tee beams.
	Investigate retrofitting of RC Tee beams with Ferro cement.	Ferro cement improves the ultimate load-bearing capacity of retrofitted beams; emphasizes safety and efficiency in retrofitting methods.
[11]	Highlight advantages of Double Tee beams for long spans.	Double Tees suitable for spans up to 22 meters; preferred for various applications due to their load-bearing capacity and resistance to moisture.
[12]	Evaluate the structural performance of reinforced concrete beams by investigating the effects of incorporating fiber-reinforced polymer (FRP) composites.	Polymer fibers reduce stress, resulting in a 33% decrease in cracks. Hollow beams show a 24% reduction, with optimal performance in C-channel carbon fiber. The study also identifies failure modes, including concrete crushing.

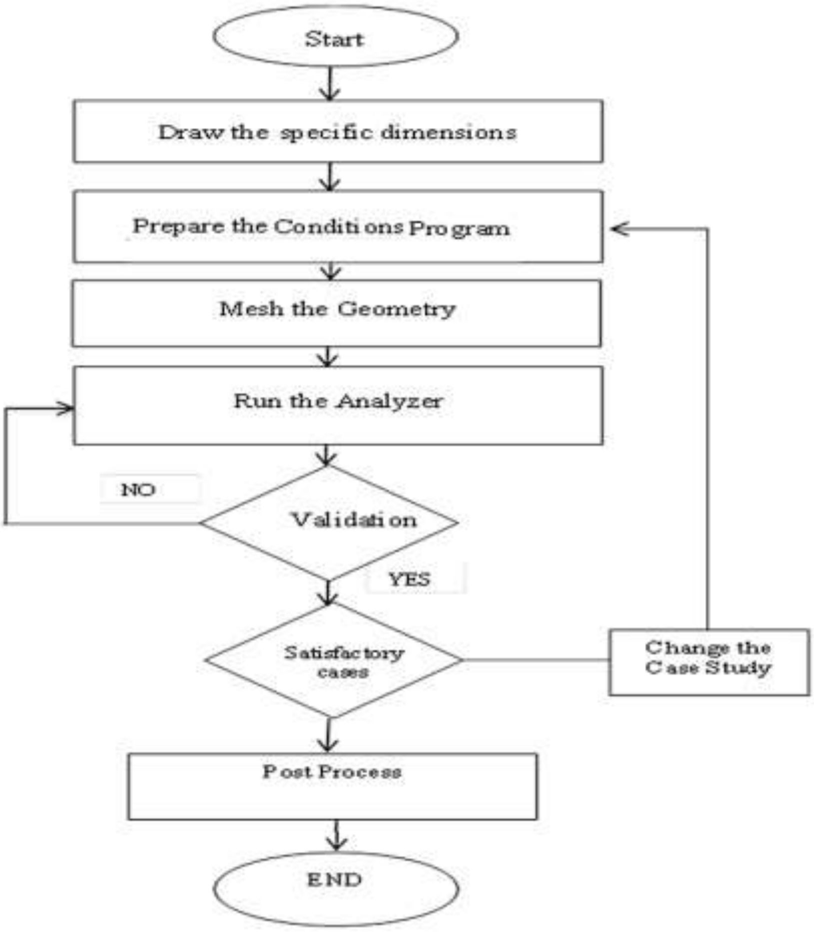

Figure 2. *Flowchart of the designing*

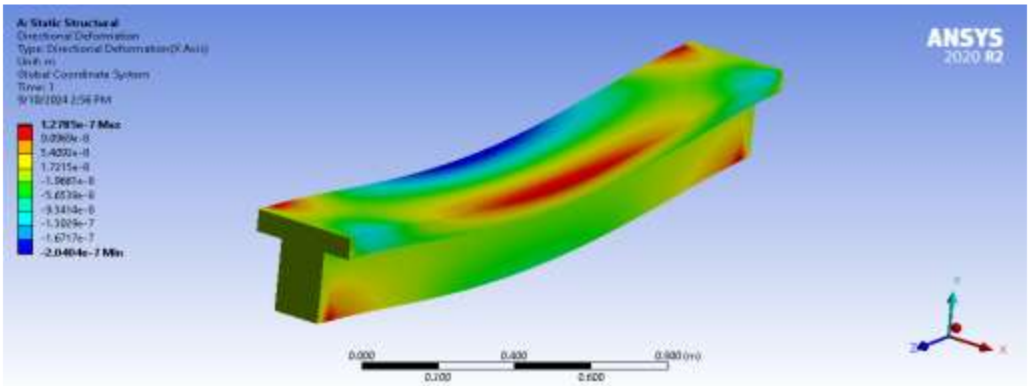

Figure 3. *Directional deformation of the validation case study*

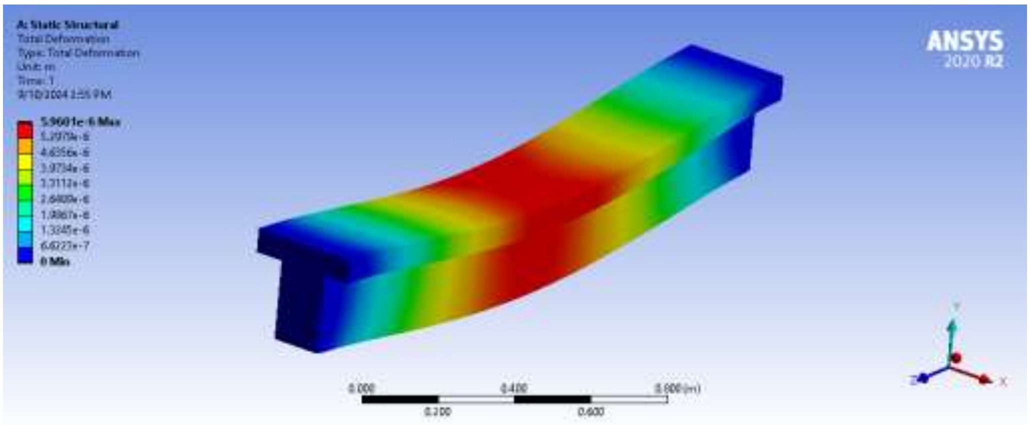

Figure 4. *Total deformation of the validation case study*

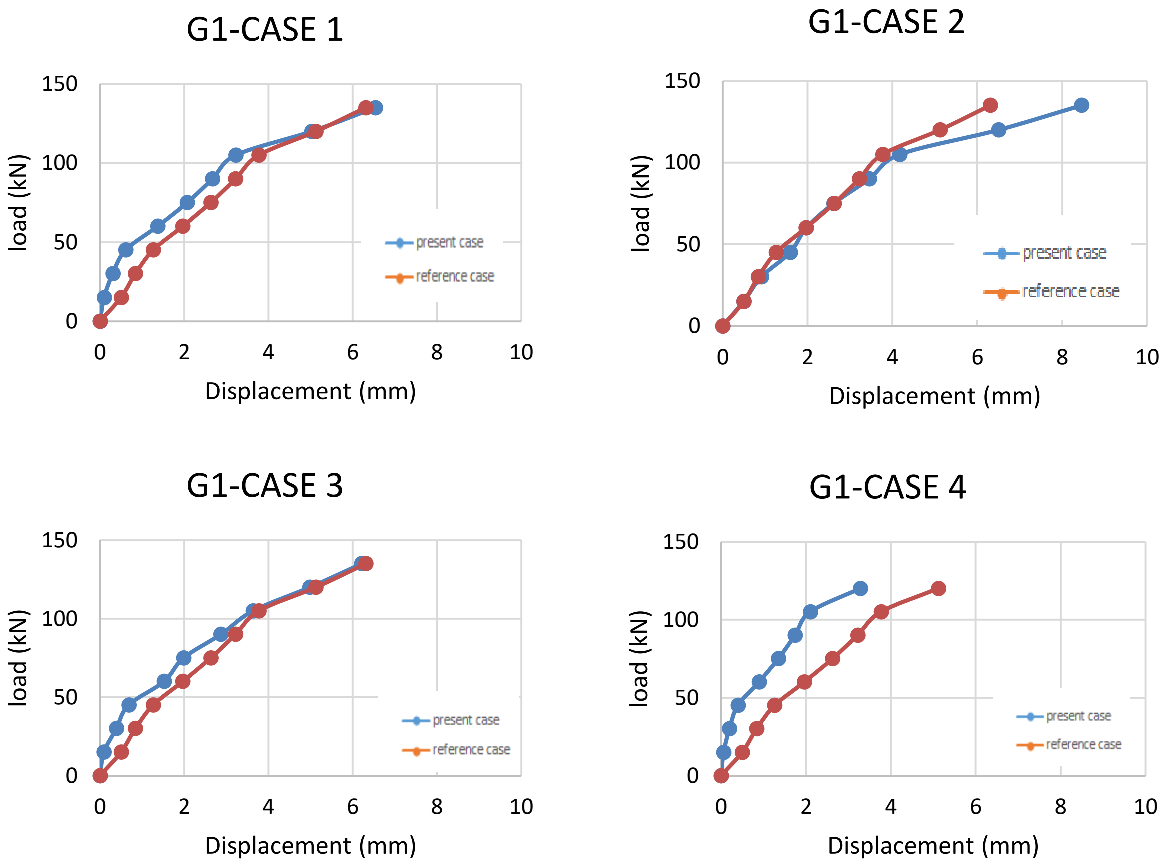

Figure 5. *G1-CASE 1 to G1-CASE 4 results*

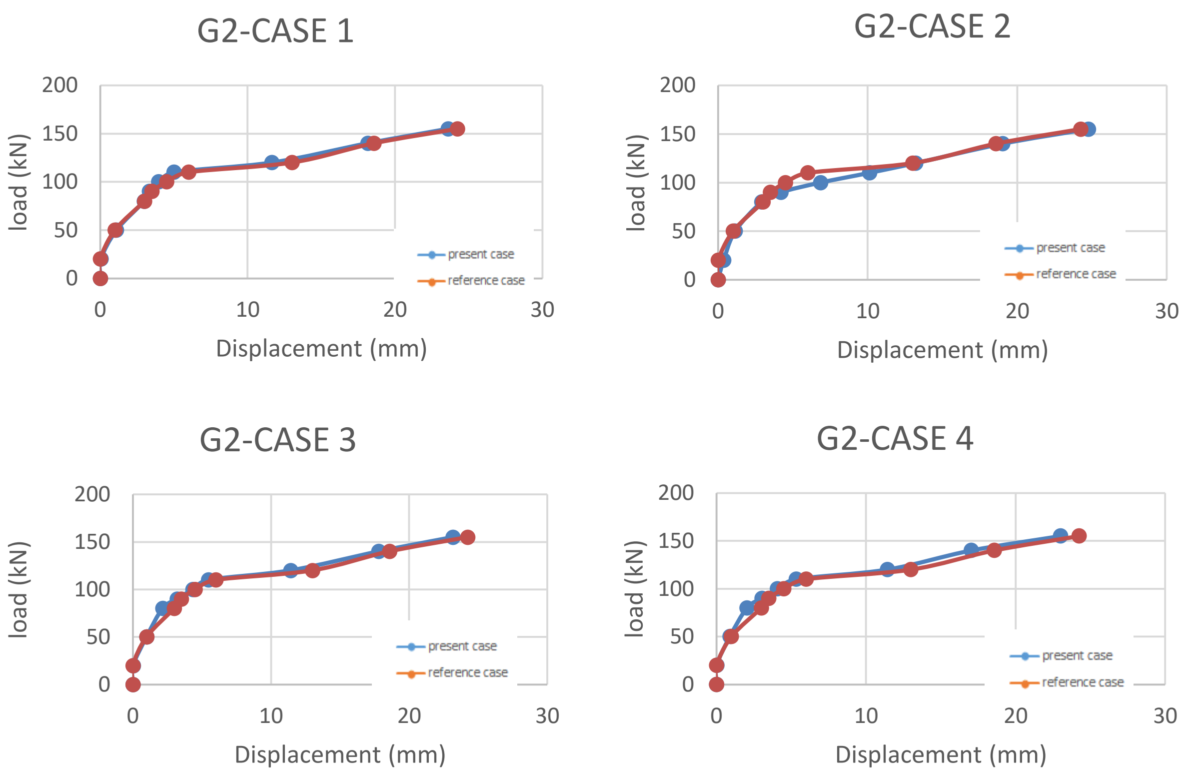

Figure 6. *G2-CASE 1 to G2-CASE 4 results*

Table 2. *The Error percentage of the validation step*

Load (kN)	Al Shami 2022	Present Study	Error %
15	0.482	0.501	4%
30	0.814	0.839	3%
45	1.252	1.263	1%
60	1.913	1.963	3%
75	2.532	2.628	4%
90	3.121	3.218	3%
105	3.671	3.769	3%
120	5.103	5.120	0%
135	6.062	6.304	4%

4. Conclusions

The sectional characteristics are significantly influenced by the flange width and beam depth. The moment of inertia for an I-section is directly proportional to the cube of its depth, significantly affecting the structure's serviceability. Tee beams have gained popularity in several construction projects recently. Tee beams offer enhanced vertical bending rigidity, reduced maintenance costs, and aesthetic appeal due to their greater section depth. As previously stated, while analyzing tee beams, we augment the depth of the section to a certain limit while accounting for beam shear. Additionally, concerning the width of the flange. The outcomes of the tests and analysis conducted for this inquiry allow for the following conclusion to be drawn. The aggregate moment of inertia of the tee beam section, as illustrated in the specification documents. When assessing the flexural strength of a tee beam, it is essential to consider its sectional properties. The summary results of case studies were:
G1-CASE 1: maximum deflection was 6.534 mm
G1-CASE 2: maximum deflection was 8.454 mm
G1-CASE 3: maximum deflection was 6.211 mm
G1-CASE 4: maximum deflection was 3.280 mm
G2-CASE 1: maximum deflection was 23.615 mm
G2-CASE 2: maximum deflection was 24.748 mm
G2-CASE 3: maximum deflection was 23.155 mm
G2-CASE 4: maximum deflection was 23.001 mm
The result of G1-CASE 4 presents perforated beams with deeper size surpassed all other typical beam kinds. This result supported by the results of second group with observed G2-CASE 4 as the best case due to beam depth. For future works, the researcher recommends to enhance the G1-CASE 4 type of tee beam which presents perforated beams with deeper and broader flanges mix with nano glass materials.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.

- **Author contributions:** The authors declare that they have equal right on this paper.

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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