



REPUBLIC OF TURKEY
ALTINBAS UNIVERSITY
Institute of Graduate Studies
Civil Engineering

**SIMULATING AND MODELING THE STRENGTHEN
BEHAVIOR OF REINFORCED CONCRETE T- SECTION
BEAM**

Kadhim ALTAMEEMI

Master's Thesis

Supervisor

Prof. Dr. Tuncer ÇELİK

Istanbul, 2022

SIMULATING AND MODELING THE STRENGTHEN BEHAVIOR OF REINFORCED CONCRETE T- SECTION BEAM



Kadhim ALTAMEEMI

Civil Engineering

Master's Thesis

ALTINBAŞ UNIVERSITY

2022

The thesis titled “SIMULATING AND MODELING THE STRENGTHEN BEHAVIOR OF REINFORCED CONCRETE T- SECTION BEAM” prepared by KADHIM ALTAMEEMI and submitted on 06/12/2022 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

Prof. Dr. Tuncer ÇELİK

Supervisor

Thesis Defense Committee Members:

Prof.Dr. Tuncer ÇELİK

Department of Engineering and
Architecture,

Altınbaş University

Asst. Prof. Dr. Mohsen SEYEDİ

Department of Engineering and
Architecture,

Altınbaş University

Prof. Dr. Barış GÜNEŞ

Department of Civil Engineering,

Istanbul University- Cerrahpasa

I hereby declare that this thesis meets all format and submission requirements of a Master's thesis.

Submission date of the thesis to the Graduate Education Institute: ____/____/____

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Kadhim ALTAMEEMI

Signature

ABSTRACT

SIMULATING AND MODELING THE STRENGTHEN BEHAVIOR OF REINFORCED CONCRETE T- SECTION BEAM

Altameemi, Kadhim ,

M.Sc., Civil Engineering, Altınbaş University,

Supervisor: Prof. Dr. Tuncer ÇELİK

Date: December/2022

Pages: 62

The structural workability of T-section members are important key solution to increase the capability of the section to handle the compression stresses in which the flange in the section and the web part can play together considerable role in the increasing of the section internal strength. The study started in its analytical routine by structural analysis for the T-section that used to face high magnitude of external loading starting from 50 kN/m. the study set the needed equation that used to identify the internal strength of the member including the geometry of the section. The study then move the analysis into deriving new equations that collected in them the parameters of the structural performance of the member. The linking of the ultimate needed moment in the equation gave important looking to design acceptance and the strength of the member. The derived equation give the residual term (R) in which its magnitude must be more than one for better design conditions. The study made many number of relationships for each parameter in the T-section (including depth of flange, width of flange, effective depth of member, reinforcement, and width of web). The study processed the relationships by applying curve fitting techniques into the dots of a specific figure to reach the applicable equation that used to give the magnitude of the residual in which the design concepts been satisfied the needed purpose. Collection of the curve fitting equation toward building more simple form of equation that included the main parameters was made to improve the T-Section design concepts. The equation can be used to investigate the minimum magnitude for each parameter to be assigned in the design. The

simulation of the T-section cases was made using ANSYS program. The simulation results was made for tow dimensional cases and the results were showed in 3d images.

Keywords: T- Section Beam, Reinforced Concrete, Simulation



TABLE OF CONTENTS

	<u>Pages</u>
ABSTRACT.....	v
LIST OF TABLES	ix
LIST OF FIGURES	x
ABBREVIATIONS.....	xii
LIST OF SYMBOLS	xiii
1. INTRODUCTION	1
1.1 OVERVIEW.....	1
1.2 T- SECTION BEAM.....	1
1.3 FLEXURAL STRENGTH CONCRETE	3
1.3.1 Flexural Mechanism	3
1.3.2 Tensile Strength of Concrete.....	3
1.4 PROBLEM STATEMENT	4
1.5 CONTRIBUTION	4
1.6 OBJECTIVE.....	4
2. LITERATURE REVIEW	5
2.1 T-BEAM IN THEORETICAL CONCEPTS	5
2.2 STRESSES IN BEAMS	7
2.3 T-BEAM IN BRIDGES	7
2.3.1 T-Beam Girder Bridge.....	9
2.3.2 Box Girder Bridge.....	9
2.4 BENEFITS OF USING T-BEAM	9
2.5 CONSIDERATION IN CONSTRUCTION OF T-SECTIONS	11
2.6 CURRENT WORK.....	11
2.7 LITERATURE SURVEY	11

3. METHODOLOGY	17
3.1 ANALYSIS OF TEE REINFORCED CONCRETE BEAM.....	17
3.2 CONSIDERATION OF STRESSES DISTRIBUTION IN T-BEAM.....	19
3.3: ANALYSIS THEORY	19
3.4 ANSYS GEOMETRICAL AND STRUCTURAL PREPARATION.....	22
4. RESULTS	26
4.1 CALCULATION AND ANALYSIS	26
4.2 ANSYS WORK.....	43
5. DISCUSSION AND CONCLUSIONS	47
5.1 CONCLUSIONS	47
5.2 FUTURE WORK	48
REFERENCES.....	49

LIST OF TABLES

	<u>Pages</u>
Table 3.1: Properties of Reinforcement And Concrete In ANSYS	22
Table 4.1: The Impact of b on the residual strength when $W=100 \text{ kN/m}$ $d = 610$ $h_f=125$ $b_w=250\text{mm}$	26
Table 4.2: The Impact of H_f on the Residual Strength When $W=100 \text{ kN/m}$	28
Table 4.3: The Impact of H_f On The Residual Strength When $W=100 \text{ kN/m}$	30
Table 4.4: The Impact of b_w on The Residual Strength When $W=100 \text{ kN/m}$	32
Table 4.5: The Impact of d On The Residual Strength When $W=100 \text{ kN/m}$	34
Table 4.6: Collection of the Fitting Equations and the Relative Differences	36
Table 4.7: Collection Of The Fitting Equations And The Relative Differences	36
Table 4.8: The Values of R from the Derived and the Structural Equations	37
Table 4.9: Collection of the Fitting Equations and the Relative Differences	39
Table 4.10: The Values of R from the derived and the structural equations	39
Table 4.11: The Values of R from the Derived and the Structural Equations	40
Table 4.12: The Values of R from the Derived and the Structural Equations	42

LIST OF FIGURES

	<u>Pages</u>
Figure 2.1: T-Section in Concrete members [53]	6
Figure 2.2: Components of T-beam Bridge [33]	9
Figure 2.3: T-beam in Slabs [35]	10
Figure 3.1: Explanation of T-Section Flange And Web [50].....	17
Figure 3.2: T-Section Appearance In Rc Slabs [51]	18
Figure 3.3: The Behavior Of Stresses In Flange, Web, And The Deformation Of T-Section Members [52].....	18
Figure 3.4: T-Section Geometrical Design Parameters [52].....	19
Figure 3.5: The Geometrical Building Of The T-Section Member In ANSYS drawing panel	23
Figure 3.6: The Case 1 Section Of The T-Section Member In Ansys Drawing Panel	23
Figure 3.7: The Case 2 Section Of The T-Section Member In ANSYS drawing panel	24
Figure 3.8: The Preparation For The Whole Member For Processing In ANSYS model panel ..	24
Figure 3.9: The Set Of Mesh For The Whole Member In ANSYS model panel	25
Figure 3.10: The Set of The Uniform Loading On The Upper Area Of The Member In ANSYS Model Panel	25
Figure 4.1: The Relationship of B And The Residual Strength When $W=100$ kN/m	27
Figure 4.2: The Fitting Equation Of B And The Residual Strength When $W=100$ kN/m	27
Figure 4.3: The Relationship of h_f And The Residual Strength When $W=100$ kN/m	29
Figure 4.4: The Fitting Equation of h_f And The Residual Strength When $W=100$ kN/m.....	29
Figure 4.5: The Relationship Of A_s and the Residual Strength When $W=100$ kN/m.....	31
Figure 4.6: The Fitting Equation of h_f And The Residual Strength When $W=100$ kN/m.....	31

Figure 4.7: The Relationship of b_w And The Residual Strength When $W=100$ kN/m	33
Figure 4.8: The Fitting Equation of b_w And The Residual Strength When $W=100$ kN/m	33
Figure 4.9: The Relationship of d and the Residual Strength When $W=100$ kN/m	35
Figure 4.10: The Fitting Equation of d And The Residual Strength When $W=100$ kN/m	35
Figure 4.11: The Relationship of Derived R and the Factor F When $W=100$ kN/m	38
Figure 4.12: The Curve Fitting Of Derived R And The Factor F When $W=100$ kN/m	38
Figure 4.13: The Relationship of the Uniform Loading W And The Correlation Factor F	41
Figure 4.14: The Relationship Of The Uniform Loading W And The Factor F	42
Figure 4.15: Normal Stresses Of T-Section $h_f = 125$ mm, $b = 500$ mm and $W = 50$ kN/m	44
Figure 4.16: Normal Stresses of T-section $h_f = 125$ mm, $b = 500$ mm and $W = 100$ kN/m	44
Figure 4.17: Normal Stresses of T-section $h_f = 125$ mm, $b = 500$ mm and $W = 200$ kN/m	45
Figure 4.18: Normal Stresses of T-section $h_f = 200$ mm, $b = 7500$ mm and $W = 100$ kN/m	45
Figure 4.19: Normal Stresses of T-section $h_f = 200$ mm, $b = 7500$ mm and $W = 200$ kN/m	46

ABBREVIATIONS

f'_c : Compressive Strength of Concrete

A_s : Area of Steel

I : Moment of Inertia

b_w : Width of Web



LIST OF SYMBOLS

T: Tension

C: Compression

d: Depth of beam

h: Height of beam

b: Width of beam

L: Length of beam

M: Moment

1. INTRODUCTION

1.1 OVERVIEW

Beam is the horizontal part in a Framed Structure that carries loading from the slab to the columns that support the beam at its ends. If the structure is made of Reinforced Cement Concrete, it is referred to as an RCC beam. RCC (Reinforced Cement Concrete) building is a concrete structure reinforced with metal deformed bars running the length of the member. The steel embedded inside the member strengthens the structure. Cement is a strong shear material capable of withstanding massive compression, but its inability to survive tensile loads makes it an unsuitable building material. As a result, the body of cementation materials needs significant reinforcement, which is obtained by incorporating additional troops in the form of malformed steel bars, which aid concrete withstand both compression and tensile applied stresses, making a more useful building material. Beams come in a variety of cross-sectional forms. When compared to other shapes, each cross-sectional shape provides higher advantages in a specific condition. element cross-sectional shapes include square, rectangular, circular, I-shaped, T-shaped, H-shaped, C-shaped, and tubular [1]. Rectangular beam is sort of element has been widely used in the construction of reinforced concrete bodies in buildings as well as in non-structural applications [2].

1.2 T- SECTION BEAM

This type of piece is often built monolithically with a reinforced concrete slab. Isolated T-beam is sometimes used to boost the compression strength of concrete [3]. Steel and concrete floors, roofs, decks, and other structures are almost always monolithic. Forms are built for element soffits, and sides and for the underside of the slab are cast all at once, in the way from the bottom in which of the deepest element to the above level of slab. Beams stirrups and bent bars extend upwards towards the slab; thus, a slab element will work in conjunction with the top which of the beam to resist latitudinal compression. The resulting element is a T-shaped beam instead of a rectangular beam; the slab serves as the beam's flanges, and the element extending downwards from the slab is known as the web or stem [4]. First and foremost, it performs better in joining because it has a greater Second moment of inertia. As the T-beam is cast monolithically with the slab, the compressive loading on the slab is shared with the help of the flange in which of the T-

beam, which increases the moment of resistance. In the same way, this lowers the need for additional compression reinforcement at the top. Rectangular beams are only strengthened singly. Rectangular beams must be reinforced twice in practice. T-beams, on the other hand, do not have to [5]. The flange is more effective at joining and providing ductility. In shear, the web is more effective. If you look at the stress distribution diagram of a T-beam, the bending shear is lower for each cross-section than in rectangular beams, where the two add together [6]. Because of the preceding two arguments, deflection is significantly minimized in the case of T-beams. Furthermore, that the concrete below the neutral axis contributes little to element strength because it is in stress. Why not remove it if it is aggregative. In the future, the action of the moment of resistance will be comparable to that of a rectangular element and a T-beam with a close to appropriate depth. As a result, T-beams are always more cost-effective than rectangular beams. In reality, it is the least expensive in the center of the usual element shapes, with the exception of box girders, which have been tested in bridge decks [7].

T-beams have a lower concrete volume. They also reduce the floor-to-floor height because the flange is already a part of the slab. These two factors, when combined, considerably reduce the amount of concrete required for construction, lowering overall costs and dead weight. Beam tension and compression. A simple analyzed beam has more than one vertical support in the form of a column and is fastened at both ends[8]. Due to the bending action of the moment, the bottom portion of the beam is pulled aside, causing tension in the bottom portion, which is known as the tension Zone Of The Beam, and the upper portion of the element is compressed and pulled inside, causing compression in the upper portion of the beam, which is known as the compression Zone Of The Beam [9]. T- beam bridges are made up of cast-in-place, reinforced concrete beams with integral deck portions on either side of the beam tops. The beams are deeper in cross section than their deck sections, resulting in the T-shape that lends them their names. The main reinforcing steel is positioned longitudinally in the bottom of the beam to withstand tension (the forces that would pull the beam apart). The deck that forms the upper level component of the T-shape is compressed (forces that squeeze or push it together). Because concrete resists compression, it is concentrated on the deck coupled with less substantial reinforcing steel spread throughout the breadth of the bridge [10]. Thanks to an aid of engineers, the progress of the tee girder type inside the early 20th century represented a better understanding of the tension and compression stresses associated with steel and concrete bridges.

The bridges were strong because reinforcing concrete and steel were strategically placed, and they were inexpensive because no elements have been wasted[11].

1.3 FLEXURAL STRENGTH CONCRETE

Flexural strength is a single metric of tensile strength in concrete. It is a measure of the ability of an unreinforced concrete beam or slab to withstand bending failure. Designers employ a flexural approach. The rupture modulus is also defined as the highest stresses applied by a fiber whenever a part is bent. The modulus of rupture, also known as the strength of concrete, is an oblique material's ability of unreinforced concrete. Bending moment, corrosion of the any metal, shrinkage, and temperature can all cause tensile stresses in addition to external load capacity. Unlike compression, tensile strength of a member cannot be determined in its natural state because no apparatus or specimen modeling has been improved to equally distribute the tensile load to the member. The indirect measurement of flexural strength, such as the One-point forces action test and the Two-point loading test, yields satisfactory results [12].

1.3.1 Flexural Mechanism

The modulus of rupture is the measure of severe fiber stresses in a member inside a flexure when the beam can be loaded using either one-point loading or symmetrical two-point loading. When an easily supported beam is bent, tensile stresses build at the bottom of the beam, and when the tensile applied stresses surpass the flexural strength of the beam, fractures begin to form at the point of greatest bending moment. The load that caused the fracture and the pattern of the crack can be utilized to calculate the flexural strength of a specific concrete member [13].

1.3.2 Tensile Strength of Concrete

The maximum amount of tensile stress is simply the amount of force necessary to pull something to the point where it breaks. In layman's terms, the tensile strength of a material is the greatest tension that it can withstand without breaking. Concrete has microscopic fissures in its body because it is made of 'small' stones. When compression pressures are given to concrete, these minute fissures do not pose any problems, but when tensile stresses are applied, those same microscopic flaws become elongated. This process repeats itself for as long as tensile pressures are applied to the concrete before it finally breaks apart. Furthermore, concrete is particularly

vulnerable to shear force (the force that causes deformation in a material) and has low elasticity. This means it lacks the ability to absorb stresses by momentarily stretching or compressing like a rubber band or spring does [14].

1.4 PROBLEM STATEMENT

The using of t-section beams can be adopted in critical places as it can carry the bridge span and other heavy loading. The unsuitable design of these members can lead to weaken the overall construction and not handle the applying loads with sufficient strength. As the advantage of t-section used by the compressive strength of flange, identifying the proper geometrical design is main thing for these members to work in better conditions.

1.5 CONTRIBUTION

The study various dimensions of t-section beam to identify its ability to resist the applying loads. The conditions of member strength with respect to internal and external properties were taken by the study to give better figure about the workability and validity of using t-section beams in different construction projects. The study aimed figure out the validity using of more cross section size in the flange area to the matter of improving the compression strength.

1.6 OBJECTIVE

- a) Step 1: Assigning the required parameters in which for design the t-section elements by identifying the relationship of the dimensions, the loading cases, the reinforcement, the concrete and steel properties and any other detective parameters in the way of the calculated strength of beams by using the ultimate stress design method.
- b) Step 2: Building effective formulas base on the design method to bond the parameters then conveying these data to statistical analysis using SPSS program.
- c) Step 3: Explaining the statistical analysis results into useful tables and charts then collecting these results by driving mathematical model.
- d) Step 4: Using the built in finite element analysis in ANSYS program to simulate the study cases and showing the results in colored graphs.

2. LITERATURE REVIEW

2.1 T-BEAM IN THEORETICAL CONCEPTS

The shape of the structure of the RCC components is highly dependent on the nature of the surrounding environment as well as on the forces and all kinds of boundary conditions that are applied to the structure. The load element which is responsible for the length of the RCC i.e. it includes all its components is considered as a complete bending moment in a fixed direction. As a result, the process of fixing the tension aspect of all components. In addition, both ends of the clips transfer moments easily and flexibly to the other part of the frame. With regard to the design component which is universal, it enables the removal of the body which is lateral and which is primarily tensioned to concrete[15]. An essential requirement for the purpose of reinforcing all aspects of tension is the provision of protection as well as support. It is necessary to provide all kinds of reinforcements all in one place and it is also necessary to provide a minimum amount of concrete mesh. In addition, the process of determining the thickness of the web can be done by measuring the spacing between the reinforcements, as well as determining the amount of torsion and all kinds of effects. This means not only the tension present in the concrete, but also the compressive aspect of the whole concrete body which is close to the axis that is neutral, the compressive stress is low, which can be removed easily. The thickness of the compression flange that is above the torsion area and is not considered as local effects should be determined [16]. Figure 1 showed the t-section with the flange width (bf), the flange depth (hf), the web width (bw) , and the member height (h).

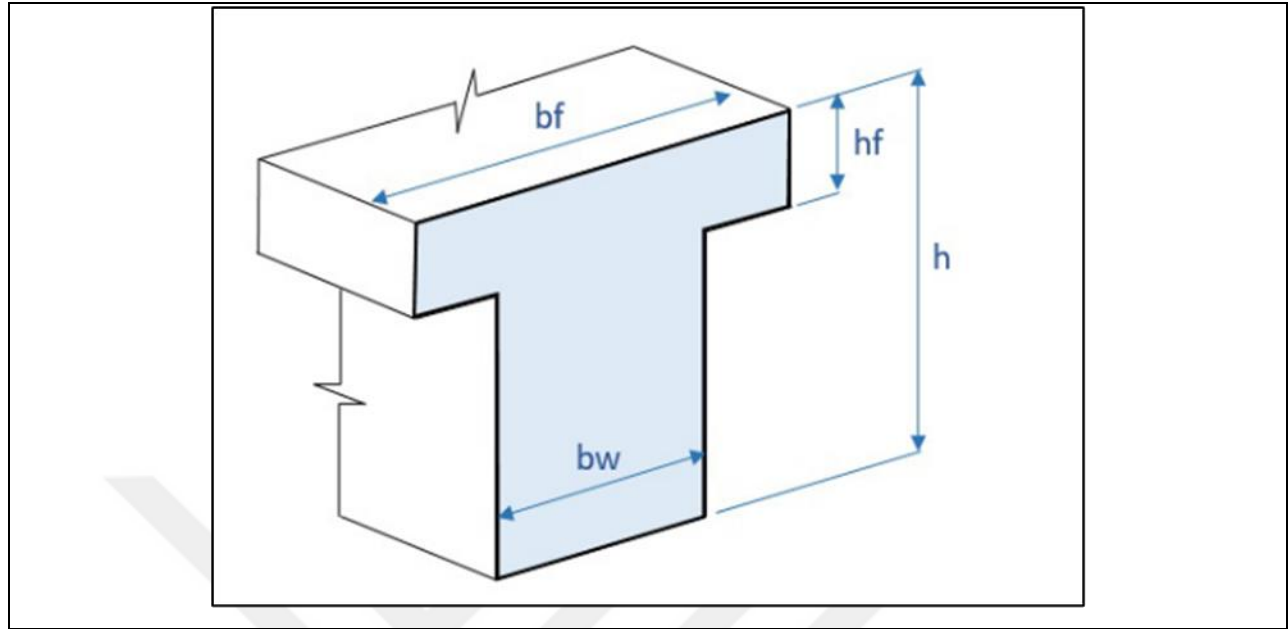


Figure 2.1: T-Section in Concrete members [53]

The depth of the web will be infinitely extended, just as the distance between the centers of tension and compression becomes infinite to obtain infinite moment resistance. However, buckling and various local impacts in which of web will define the depth of the web in the future. Reinforcement will not be employed on the compression side, which will minimize the component's cost in the future, unless minimum reinforcement is given for in not as local impacts [17]. In most practical scenarios, bending points are treated in the same way for determining RCC components: It will be extremely rare in the future for one component to dominate the entire length, accompanied only by bending moments. Bending may cause it to reverse direction. Other forces, such as axial and shear forces, will always act in addition to the bending moment. As a result, the T-section beam's will be compression flanged over with its reinforcement features [18]. In the case of pre-stress type of concrete member, the depth of the web will be determined by system requirements. For very large cross sections, pre-stress or post-stress are both thought to increase material utilization. The beam, or flexural member, is a common structural and mechanical component, and its basic force analysis is one of the most fascinating aspects of material mechanics. A beam is a member that bends as a result of weights applied transverse to its long dimension. A simply-supported element, for example, loaded at its weak points will deform into the exaggerated bending shape [19].

Before delving deeper into the force analysis of elements, it is useful to categorize some of the main types of beams and loadings encountered in practice. Beams are commonly classed based on the presence or absence of supports or responses. A simple beam is an element that is supported at both ends by pins, rollers, or flat surfaces. A basic support will generate a reaction normal to the beam, but will not provide a moment for the reaction. If one or more ends of a beam extend beyond the supports, it is referred to as a simple beam with overhang [20]. The built-in end is said to be fixed if no rotation occurs and constrained if only a small amount of rotation occurs. The supports represent a cantilever beam, an element fixed (or restrained) at one end and freely supported near the other end (which has an overhang), and an element fixed (or restrained) at both ends. Cantilever beams and simple beams have two reactions (two forces or one force and a couple), and these reactions can be determined by applying equilibrium equations to a free-body diagram of the element. Such beams are said to be statically determinate since the reactions may be determined from the equations of equilibrium. Continuous and other beams with just transverse loads and more than two reaction sections are referred to as statically indeterminate since there are insufficient equations of balance to determine the reactions [21].

2.2 STRESSES IN BEAMS

The axial stress but also shear stress (vertical and horizontal) that arise in a loaded beam are determined by the orders of magnitude of flexure and shear in the beam. Deciding the axial force, also recognized as beam tensile moment, and shear stress, also known as horizontal shear stress, are both crucial. For starters, it will enable the designer to assess whether a particular package is a secure load under the specified load. Second, it will enable the designer to select the best package for a load. Are both critical efforts to ensure the product's safety and efficiency. Couples of forces (flexural stresses) and shearing stresses on each cross section of the beam are caused by action on the element, as is deflection perpendicular to the longitudinal axis of the beam. Bending is caused by transverse loading, and joining is a highly severe way of stressing a structure. On one side, the bent beam is stretched, while on the other, it is compressed [22].

2.3 T-BEAM IN BRIDGES

a) Superstructure or Decking: This includes slabs, girders, and trusses, among other things. This carries the load that passes above it and transmits the forces generated by the load to adequate to the substructures [23].

- b) Bearings: Bearings convey the loading from the decking to the substructure and are given to distribute the load uniformly above the substructure that may not have sufficient bearing strength to handle the superstructure load directly [24].
- c) Piers and Abutments: These are vertical structures that support the deck/bearings and convey the load down to the bed/earth inside the foundation [25].
- d) Wing walls and Returns: These are built as extensions of the abutments to hold the ground in which the approach bank partakes [26].
- e) v. Foundation: It should be just enough to avoid being affected by the cleanliness caused by the flow of the Colorado River. A foundation shall be provided for equitably transferring and dividing the loading from berths as well as abutments and wings or back to the tier [27].

T-girder bridges had also cast-in-place steel and concrete support beams with incorporated deck parts on each side of the steel beam tops. The beams' cross-sections are deeper than sections of their exterior, likely to result in the T-shape that gives them their name. To resist tension, the primary armature is placed longitudinally just at bottom of the support beam (the forces that can separate the girder). The top element of the T-surface shapes is condensed. Even though concrete resists constraint, it is placed in the center of the board, with a few large rebar girders finished installing across the structure's width[28]. The early twentieth-century development of the t-element type reflects better knowledge of shear and tension powers within steel and concrete bridges by designers. The tee girders were poured as a single unit, regardless of how many parallel beams were required to form the bridge. They are typically tested over distances ranging from 25 to 60 feet, though many spans allow again for construction of lengthy bridges. T-beam in bridges are usually long-lasting because the strengthening framework and cement are placed where they're most needed, and they are cheap because no material is wasted[29]. Bridges are structures that provide a passage across a pit without closing the route beneath. They may be required for a passage in which of railway, roadway, footpath, and even conveyance of fluid, bridge site might be chosen in such a way that it provides maximum economic and social benefits, affectivity, effectiveness, and equality. Bridges are the lifelines and backbones of a nation in times of war. Bridges represent humanity's hopes and aspirations. They shorten distances, speed up transportation, and make business easier. Bridge construction is an important

component of communication and an important indicator of civilization's progress. Bridges serve as memorials to the work of civil engineers [30].

2.3.1 T-Beam Girder Bridge

A load-bearing structure made of reinforced concrete, wood, and metal with a t-shaped cross section. In resisting compressive loads, the top of the t-shape cross section functions as a flange or compression member. The web of the beam below the compression flange resists shear loads [31].

2.3.2 Box Girder Bridge

The primary beams of this type of connection are made up of hollow box-shaped girders. The cross - sectional area of a carton is typically triangular as well as trapezoidal. These bridges are commonly used for major highway flyovers as well as conventionally increased buildings throughout light rail transport[32].

General behavior of t-beam components was showed in figure 2:

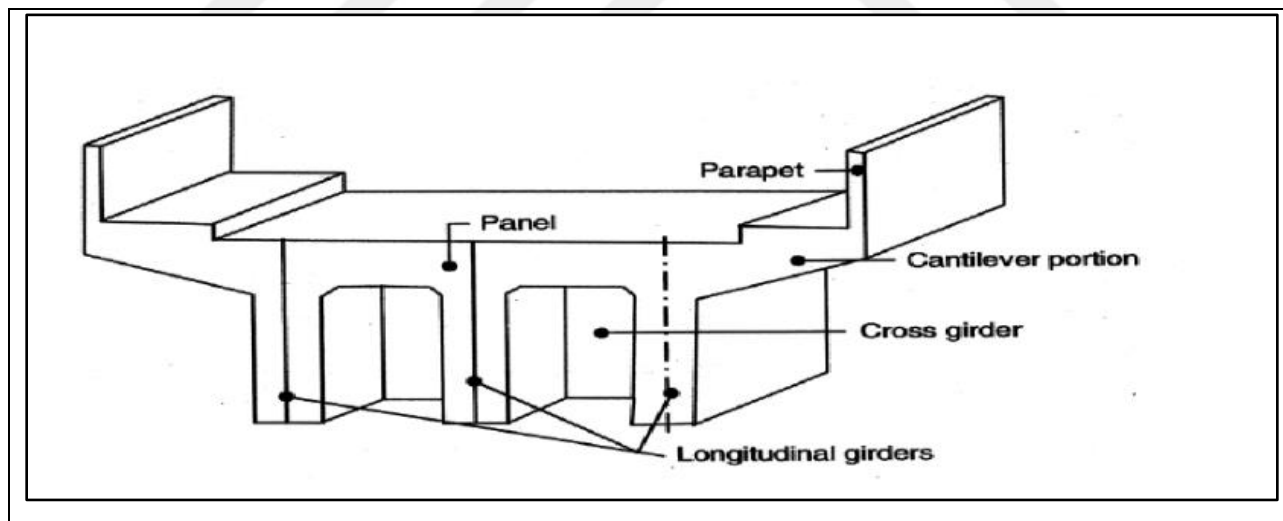


Figure 2.2: Components of T-beam Bridge [33]

2.4 BENEFITS OF USING T-BEAM

First and foremost, it performs better in joining because it has a greater moment of inertia. Because the T-beam is cast monolithically with the slab, the compressive loading on the slab is shared with the help of the flange in which of the T-beam, which increases the moment of

resistance. In the same way, further compression reinforcement at the top is reduced. In our textbooks, rectangular beams are only strengthened singly. Rectangular beams must be reinforced twice in practice. T-beams, on the other hand, do not have to [34]. Figure 3 explained the role of t-beam in slabs.

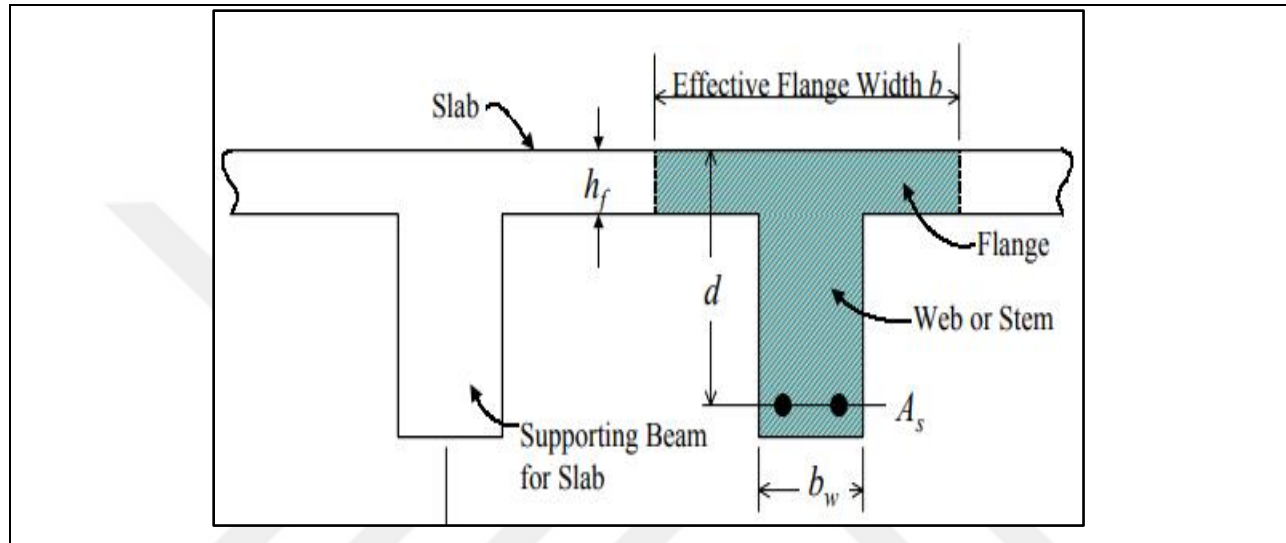


Figure 2.3: T-beam in Slabs [35]

The flange is more effective in joining and providing ductility. In shear, the web is more effective. If you look at the stress distribution diagram of a T-beam, you'll notice that the bending force is spread more in the flange and the shear force is distributed more on the web. As a result, the resulting bending shear is lower for any cross-section than for rectangular parts, where multiple add up [36]. Deflection is greatly minimized in the case of T-beams due to the aforesaid many sites. Furthermore, we know that the body of concrete below the actual axis contributes little to beam strength because it is in stress. So why not get rid of it? The moment of strength for a rectangular beam and a T-beam of equal depth will be comparable. As a result, T-beams are typically more cost effective than rectangular beams. Except for box girders used in link decks, it is the least expensive of the popular beam shapes. T-beams have a lower volume than concrete. They also minimize the ground to ground height because the flange is already a part of the slab. These two elements, when combined, significantly reduce the body of concrete necessary for the building, lowering both cost and dead weight [37].

2.5 CONSIDERATION IN CONSTRUCTION OF T-SECTIONS

If the flange is very wide in a T-section, the compressive applied stresses are at their maximum for the places adjacent to the beam and fall approximately in a parabolic shape to virtually 0 at a distance x from the face of the beam. Stresses change vertically in the same way, from a maximum at the flange's top fibers to a minimum at the flange's tiny fibers. This variation is determined by the position of the neutral axis and the transition of the flange from elastic to inelastic deformation along its vertical axis. An equivalent stress area can be thought of as the stress distribution above the flange width (b), resulting in an equivalent flange width (b_e) of uniform stress. Depending on the proportions of the cross section, the magnitude of tensile steel, and the resistance of the materials, the neutral axis of a T beam may be in the flange or in the web [38]. If the predicted depth to the neutral axis is less than or equal to the flange thickness h_f , the element can be considered as a rectangular beam with a width equal to the impressive flange width b_f . The preceding argument is no longer applicable when the neutral axis is in the web, as. Methods for accounting for the reliable T-shaped compressive zone must be established in this scenario [39][40].

2.6 CURRENT WORK

The study aimed to cover the matter of the design of T-section reinforced concrete beams and its useful role in buildings by using both statistical analysis and then simulating. The cases inside the study under specific loading were analyzed using SPSS program then arranging the data toward building effective model the improve and ease the design method progress for supporting the choosing of these type of section for better decision. The output of the study was explained in figures and tables and formulas. The simulation was implemented by using ANSYS workbench program in which based on finite element analysis.

2.7 LITERATURE SURVEY

The study worked on building a model for the final improvement of T-shaped reinforced concrete sections under bending stress. The modeling takings into version the nonlinear of behavior of concrete, along with the equivalent rectangle equation for solidity and non-tensile of the strength, and the elastic and plastic behavior of the steel. The greatest amount of bending motion for a moment considering only one case reinforcement is found in this work for T

section. The optimal area equations for reinforcement and localization are provided in the same way. These formulas are represented in terms of mechanical and the geometry properties, Advance a procedure that can be extended to sections that are not quite; Determining when the optimal design parameters for it can be put into computer code [41].

The study proposed a modified fiber-based modeling to handle numerical analysis over seismic phenomena in T-shaped CFST columns. The beneficial effect of stiffeners over the flexural strength of steel tube and on the strength and flexibility of concrete is explored for the first time in this hysteretic analysis of specially designed CFST columns. The numerical model is used to generate the hysteretic curves of samples with load and horizontal displacement, which are then accurately confirmed with test results in hardness, resistance, ductility, and power dissipation capacity. This summarized numerical model is able to predict the seismic behavior of specially formed CFST plumes with suitable accuracy. In numerical modeling, an alternative reversal result is presented to include an Euler-Bernoulli component in a longitudinal direction to consider the motion that is an inflection point in any column. An iterative control algorithm is used to simplify the arc length methods. This numerical modeling can be used to investigate over plumes with an asymmetric cross-section with good accuracy compared to previous assumptions in which the member is skewed in classical fibers - as the base of the model. The skeleton curve, load criterion and discharge criterion are proposed in the form of a recovery force model. The stiffness, resistance and displacement of any load path are regressed using experimental and numerical parametric data. The load and horizontal hysteretic displacement curves of the recovery force model correlate well with the experimental data. This simplified approach can be used to restore force modeling in engineering practice [42]. The study showed that (FRP) installed near the surface has gained great interest and field applications in recent years. While extensive research has been done on the behavior of NSM-FRP-enhanced rectangular section RC bundles and the effect of important parameters, there is a dearth of studies on T-section RC bundles. Moreover, the theoretical methods for predicting the bending strength of NSM-reinforced RC beams have not been experimentally verified. As a result, the present study explores the behavior of T-section RC beams reinforced with NSM FRP tapes under the influence of monotonic bending forces and compares the experimental results with the predictions of a first-principles-derived bending model. Ten RC T-section beam samples reinforced with NSM FRP bars were considered, in addition to three standard samples. The

samples were compared and examined for failure mode, crushing resistance, yield, final capacity, bending toughness, and ductility. Based on the experimental results, a general increase in bending stiffness was found for the reinforced samples, especially in the post-yield loading classes. Analytical predictions of bending strength were made and confirmed by experimental data. To account for changes in the effective area of the FRP tapes used in the sectional strength calculations, a tuning parameter of a bending stiffness prediction model has been proposed[43].

The study investigated the restoration of reinforced concrete beams using carbon fiber reinforced polymers (CFRP). Four-section T-section reinforced crushed concrete beams with many round holes were fixed by CFRP and screened inside pure torsion. Repair beams were tested for the effect of the amount of CFRP sheets on top of the beams on crushing and final torque behavior, torsion angle, and failure modes. The results of the proposed repair technique revealed that high-strength carbon fiber-reinforced plastic chips had a significant effect on restoring section stiffness with an efficiency of 85 percent, while effectively repairing the fracture torsional strength. Section at 82 percent - 80 percent of the crack torsional strength. Based on the results of pilot tests, the following steering results are found: (1) The recovery process restores 80 to 85 percent of the torsional strength. This means that the technology used has good torsional strength. (2) When using the same longitudinal and transverse reinforcements, the provision of opening in the beams reduces cracking and final torsional strength (3) The fractures begin at the support and run around the beams to the edge, so the size of the cracks increased in proportion to their presence [44]. The study analyzed the tensile test procedure for generating stress-strain curves used in finite element calculations. Which of the finite element calculations gave appropriate results? The numerical models were good enough to predict the load bearing capacity. The distorted appearance of the tested and estimated beam columns was similarly identical. Various modifications of Eurocode 9 have been investigated in an effort to improve output. When calculating the bending reduction parameters for a welded section, one improvement was to use the final strength of the heat-affected area instead of the yield strength of the original material. In the reaction formulas, the calculation of the bending action of the torque amplitude was also changed.. The modulus of the plastic section was used to calculate the amplitude of the joining moment at the end of the web that was under stress. When the bending moment operates in the opposite direction, the calculation of the bending moment capacity was based on the rating of the modified web element. According to the results of this thesis,

Eurocode 9 is also strict in the classification of cross-sections. The method by which the bending action of the instantaneous amplitude of asymmetric cross-sections is determined in the reaction formulas requires additional investigation.. The tensile failure at the web tip was also explored. The thesis shows that when it comes to asymmetric cross-sections, the symbols must be improved. There is some information provided on how to improve Eurocode 9 [45].

The study was about conducting an experimental work to verify the performance of HSC T-reinforced girders which have flange holes in the bending area. The study depicts the behavior of an RC beam with an aperture that has not been enhanced with further reinforcements. In this experimental investigation, three beams, one rectangular and one T-shaped element without a reference element hole, and the remaining beam with one rectangular flange with a 180360 mm hole were cast in the central part. These packages were put through one-point load tests. The effect of the flange orifice was examined in terms of ultimate failure load, maximum deflection, and failure mode. Based on the test results, it was possible to determine that the final load-bearing capacity of the T-shaped RC element with a flange opening in the bending area was reduced by approximately 2.30 percent[46].

The study addressed the challenge of estimating the appropriate flange width for bending T-sections of reinforced concrete. The study was carried out in the numerical condition in order to determine the effect of parameters larger than the value of the presentation. The analysis focused on multi-span reinforced concrete slabs harmoniously paired with two-span reinforced concrete beams. There were two types of material models used: elastic for concrete and plastic for reinforced concrete. The numerical case analysis performed here showed that the thickness of the slab interacting with the element has a significant effect on the width of the slab. In the case of thinner plates (in the examples examined, 12 and 8 cm), the effective edge can have a significant impact on the results. Failure to consider board thickness when choosing which effective widths to use may result in an overestimation of the load bearing capacity of the section. The magnitude of this overestimation is determined by the stress value and reinforcement level of the section [47].

The study had explored the web impeding capability of high-strength non-shaded CFS sections under End-Two-Flange (ETF) stresses work settings. Nonlinear finite element (FE) analysis was used to perform the numerical and visual simulations. The generated models were tested against existing experimental data before being used as a basis for a comprehensive parametric

investigation. The final parametric study impeding web capability was used to analyze the accuracy of the derivation equations available in the standards and those proposed in the relevant research. The evaluation showed that the current derivation equations are not suitable for estimating the maximum disrupted web capacity of high-strength CFS channel sections under the condition of ETF action. As a result, a modified design equation was introduced, using the same technique used to calculate the existing parameters, and a new approach to the direct force method (DSM) was developed[48]. The study showed that the shear design of reinforced concrete beams accompanied by a section only specifies the contribution of the web, which is mainly provided by the overall mesh. With increasing loading and formation of large mesh gaps, the overall interlock decreases and shear stresses tend to focus around the neutral axis, which is frequently located at the edges of the T-beams, where their contribution to shear resistance is negligible, as shown experimentally. Thus, the contribution of the flanges can lead to significant cost savings in new structures and can be critical when evaluating the shear capacity of existing structures. To estimate this contribution, the nonlinear 3D-FEA simulations were upgraded and calibrated, along with the results of shear tests performed over the RC T-beams with the authors' help. Once corrected, modeling was used to assess the shear response to beams with variable geometry and longitudinal reinforcement, as is common practice. It has been discovered that, up to a certain point, the contribution of the flanges to shear resistance increases when the amount of longitudinal reinforcement decreases, the width of the flange increases, and the thickness of the flange increases. According to a recent study, the maximum contribution of the flanges to the total shear strength is 31.3%. Furthermore, numerical modeling has been used to visualize and quantify properties that are difficult to obtain experimentally, such as the distribution of shear stresses between the web and the flanges. The latter study will help to establish an expression for the effective width of the shear flanges[39]. The study showed that when the precast beams are joined as a continuous structure, the longitudinal reinforcement in the flange edges is dispersed in a quasi-momentary region of contact, causing the longitudinal shear at the intersection of the web flange with the tension flange. The propagation phase of the reinforcement affects the amount of forces in the plane at the junction, which can cause the edges to crack and subsequently separate from the web.. Separation should be avoided by including the transverse reinforcement in the flanges. The longitudinal shear between the web and the flange, as well as the desired empirically and computationally required transverse reinforcement in cantilever

composite T-girders with the flange under tension, are investigated. Comparison of experimental and computational results showed that longitudinal shear distributions based on traditional element theory may not lead to safe side outcomes. Analyzes using a specially designed truss model and a modified stress site theory are in better agreement with the experimental data.



3. METHODOLOGY

3.1 ANALYSIS OF TEE REINFORCED CONCRETE BEAM

Reinforced concrete floors are almost always monolithic, with the exception of precast systems. Forms are built for beam soffits and sides, as well as slab undersides, and the complete structure is cast at after, from the bottom of beam that deepest to the region top of the slab. A reinforced concrete floor system is typically made up of monolithic slabs and beams. As a result, the two parts work in an integrated manner to be able to bear all loads. These bundles have additional widths located at their tops, which are known as the flanges, and these bundles that result in the shape of the letter T.

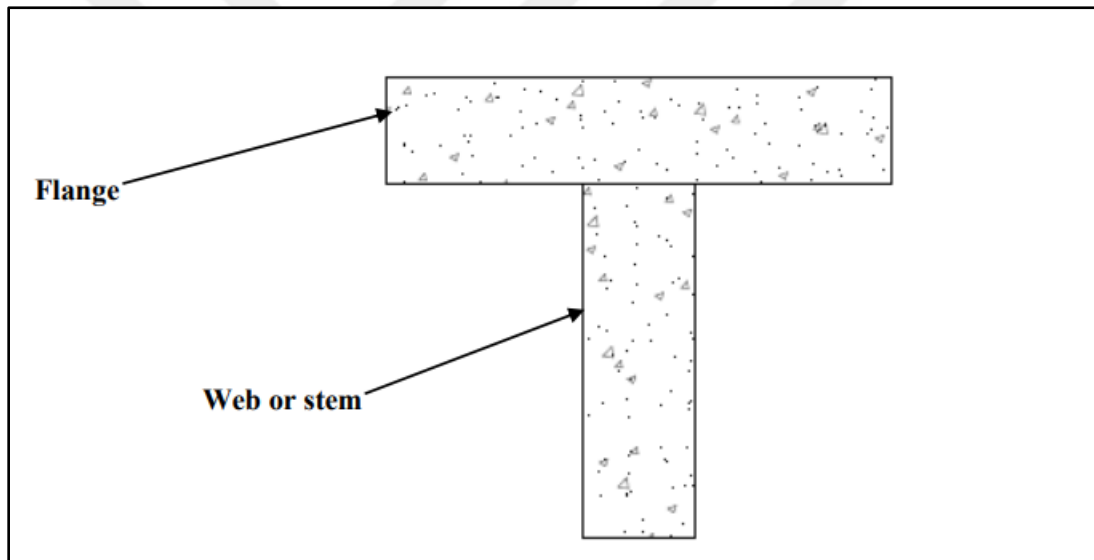


Figure 3.1: Explanation of T-Section Flange And Web [50]

The slab is assumed to transport the load to the supporting beam in the figure below; during building projects, the concrete inside the articles is sited and permitted to set previously the concrete in the ground is placed. Concrete is then sited inside the beams and the large piece in a uniform fashion in the following construction operation. As a result, as noted by the shading in the figure, the slab needs to serve as the column flange of the beams. This type of beam is known as a T-beam. Both sides of the inner beam, AB, are flanged.

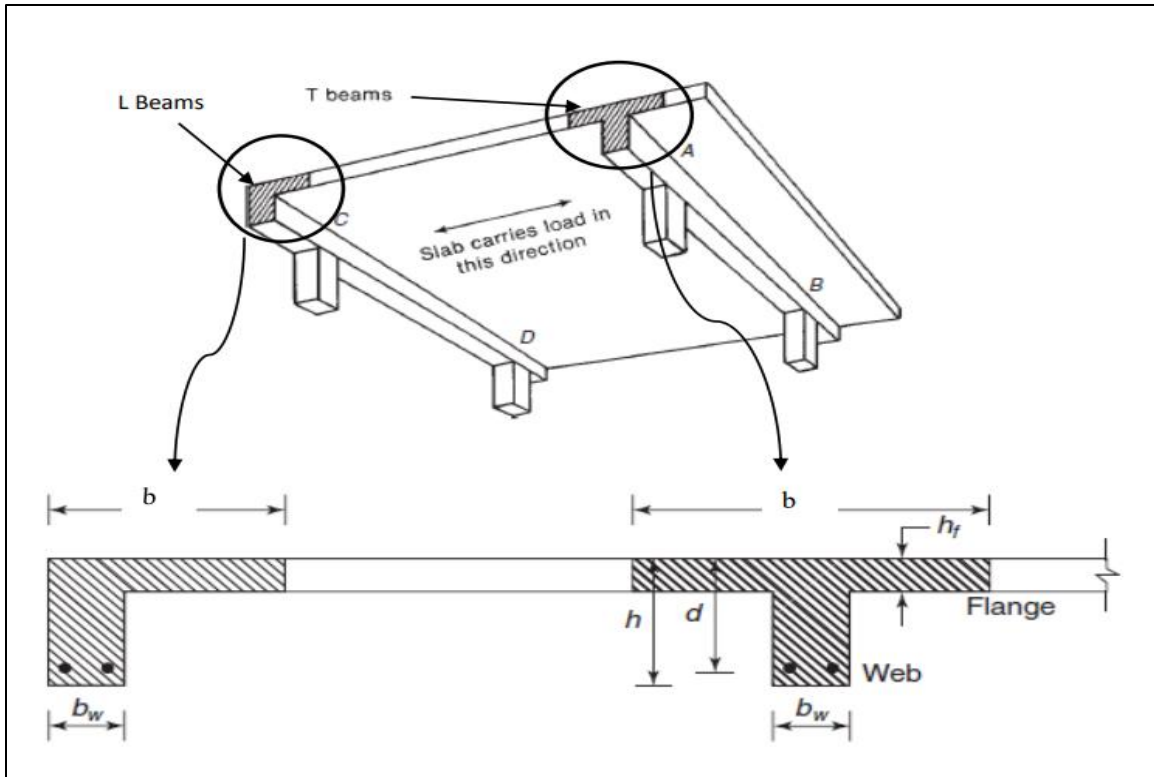


Figure 3.2: T-Section Appearance In Rc Slabs [51]

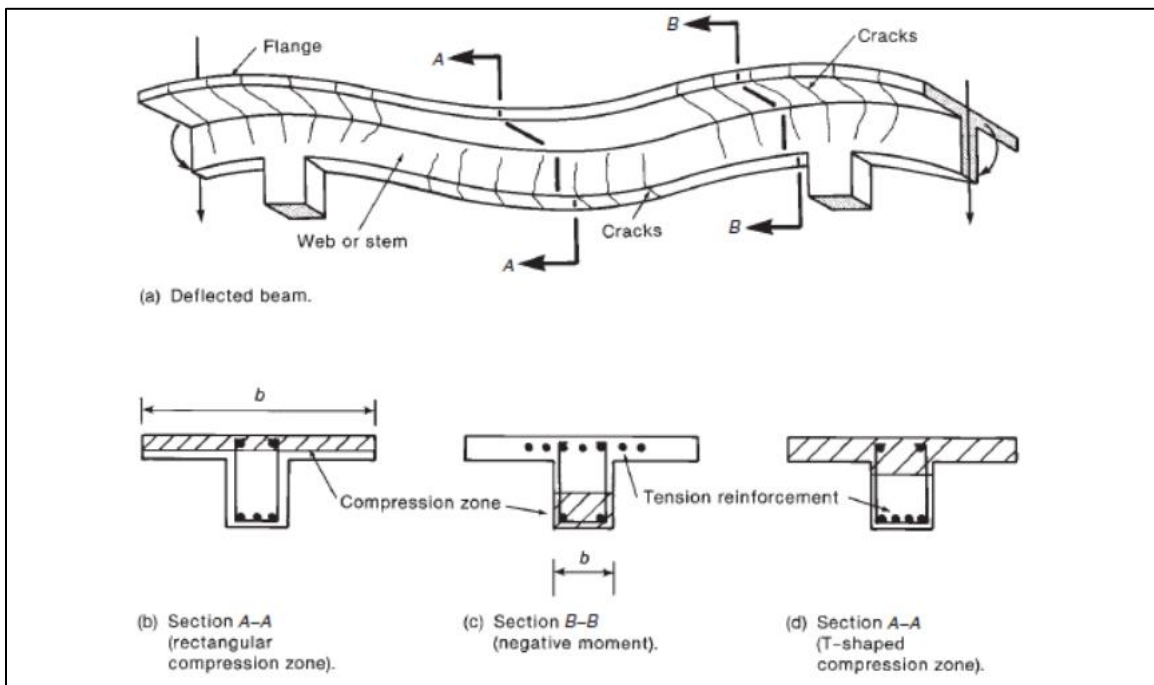


Figure 3.3: The Behavior Of Stresses In Flange, Web, And The Deformation Of T-Section Members [52]

3.2 CONSIDERATION OF STRESSES DISTRIBUTION IN T-BEAM

At mid-span, the compression zone is in the flange, generally, it is rectangular. Although, in very rare cases for typical reinforced concrete construction, the neutral axis may shift down into the web, giving a T-shaped compression zone. At the support, the compression zone is at the bottom of the beam and is rectangular; one can conclude that for the analyzing of T beams the neutral axis can fall either on the web or in the flange. If the (N.A) falls in the flange, the rectangular formulas apply. If the (N.A) falls in the web, the section above the (N.A) no longer consists of a single rectangular, and thus the Tee beam formulas apply.

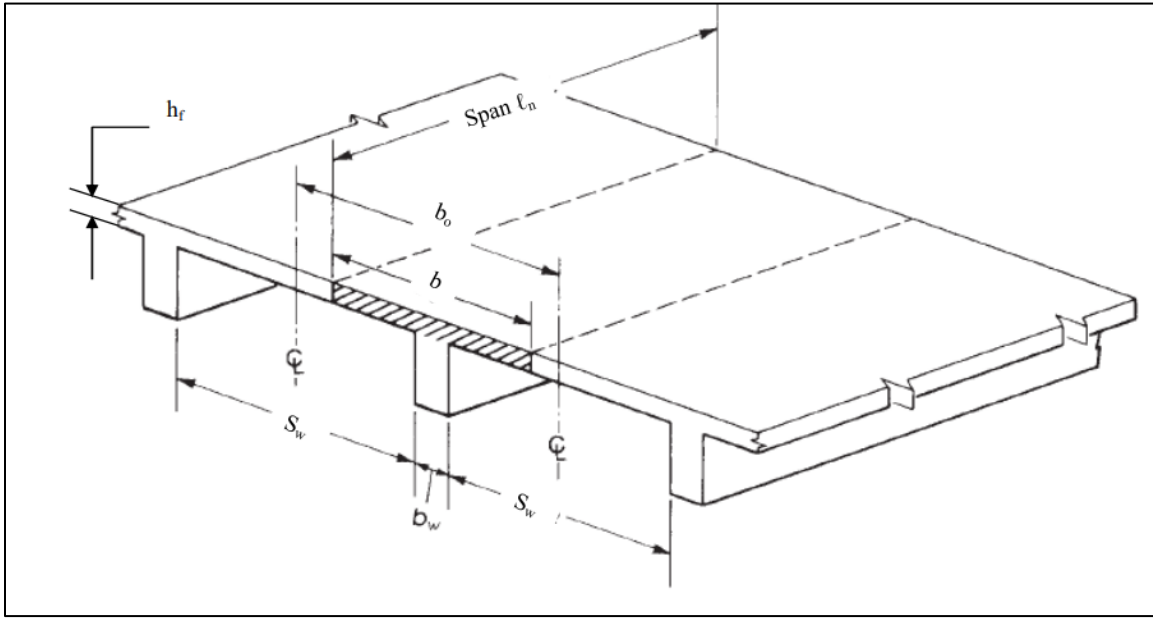


Figure 3.4: T-Section Geometrical Design Parameters [52]

3.3: ANALYSIS THEORY

The important step in analysis of the T-section beam is the identifying of the beam if it is flange carried portion of the compression stresses or only the web part. The main parameters of the geometrical shape of the T-section can be used to figure out the workability of this type of section. The main stages of analysis move through the following equations:

$$\rho_w = \frac{As}{b_w d} \quad (3.1)$$

$$A_{sf} = \frac{0.85 f' c h_f (b - b_w)}{F_y} \quad (3.2)$$

$$\rho_{max} = 0.85 \beta_1 \frac{f'c}{F_y} \frac{\epsilon}{\epsilon + 0.004} + \frac{Asf}{b_w d} \quad (3.3)$$

The section can be considered in tension failure if:

$$\rho_w \leq \rho_w max$$

The compression failure is not desired which can be reached if:

$$\rho_w > \rho_w max$$

$$As_{min} = 0.25 \frac{\sqrt{f'c}}{f_y} b_w d \text{ and must be greater than } \frac{1.4}{f_y} b_w d \quad (3.4)$$

The other important consideration is the workability in strength of the t-section, in other word, if the flange can resist the stresses or only the web face the external stresses. The threshold for that is the distance from the upper level of the cross section to neutral axis (a) and the depth of flange (hf). The examination can be adopted as the following:

$$a = \frac{As F_y}{0.85 f'c b} \quad (3.5)$$

If $a \leq hf$: the section is rectangular in structural analysis

If $a > hf$: the section is T-section in structural analysis

For rectangular section:

$$Mu = As F_y \left(d - \frac{a}{2} \right) \quad (3.6)$$

For T-section:

$$Mu = [0.85 f'c hf (b - b_w)] \left(d - \frac{hf}{2} \right) + [0.85 f'c at b_w] \left(d - \frac{at}{2} \right) \quad (3.7)$$

$$at = \frac{(As - Asf) F_y}{0.85 f'c b_w} \quad (3.8)$$

$$Asf = \frac{0.85 f'c hf (b - b_w)}{F_y} \quad (3.9)$$

$$at = \frac{\left(As - \frac{0.85 f'c hf (b - b_w)}{F_y} \right) F_y}{0.85 f'c b_w} \quad (3.10)$$

$$at = \frac{As F_y}{0.85 f'c b_w} - \frac{hf (b - b_w)}{b_w} \quad (3.11)$$

If $hf = \alpha a$ then:

$$at = \frac{As Fy}{0.85 f'c b_w} - \frac{\alpha a (b - b_w)}{b_w} \quad (3.12)$$

$$\begin{aligned} Mu &= [0.85 f'c \alpha a (b - b_w)] \left(d - \frac{\alpha a}{2}\right) + [0.85 f'c at b_w] \left(d - \frac{at}{2}\right) \\ Mu &= [\alpha a 0.85 f'c b] \left(d - \frac{\alpha a}{2}\right) - [\alpha a 0.85 f'c b_w] \left(d - \frac{\alpha a}{2}\right) + [0.85 f'c at b_w] \left(d - \frac{at}{2}\right) \end{aligned} \quad (3.13)$$

$$\begin{aligned} Mu &\left([\alpha a 0.85 f'c b] d - [\alpha a 0.85 f'c b] \frac{\alpha a}{2} \right) \left([\alpha a 0.85 f'c b_w] d - \right. \\ &\left. [\alpha a 0.85 f'c b_w] \frac{\alpha a}{2} \right) + ([0.85 f'c at b_w] d - [0.85 f'c at b_w] \frac{at}{2}) \end{aligned} \quad (3.14)$$

$$Mu = [0.85 f'c] \left(\alpha b d a - \alpha^2 \frac{b a^2}{2} - \alpha b_w d a + \alpha^2 \frac{b_w a^2}{2} + b_w d at - \frac{b_w at^2}{2} \right) \quad (3.15)$$

$$\frac{Mu}{0.85 f'c} = \left(\alpha b d a - \alpha^2 \frac{b a^2}{2} - \alpha b_w d a + \alpha^2 \frac{b_w a^2}{2} + b_w d at - \frac{b_w at^2}{2} \right) \quad (3.16)$$

$$\frac{Mu}{0.85 f'c} = \left(\alpha^2 \frac{b_w a^2}{2} - \alpha^2 \frac{b a^2}{2} + \alpha b d a - \alpha b_w d a + b_w d at - \frac{b_w at^2}{2} \right) \quad (3.17)$$

$$\frac{Mu}{0.85 f'c} = \left(\alpha^2 \left(\frac{b_w a^2}{2} - \frac{b a^2}{2} \right) + \alpha (b d a - b_w d a) + b_w d at - \frac{b_w at^2}{2} \right) \quad (3.18)$$

For critical condition in which the available strength of the T-section is equal to external moment applied on the member:

$$\left(\alpha^2 \left(\frac{b_w a^2}{2} - \frac{b a^2}{2} \right) + \alpha (b d a - b_w d a) + b_w d at - \frac{b_w at^2}{2} \right) - \frac{Mu}{0.85 f'c} = 0 \quad (3.19)$$

For the case of uniform loading on RC beam, the maximum loading that can be faced by the member by identifying the maximum moment along the beam, the equation is:

$$M_{max} = \frac{W L^2}{8}$$

$$\left(\alpha^2 \left(\frac{b_w a^2}{2} - \frac{b a^2}{2} \right) + \alpha (b d a - b_w d a) + b_w d at - \frac{b_w at^2}{2} \right) - \frac{W L^2}{6.8 f'c} = R \quad (3.20)$$

Where R is term represented the residual strength that the difference between the available and the applied on

If $R > 0$ then the section can carried out the applied load

If $R < 0$ then the section must be reinforced or updated in its design stage

From these equation, the magnitude of the factor α can be calculated for various range of the design loading and other parameters of the dimensional properties of the T-section cross section.

If the value of α determined is greater or equal one, the section is work as the rectangular cross section beam analysis theory, while if the magnitude of α is below one then the section work as T-section and the analysis pathway is true

3.4 ANSYS GEOMETRICAL AND STRUCTURAL PREPARATION

The cases of the T-section that building in the program were two cases

Case1: $h_f = 125$ mm, $b = 500$ mm, $b_w = 250$ mm, $h = 475$ mm, and reinforcement 8 $\varnothing 12$ mm bars

Case1: $h_f = 200$ mm, $b = 7500$ mm, $b_w = 250$ mm, $h = 550$ mm, and reinforcement 8 $\varnothing 12$ mm bars.

Table 3.1: Properties of Reinforcement And Concrete In ANSYS

Item	Symbol	Magnitude in ANSYS
Compressive strength of concrete	F_c	25 MPa
Modulus of elasticity of Concrete	E_c	$30 \cdot 10^3$ MPa
Tensile strength of concrete	F_t	3 MPa
Tensile strength of steel	F_y	420 MPa
Modulus of elasticity of steel	E_s	$200 \cdot 10^3$ MPa

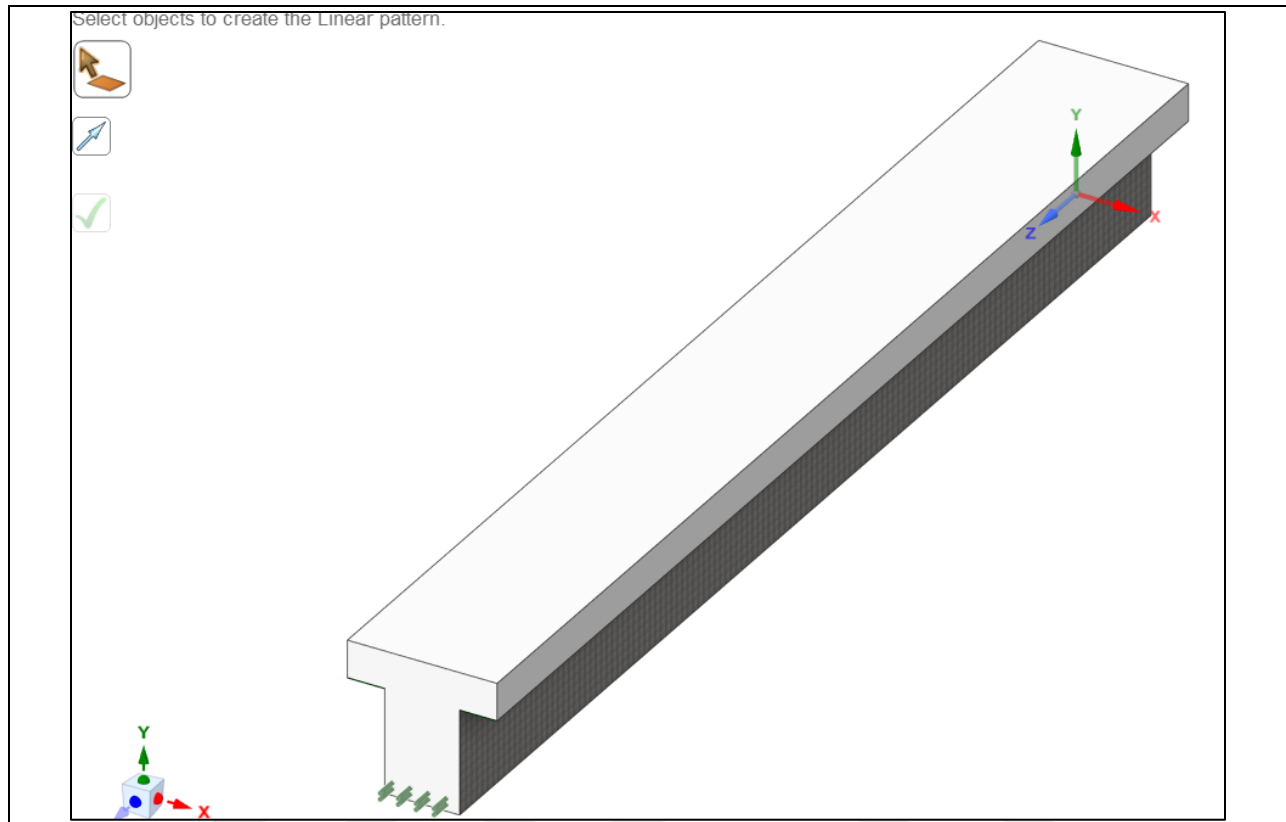


Figure 3.5: The Geometrical Building Of The T-Section Member In ANSYS drawing panel

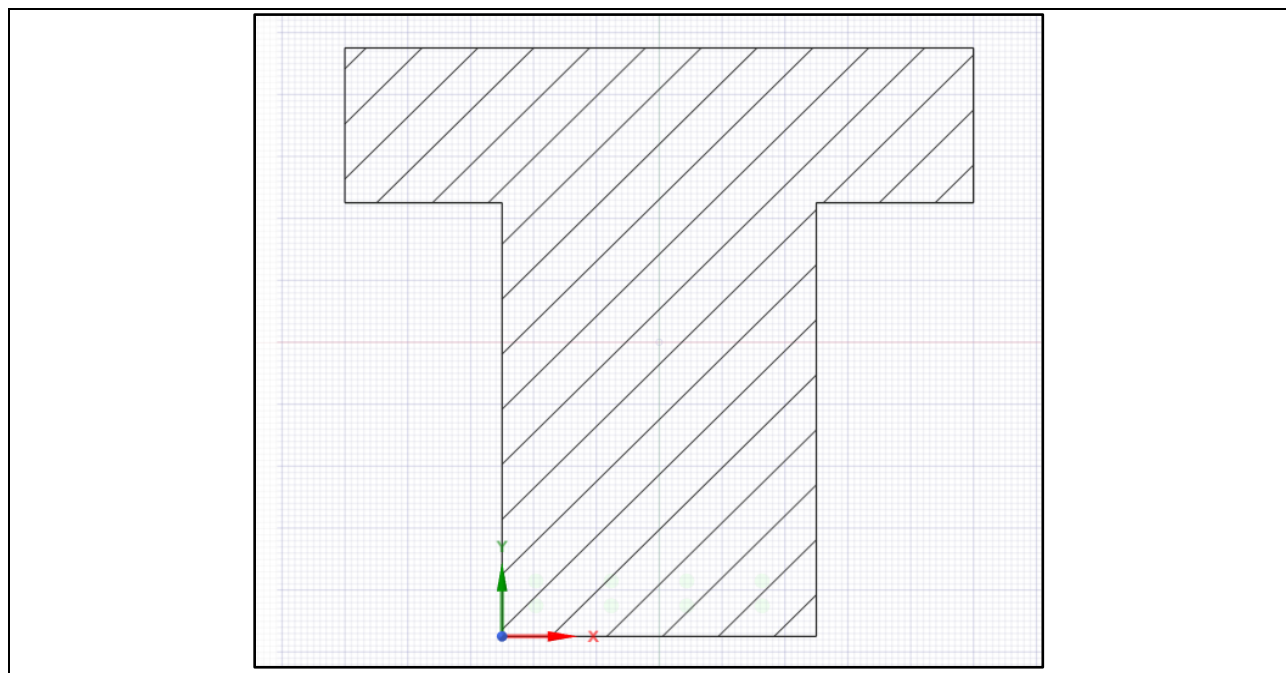


Figure 3.6: The Case 1 Section Of The T-Section Member In Ansys Drawing Panel

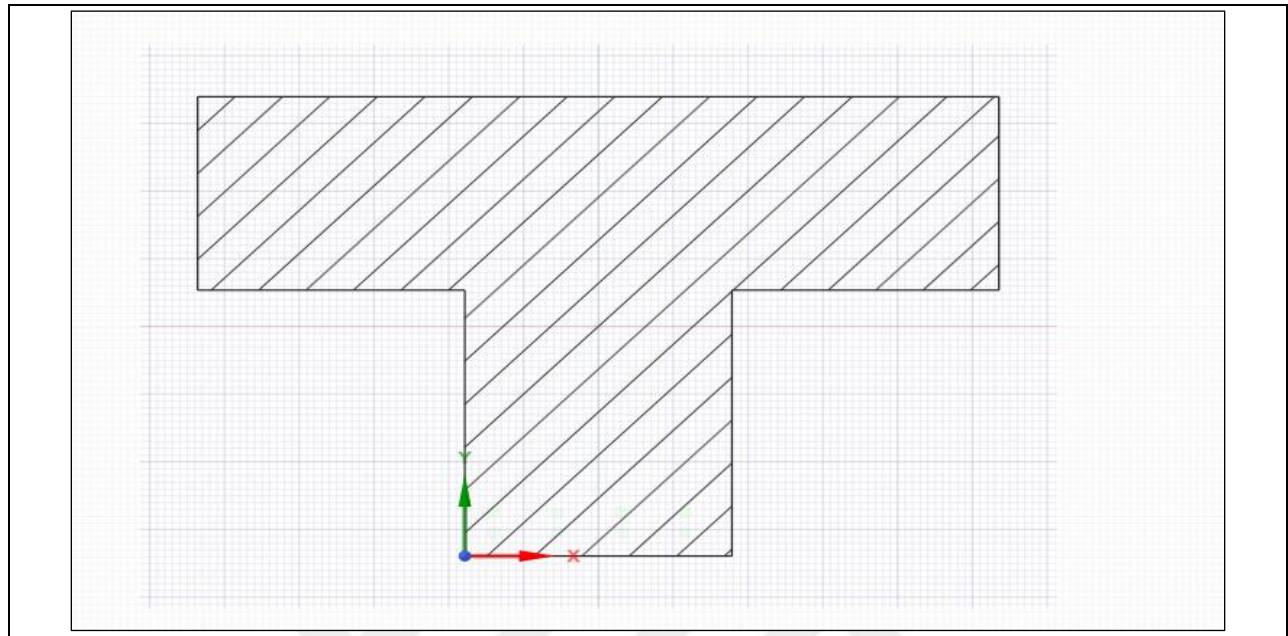


Figure 3.7: The Case 2 Section Of The T-Section Member In ANSYS drawing panel

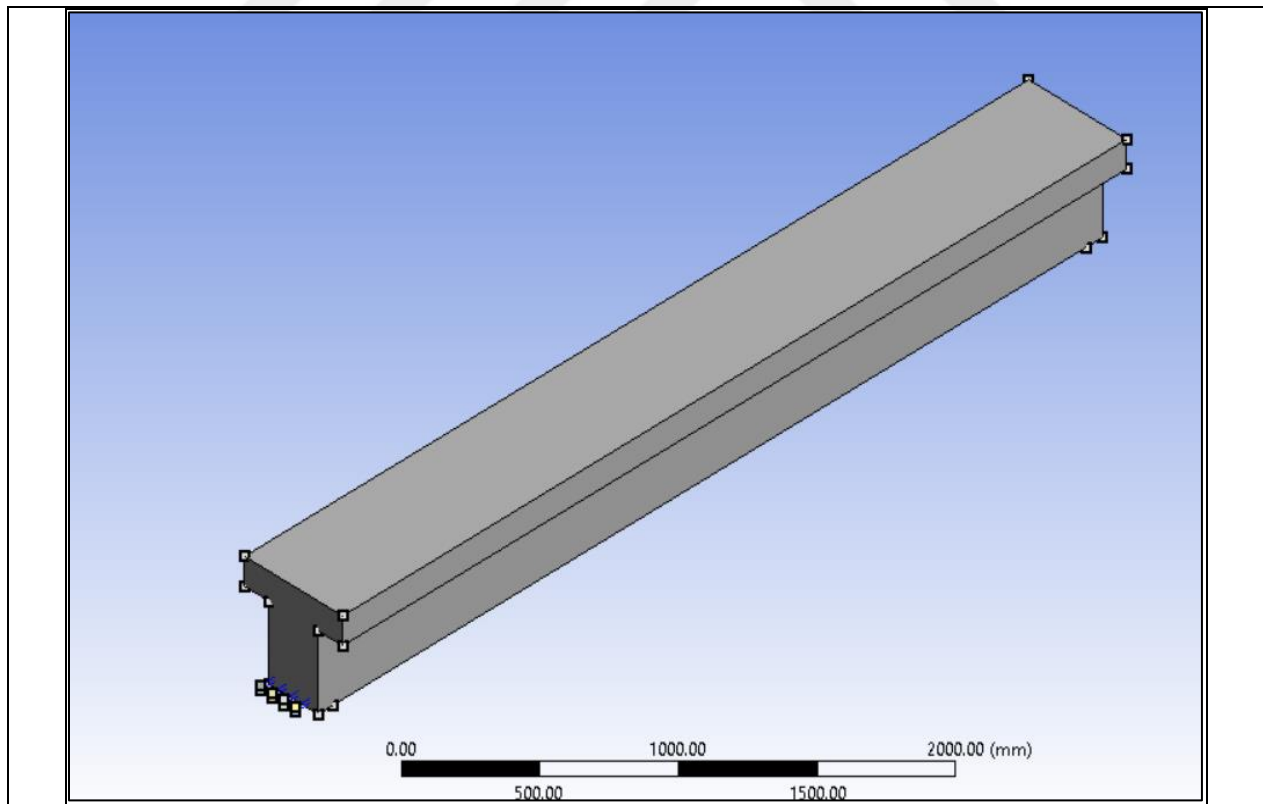


Figure 3.8: The Preparation For The Whole Member For Processing In ANSYS model panel

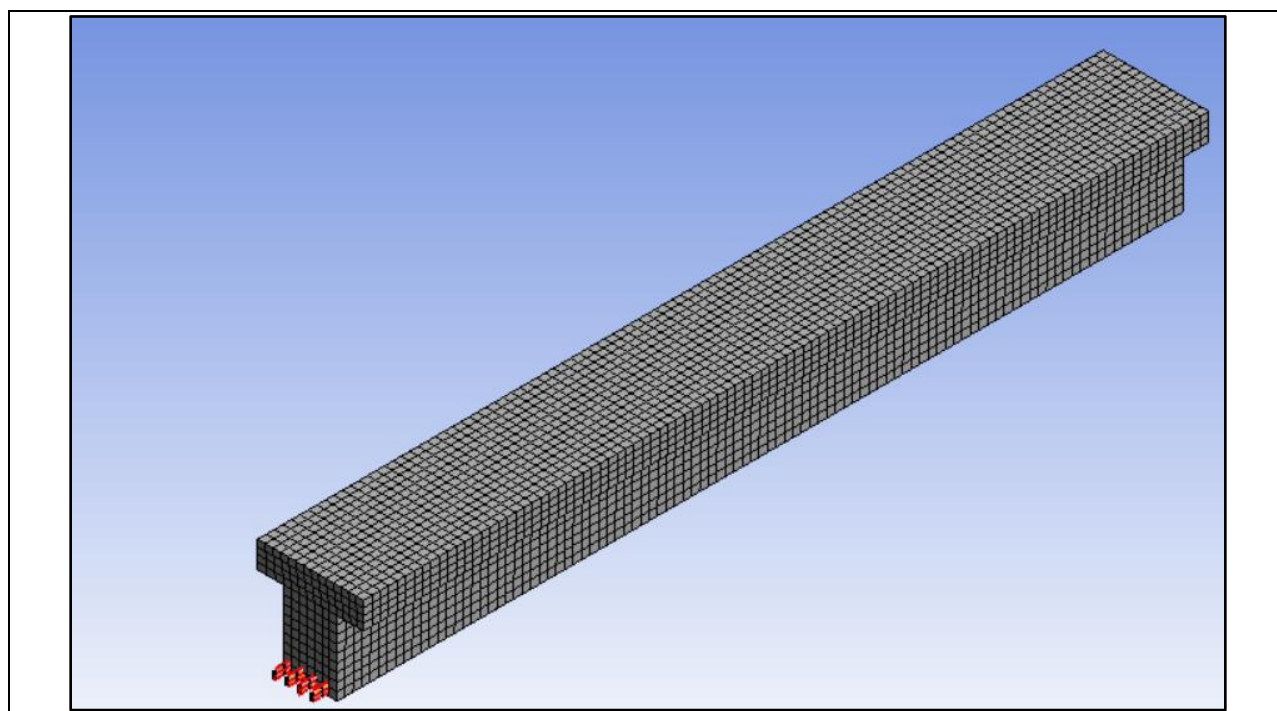


Figure 3.9: The Set Of Mesh For The Whole Member In ANSYS model panel

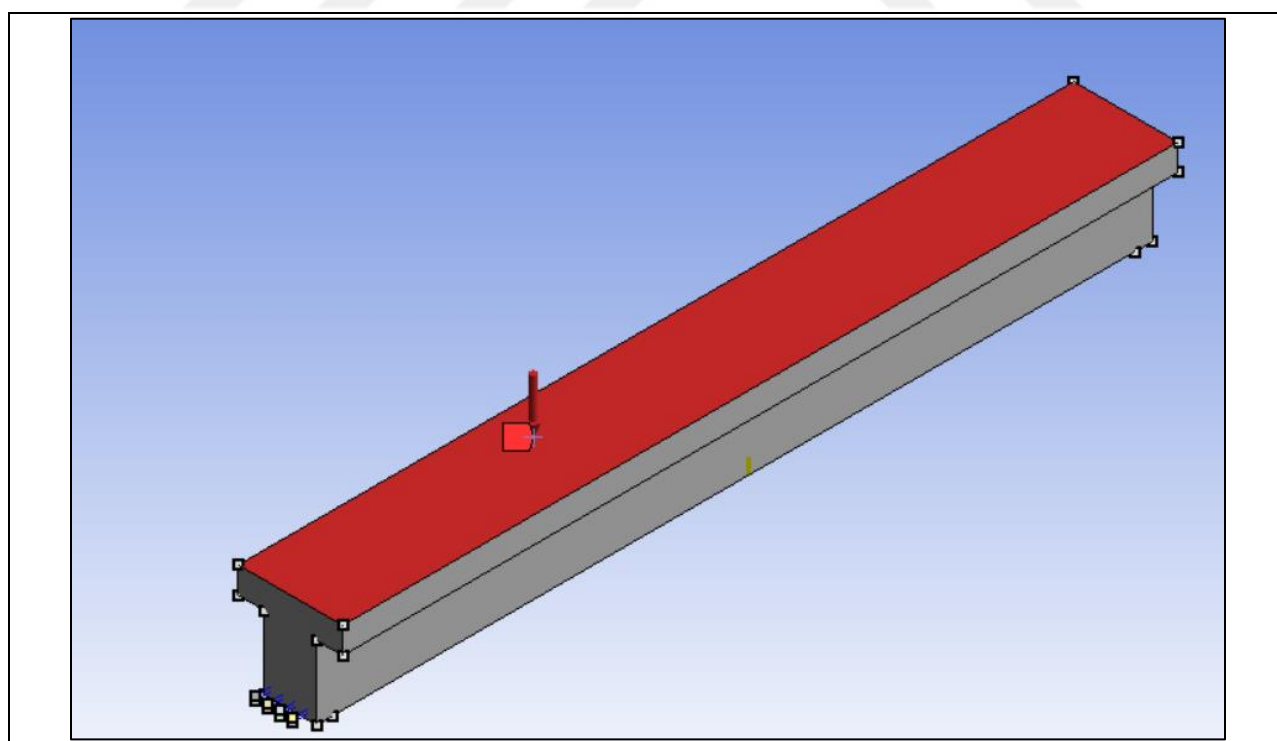


Figure 3.10: The Set of The Uniform Loading On The Upper Area Of The Member In ANSYS Model Panel

4. RESULTS

4.1 CALCULATION AND ANALYSIS

The cases of t-section member depend on the geometrical properties of the cross section as well as the external loading. The application of the derived equation was arranged into the resultant data. The effect of the width of the flange (b) was calculated and explained in table 4.1

Table 4.1: The Impact of b on the residual strength when $W=100$ kN/m $d=610$ $h_f=125$ $b_w=250$ mm

b	R
260	15.70
280	16.25
300	16.77
320	17.27
340	17.74
360	18.19
380	18.61
400	19.00
420	19.38
440	19.72
460	20.04
480	20.34
500	20.61
520	20.86
540	21.08

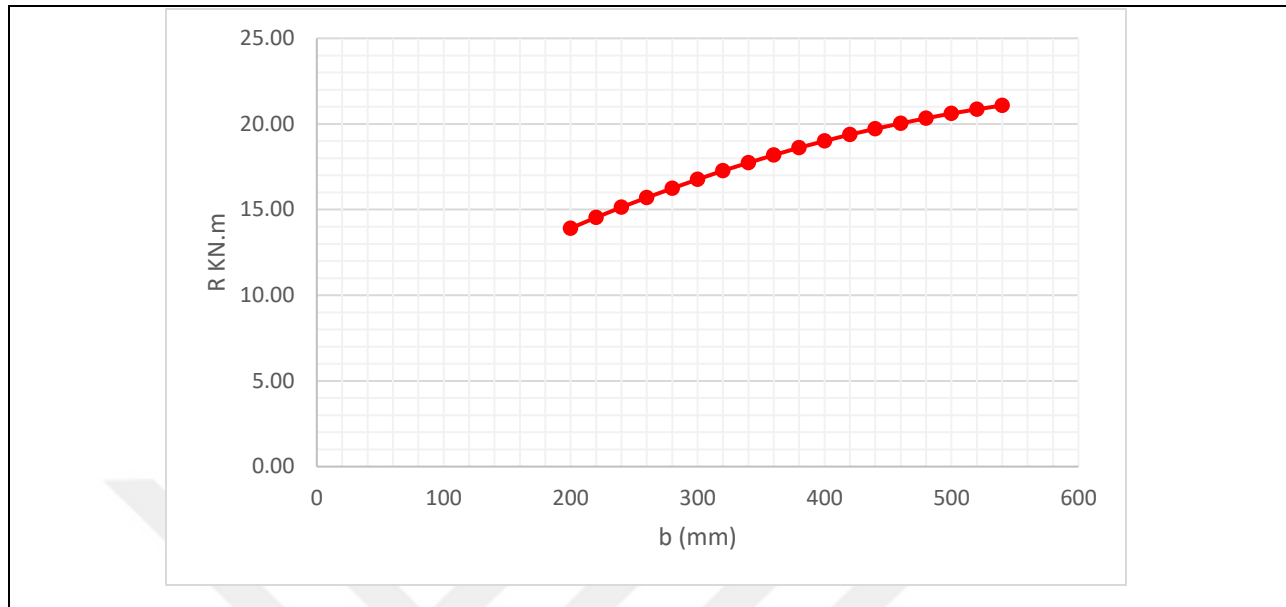


Figure 4.1: The Relationship of B And The Residual Strength When W=100 kN/m

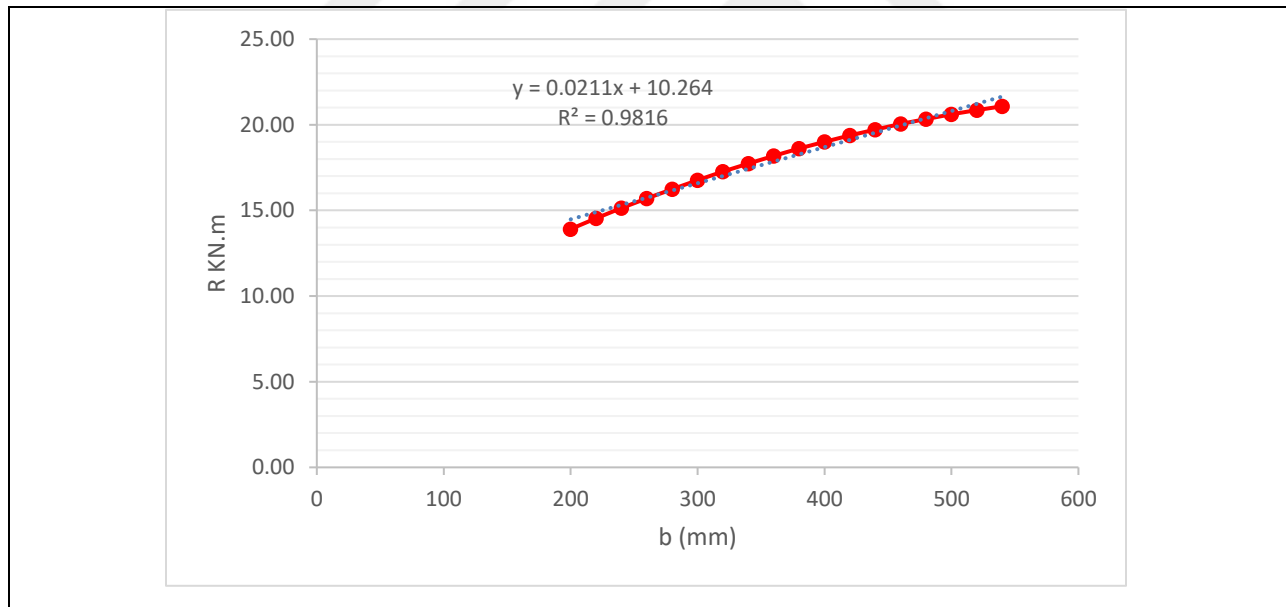


Figure 4.2: The Fitting Equation Of B And The Residual Strength When W=100 kN/m

The difference for the value of R in relative to that of b according to the curve fitting

$$\text{relative difference of } b = \frac{21.08 - 15.7}{540 - 260} = 0.02$$

Table 4.2: The Impact of Hf on the Residual Strength When W=100 kN/m

hf	R
125	20.61
126	20.62
127	20.63
128	20.64
129	20.65
130	20.66
131	20.66
132	20.67
133	20.68
134	20.68
135	20.69
136	20.69
137	20.70
138	20.70
139	20.71
140	20.71
141	20.71
142	20.71

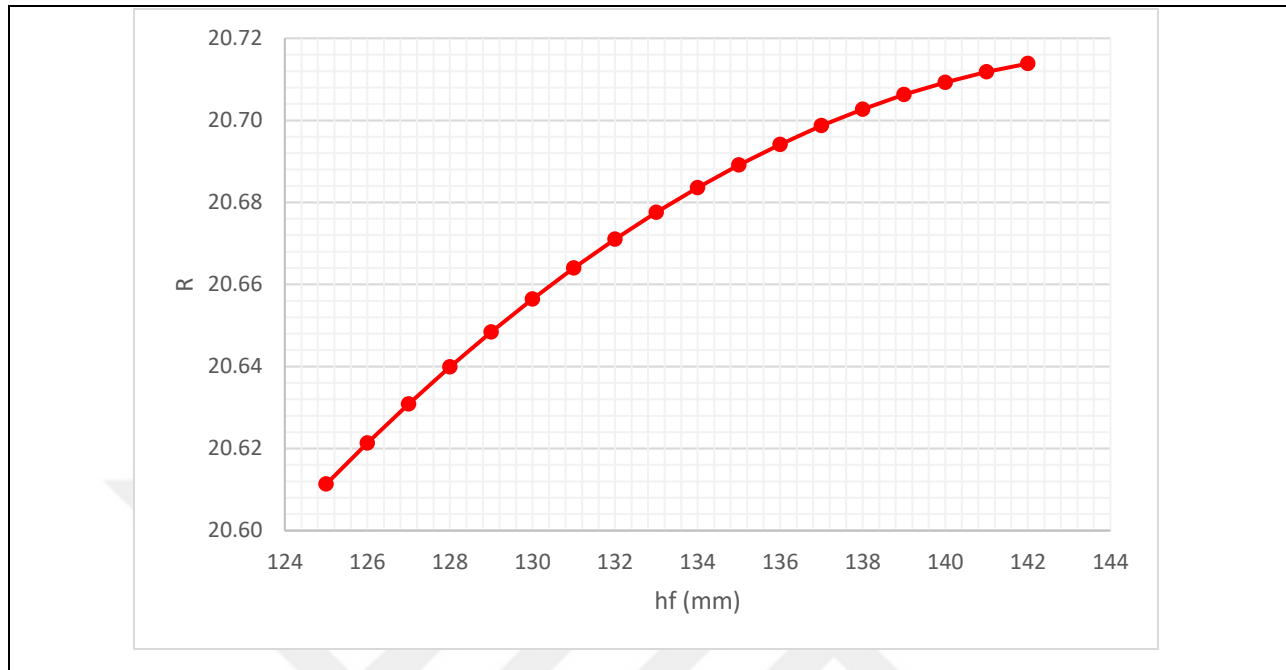


Figure 4.3: The Relationship of hf And The Residual Strength When W=100 kN/m

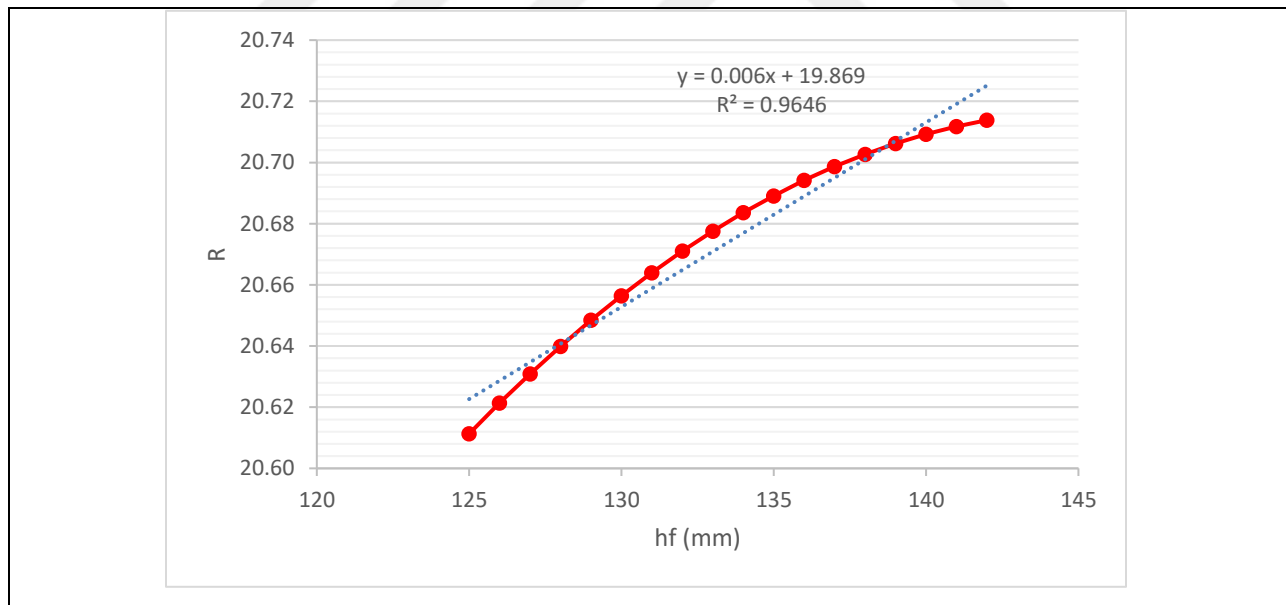


Figure 4.4: The Fitting Equation of hf And The Residual Strength When W=100 kN/m

$$\text{relative difference of } hf = \frac{20.71 - 20.61}{142 - 125} = 0.006$$

Table 4.3: The Impact of Hf On The Residual Strength When W=100 kN/m

As	R
1800	6.44
2000	9.15
2200	11.75
2400	14.26
2600	16.67
2800	18.99
3000	21.20
3200	23.32
3400	25.34
3600	27.26
3800	29.09
4000	30.81
4200	32.44
4400	33.98
4600	35.41
4800	36.75
5000	37.99
5200	39.13

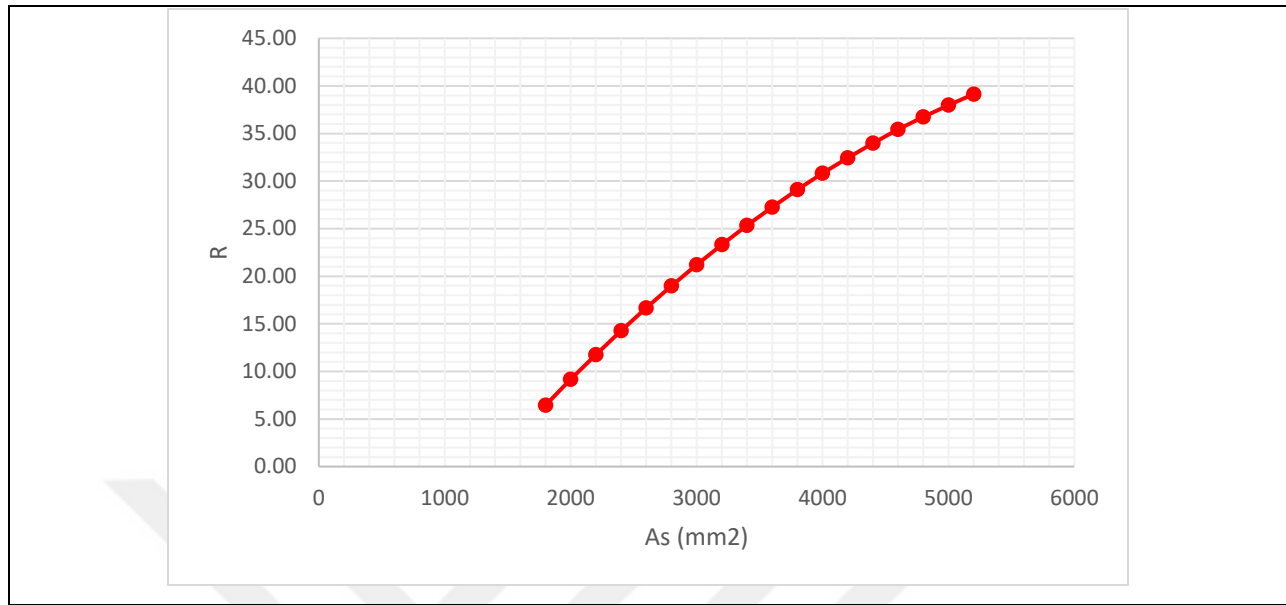


Figure 4.5: The Relationship Of A_s and the Residual Strength When $W=100 \text{ kN/m}$

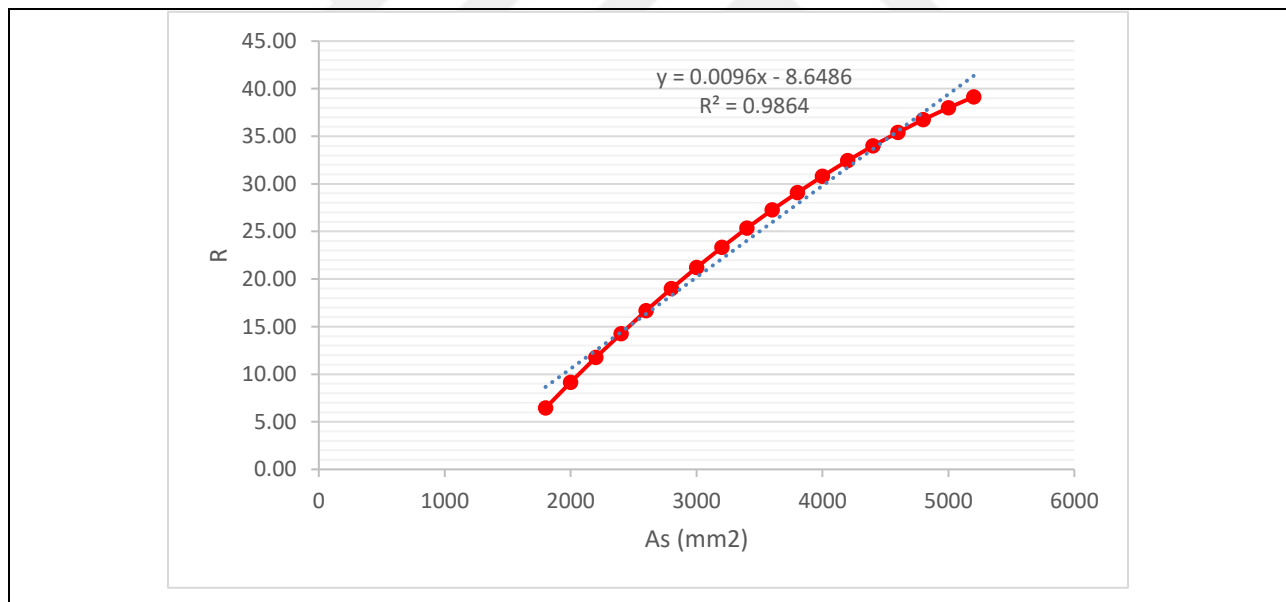


Figure 4.6: The Fitting Equation of h_f And The Residual Strength When $W=100 \text{ kN/m}$

$$\text{relative difference of } A_s = \frac{39.13 - 6.44}{5200 - 1800} = 0.0096$$

Table 4.4: The Impact of bw on The Residual Strength When W=100 kN/m

bw	R
165	20.50
170	20.51
175	20.52
180	20.53
185	20.54
190	20.54
195	20.55
200	20.56
205	20.56
210	20.57
215	20.58
220	20.58
225	20.59
230	20.59
235	20.60
240	20.60
245	20.61
250	20.61

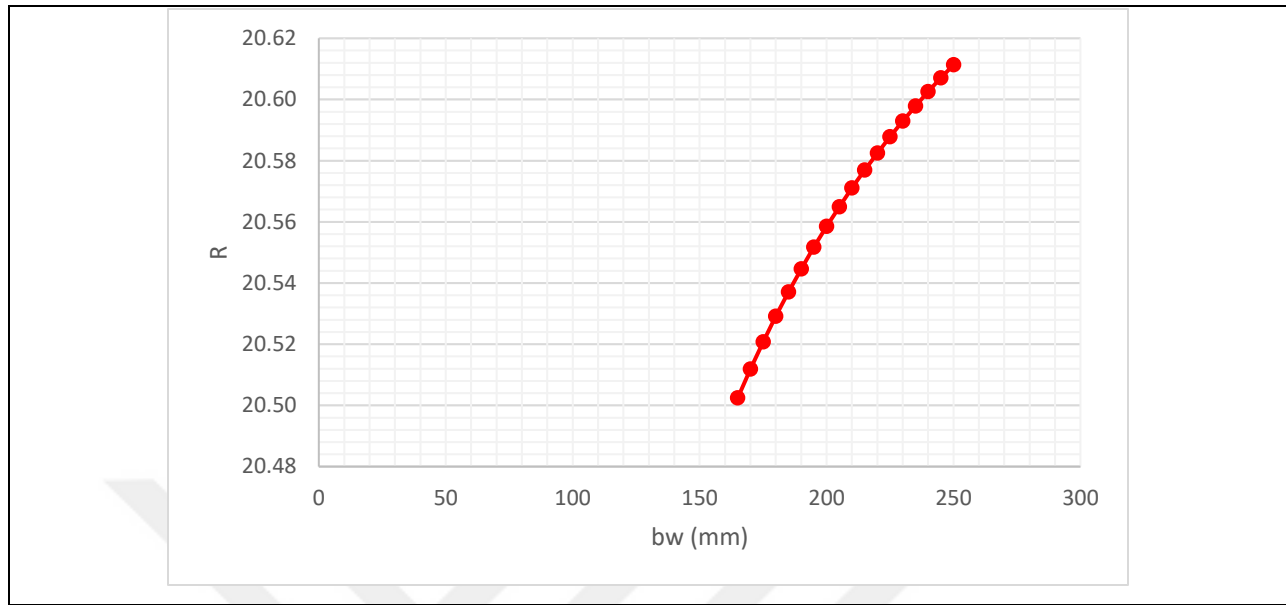


Figure 4.7: The Relationship of bw And The Residual Strength When $W=100$ kN/m

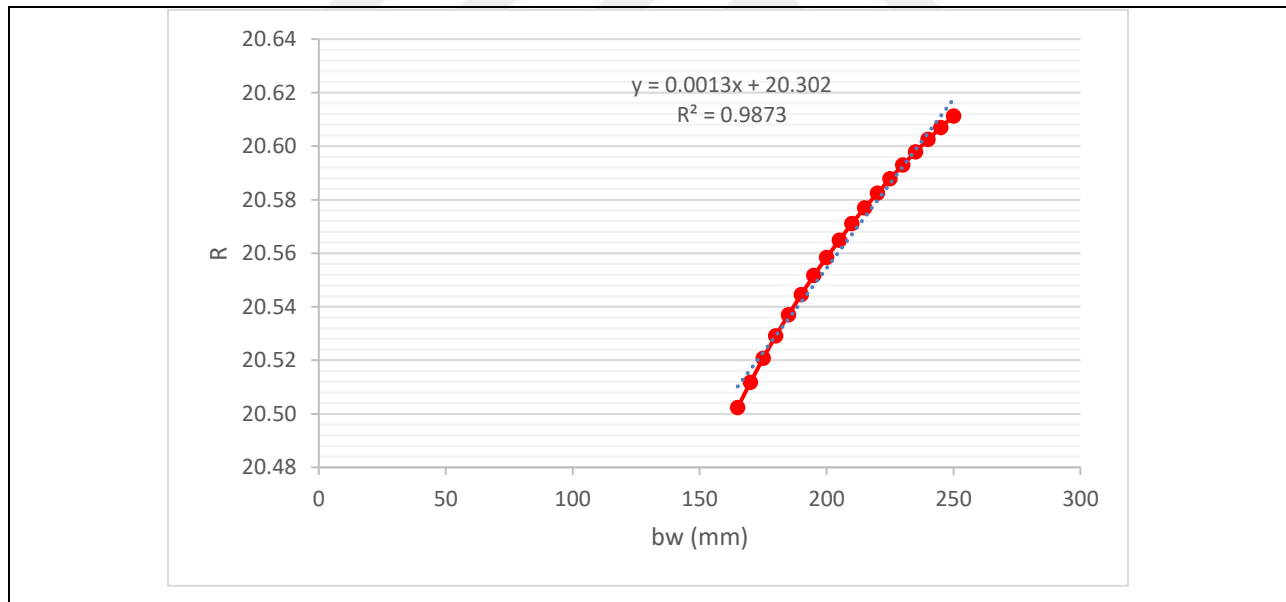


Figure 4.8: The Fitting Equation of bw And The Residual Strength When $W=100$ kN/m

$$\text{relative difference of } A_s = \frac{20.61 - 20.5}{250 - 165} = 0.00128$$

Table 4.5: The Impact of d On The Residual Strength When W=100 kN/m

d	R
450	8.97
460	9.69
470	10.42
480	11.15
490	11.88
500	12.61
510	13.33
520	14.06
530	14.79
540	15.52
550	16.24
560	16.97
570	17.70
580	18.43
590	19.16
600	19.88
610	20.61
620	21.34

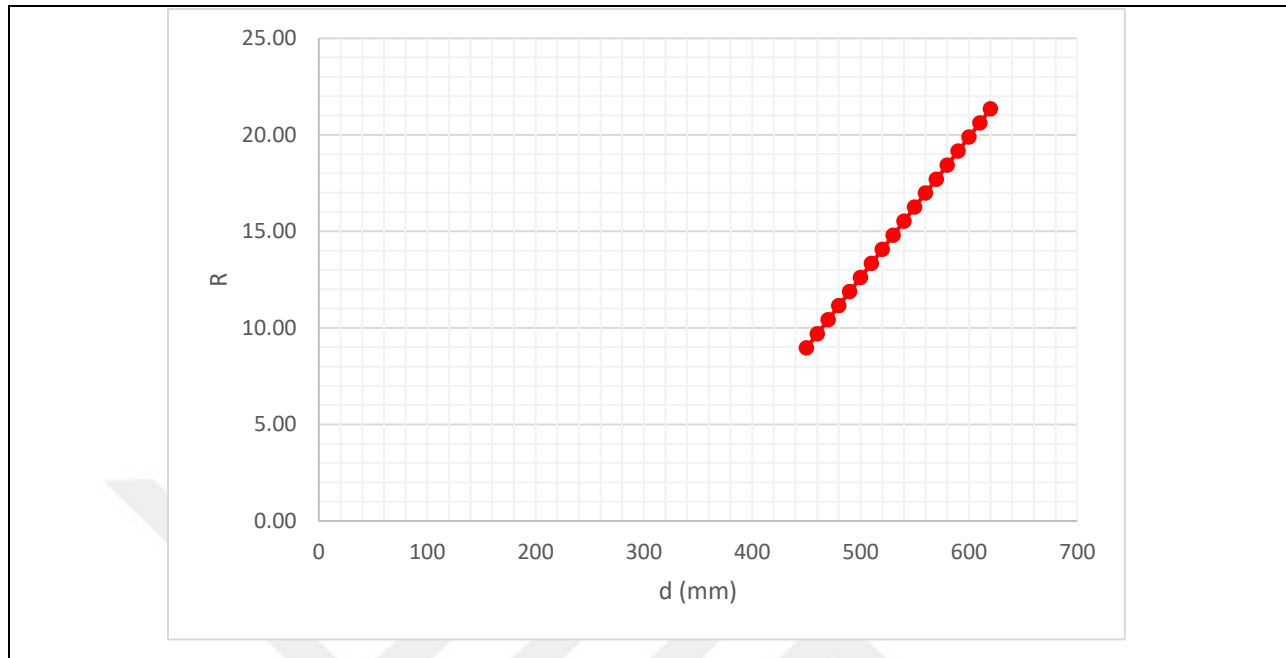


Figure 4.9: The Relationship of d and the Residual Strength When $W=100$ kN/m

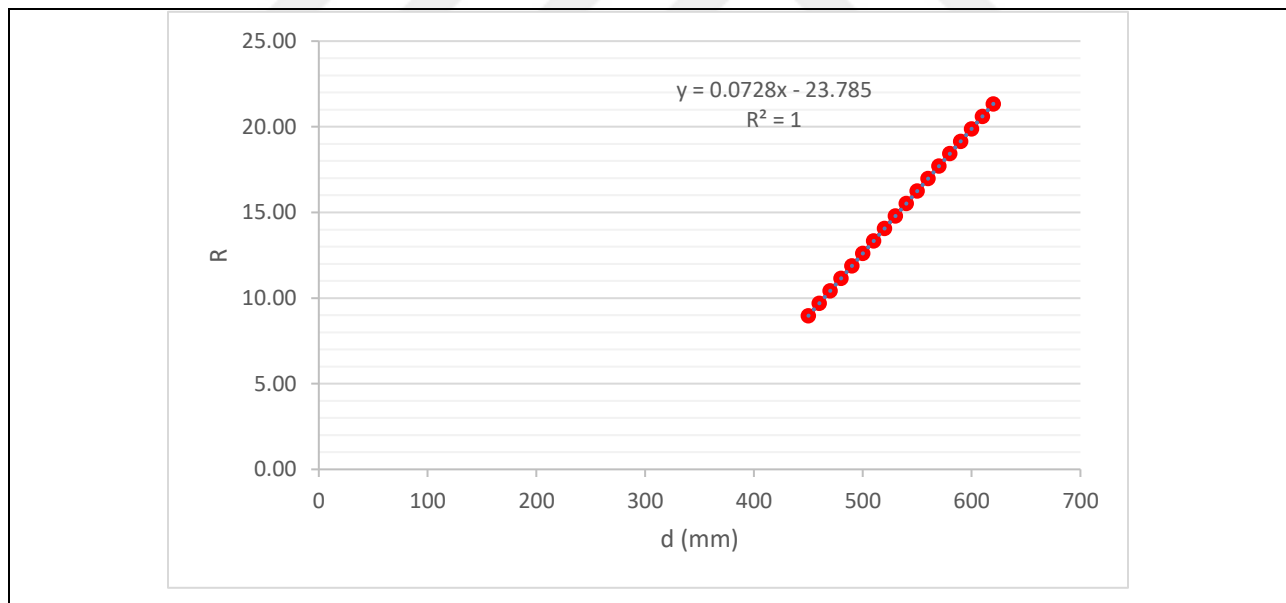


Figure 4.10: The Fitting Equation of d And The Residual Strength When $W=100$ kN/m

$$\text{relative difference of } d = \frac{21.34 - 8.97}{620 - 450} = 0.0727$$

Table 4.6: Collection of the Fitting Equations and the Relative Differences

Item	Equation	Relative difference
b	$y = 0.0211x + 10.264$	0.021
hf	$y = 0.006x + 19.869$	0.006
As	$y = 0.0096x - 8.6486$	0.0096
bw	$y = 0.0013x + 20.302$	0.00128
d	$y = 0.0728x - 23.785$	0.0727

From table 4.6, the percent of impact for each item was calculated as percent for the all impact values and included in table 4.7

Table 4.7: Collection Of The Fitting Equations And The Relative Differences

Item	Relative difference	Relative difference %
b	0.021	18.99
hf	0.006	5.426
As	0.0096	8.681
bw	0.00128	1.158
d	0.0727	65.74

The summing of the equation with the percent of relative differences for each parameter was:

$$R = 0.19 (0.0211 b + 10.264) + 0.054 (0.006 hf + 19.869) + 0.0868 (0.0096 As - 8.6486) + 0.0115 (0.0013 bw + 20.302) + 0.65 (0.0728 d - 23.785)$$

$$R = 0.004 b + 0.195 + 0.0003 hf + 1.073 + 0.00083 As - 0.75 + 0.000014 bw + 0.233 + 0.047 d - 15.46$$

$$R = 0.004 b + 1.95 + 0.0003 hf + 1.073 + 0.00083 As - 0.75 + 0.000014 bw + 0.233 + 0.047 d - 15.46$$

$$R = 0.004 b + 0.0003 hf + 0.00083 As + 0.000014 bw + 0.047 d - 12.954$$

For checking the R values for different range of the variables, table 4.8 included the values of R when all parameters were changed.

Table 4.8: The Values of R from the Derived and the Structural Equations

R from derived equation	R from structural equation	Difference
10.53	-3.52	-14.05
11.25	-1.52	-12.76
11.96	0.57	-11.39
12.68	2.74	-9.94
13.40	5.00	-8.40
14.11	7.35	-6.76
14.83	9.80	-5.03
15.54	12.33	-3.21
16.26	14.97	-1.29
16.98	17.70	0.72
17.69	20.52	2.83
18.41	23.45	5.04
19.13	26.47	7.35
19.84	29.60	9.76
20.56	32.82	12.27
21.28	36.15	14.87
21.99	39.58	17.59
22.71	43.11	20.40

The differences for the equations (derived and structural) was drawn in figure 4.11:(F is the factor that used to close the equation to the actual results).

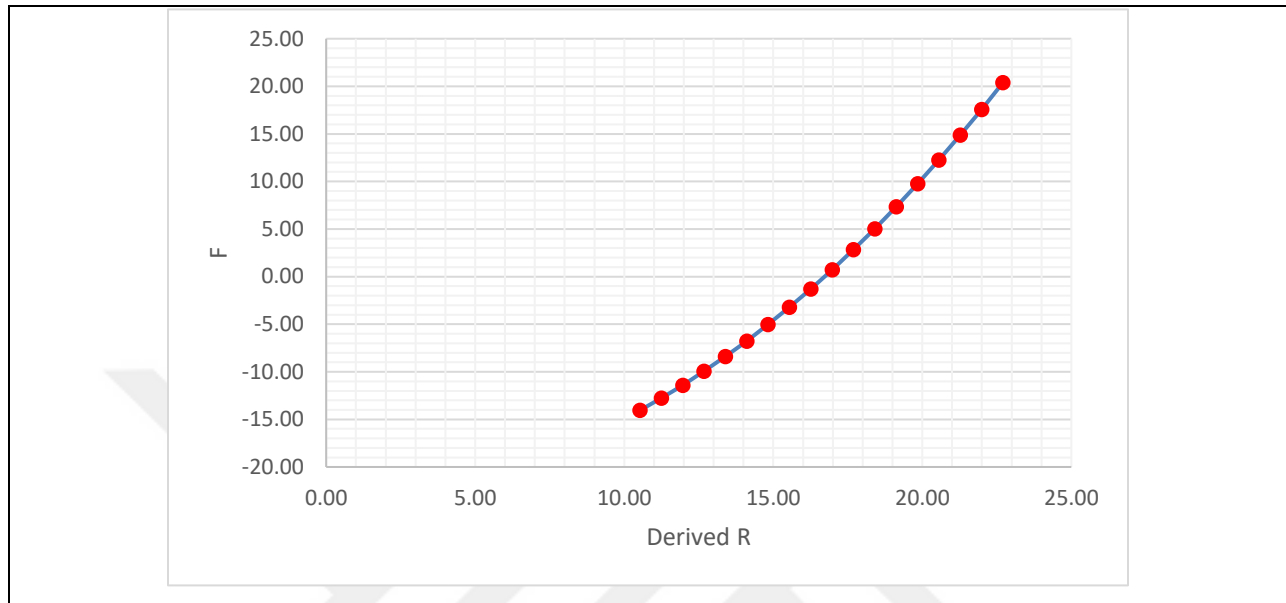


Figure 4.11: The Relationship of Derived R and the Factor F When W=100 kN/m

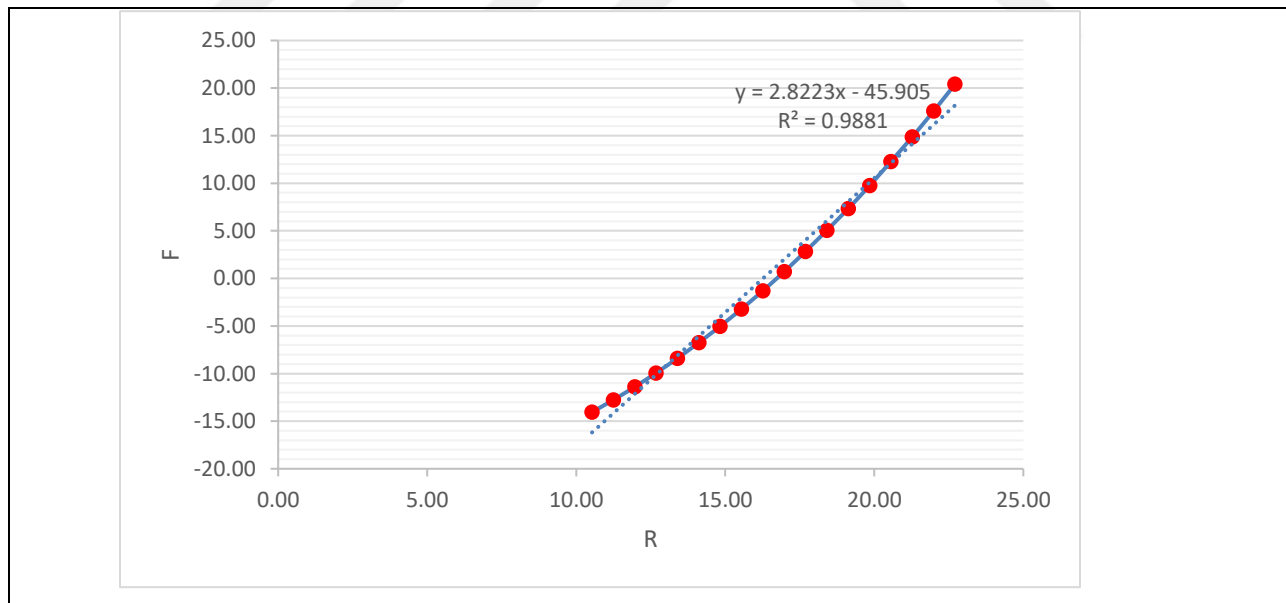


Figure 4.12: The Curve Fitting Of Derived R And The Factor F When W=100 kN/m

Table 4.9: Collection of the Fitting Equations and the Relative Differences

item	Equation for correlation	Relative equation for item
b	$y = 2.8223x - 45.905$	$2.822 \cdot 0.004 = 0.011288$
hf	$y = 2.8223x - 45.905$	$2.822 \cdot 0.0003 = 0.000846$
As	$y = 2.8223x - 45.905$	$2.822 \cdot 0.00083 = 0.00234$
bw	$y = 2.8223x - 45.905$	$2.822 \cdot 0.000014 = 0.0000395$
d	$y = 2.8223x - 45.905$	$2.822 \cdot 0.047 = 0.132$

$$F = 0.01128 b + 0.000846 hf + 0.00234 As + 0.0000395 bw + 0.132 d - 82.46$$

$$R' = R + F$$

$$R = 0.004 b + 0.195 + 0.0003 hf + 1.073 + 0.00083 As - 0.75 + 0.000014 bw + 0.233 + 0.047 d - 15.46$$

$$R' = 0.01528 b + 0.001146 hf + 0.00317 As + 0.0000535 bw + 0.179 d - 95.42$$

Table 4.10: The Values of R from the derived and the structural equations

R from structural equation	R from derived equation	difference
-3.52	-5.96	2.44
-1.52	-3.22	1.71
0.57	-0.49	1.06
2.74	2.24	0.50
5.00	4.97	0.03
7.35	7.70	-0.35
9.80	10.43	-0.63
12.33	13.16	-0.83
14.97	15.89	-0.92
17.70	18.62	-0.93
20.52	21.35	-0.83
23.45	24.09	-0.63
26.47	26.82	-0.34

Table 4.10: The Values of R from the derived and the structural equations “Table Continued”

R from structural equation	R from derived equation	difference
29.60	29.55	0.05
32.82	32.28	0.55
36.15	35.01	1.14
39.58	37.74	1.84
43.11	40.47	2.64

By increasing the external uniform loading, the magnitude of R' must be corrected again to include the reliability to give values that match the desire loading in design. Table 4.11 contained the data of R' when the values of W increased.

Table 4.11: The Values of R from the Derived and the Structural Equations

W (kN/m)	R from structural equation	R from derived equation	difference
100	-3.52	-5.96	2.44
110	-3.35	-3.22	-0.13
120	-3.11	-0.49	-2.61
130	-2.78	2.24	-5.01
140	-2.35	4.97	-7.32
150	-1.84	7.70	-9.54
160	-1.23	10.43	-11.66
170	-0.53	13.16	-13.69
180	0.26	15.89	-15.63
190	1.15	18.62	-17.47
200	2.14	21.35	-19.21
210	3.23	24.09	-20.86
220	4.42	26.82	-22.40
230	5.70	29.55	-23.85

Table 4.11: The Values of R from the Derived and the Structural Equations “Table Continued”

W (kN/m)	R from structural equation	R from derived equation	difference
240	7.09	32.28	-25.19
250	8.58	35.01	-26.43
260	10.17	37.74	-27.57
270	11.86	40.47	-28.61

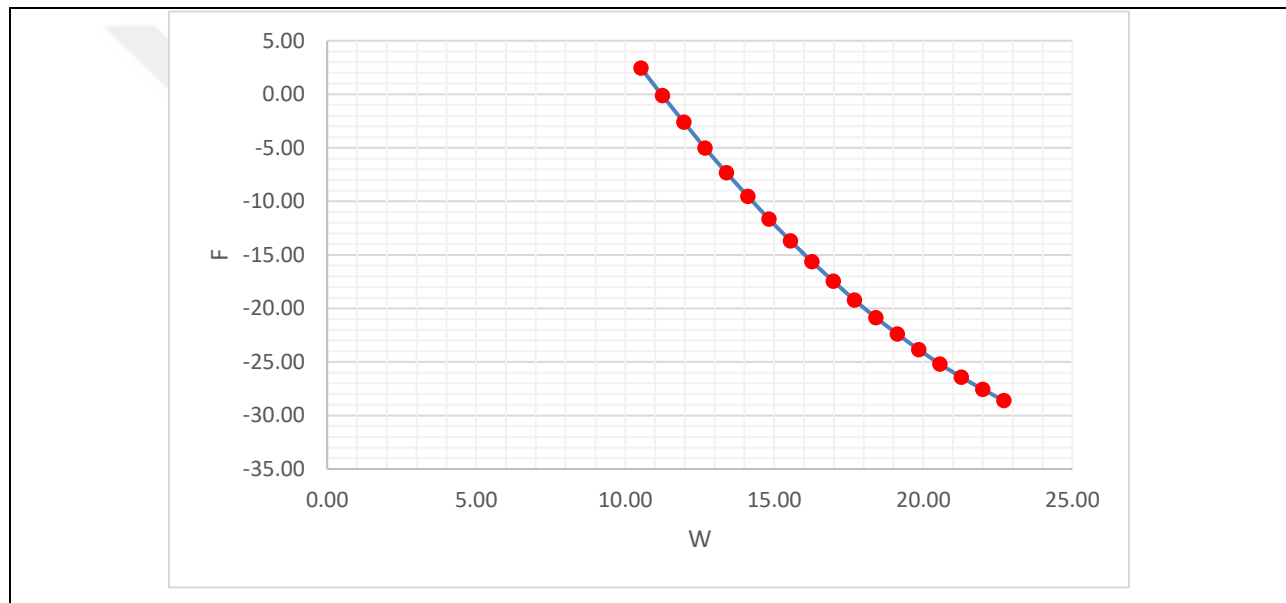


Figure 4.13: The Relationship of the Uniform Loading W And The Correlation Factor F

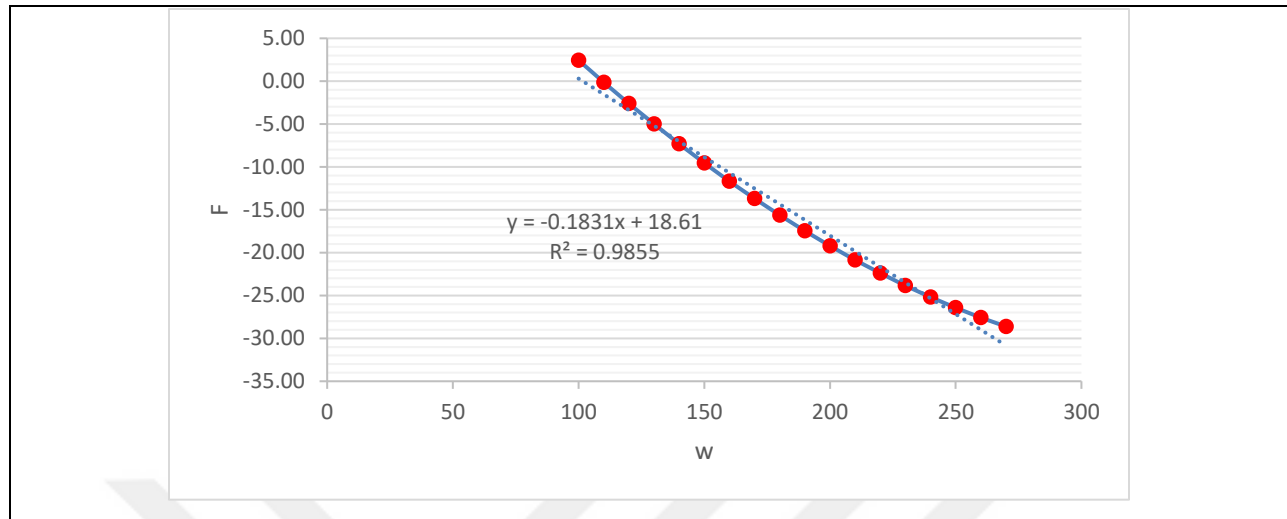


Figure 4.14: The Relationship Of The Uniform Loading W And The Factor F

The equation of R in the updated form lead to:

$$R'' = 0.01528 b + 0.001146 hf + 0.00317 A_s + 0.0000535 bw + 0.179 d - 95.42 - 0.1831 * W + 18.61$$

$$R'' = 0.01528 b + 0.001146 hf + 0.00317 A_s + 0.0000535 bw + 0.179 d - 0.1831 * W - 76.81$$

The equation can be used to identify the minimum magnitude of each parameter to satisfy $R''=0$ in which the strength in the member equal or close to the external moment applied.

Table 4.12: The Values of R from the Derived and the Structural Equations

W (kN/m)	R from structural equation	R from derived equation	difference
100	-3.52	-5.66	2.14
110	-3.35	-4.76	1.40
120	-3.11	-3.86	0.75
130	-2.78	-2.96	0.18
140	-2.35	-2.06	-0.30
150	-1.84	-1.16	-0.68
160	-1.23	-0.26	-0.98
170	-0.53	0.64	-1.18

Table 4.12: The Values of R from the Derived and the Structural Equations “Table Continued”

W (kN/m)	R from structural equation	R from derived equation	difference
180	0.26	1.54	-1.28
190	1.15	2.44	-1.29
200	2.14	3.34	-1.20
210	3.23	4.24	-1.01
220	4.42	5.14	-0.73
230	5.70	6.04	-0.34
240	7.09	6.94	0.14
250	8.58	7.84	0.73
260	10.17	8.74	1.42
270	11.86	9.64	2.21

4.2 ANSYS WORK

The simulation of the cases of T-section inside the ANSYS program was made for number of cases including variation of the depth of the T-section. The images in the following figures represented the variation of the stresses and other conditions along the beam section and span. The stresses were calculated for $W = 50, 100$, and 200 kN/m for case 1 and $W = 100$ and 200 kN/m for case 2. The stresses indicated by the program showed increasing in tension and compression magnitudes according the geometry of the sections and the impact of the increment of the applied loading.

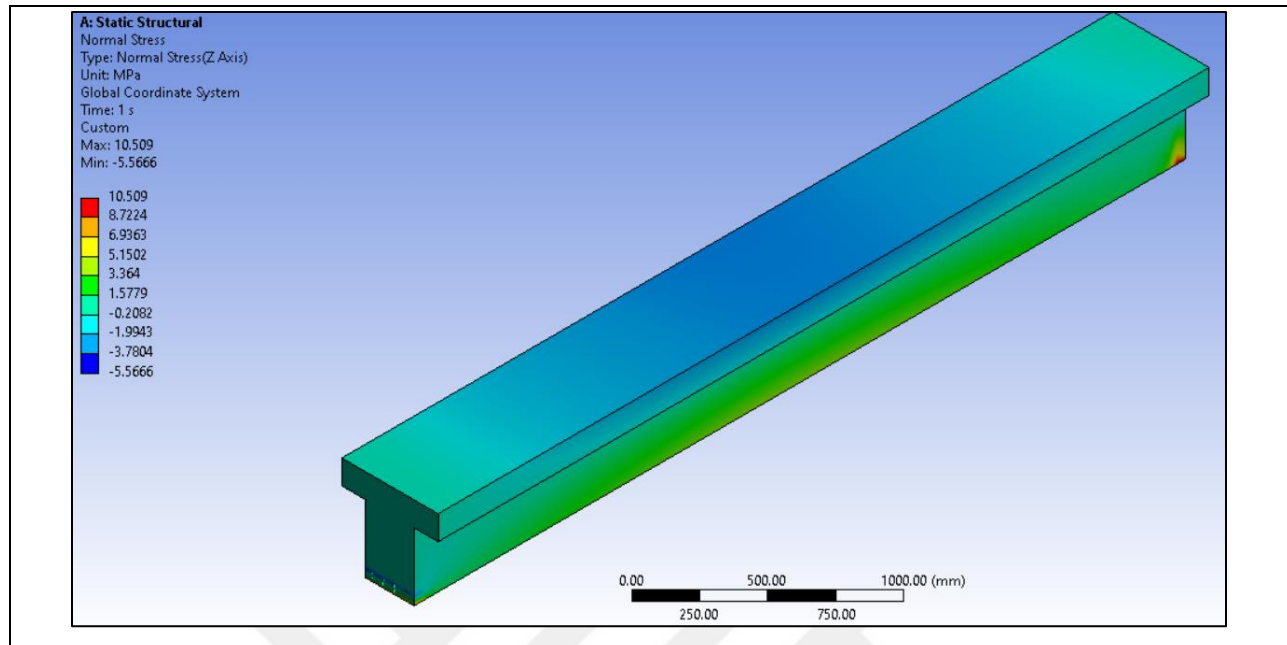


Figure 4.15: Normal Stresses Of T-Section $h_f = 125$ mm, $b = 500$ mm and $W = 50$ kN/m

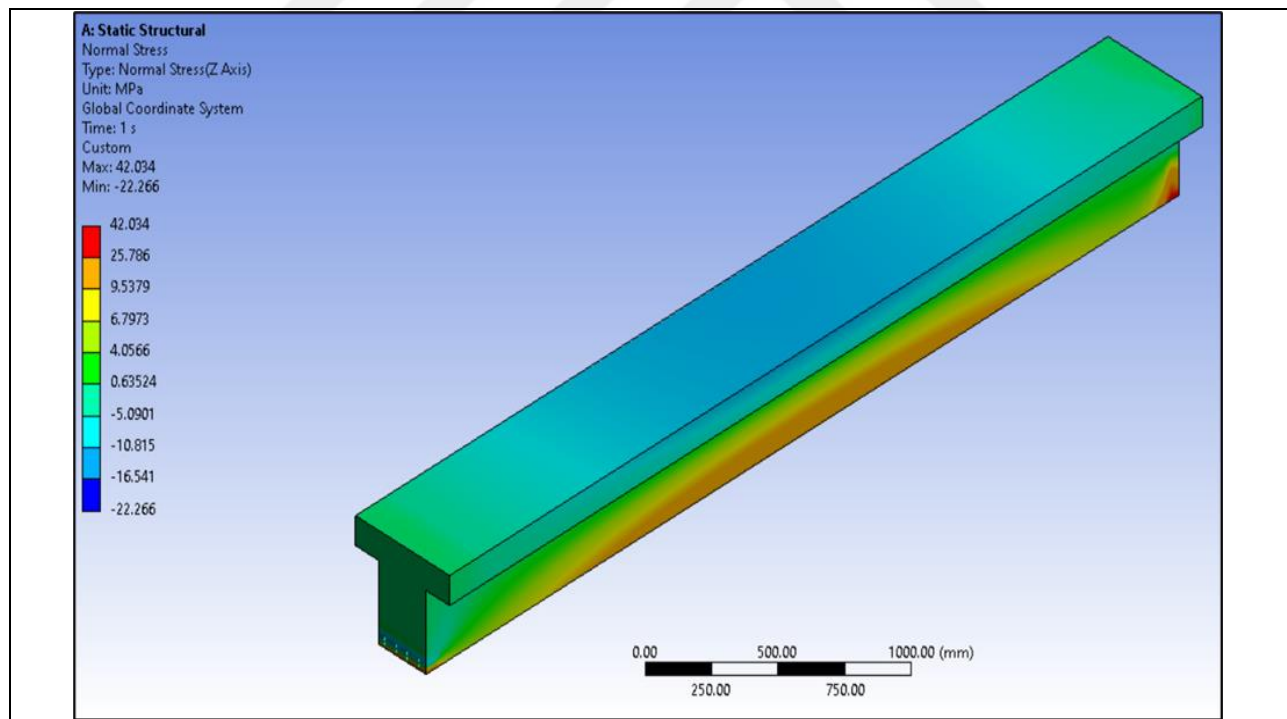


Figure 4.16: Normal Stresses of T-section $h_f = 125$ mm, $b = 500$ mm and $W = 100$ kN/m

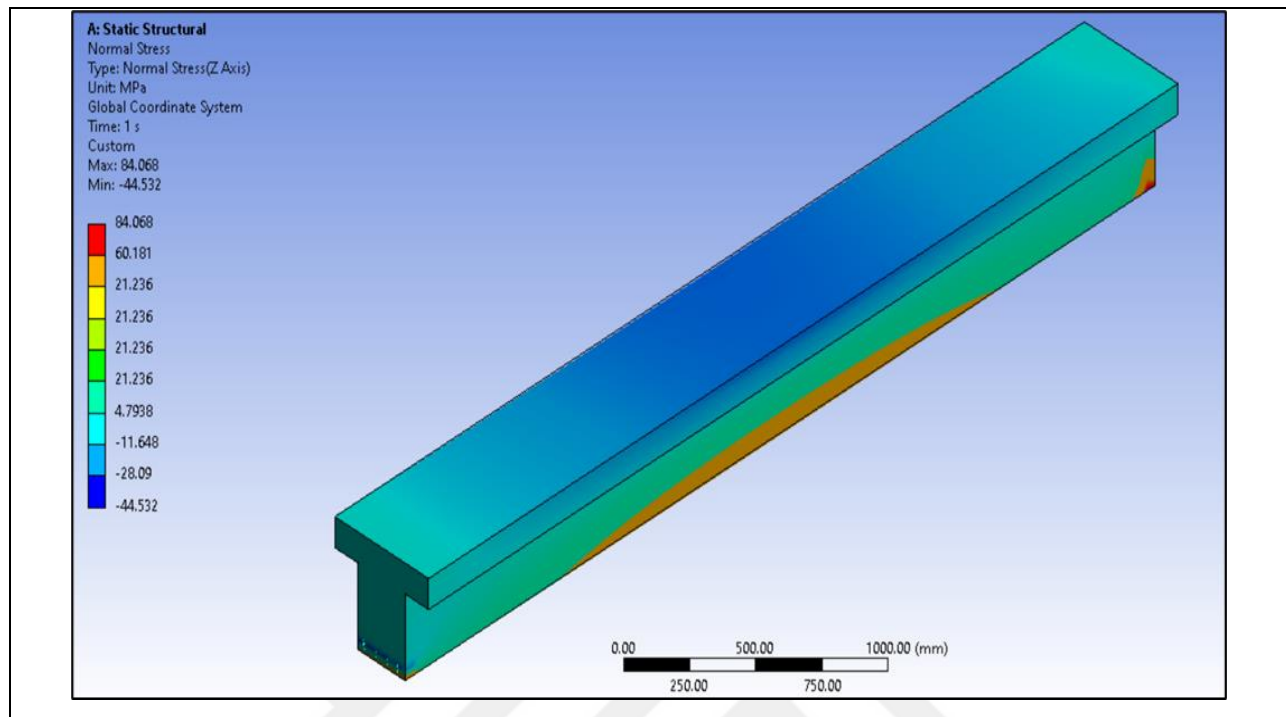


Figure 4.17: Normal Stresses of T-section $h_f = 125$ mm, $b = 500$ mm and $W = 200$ kN/m

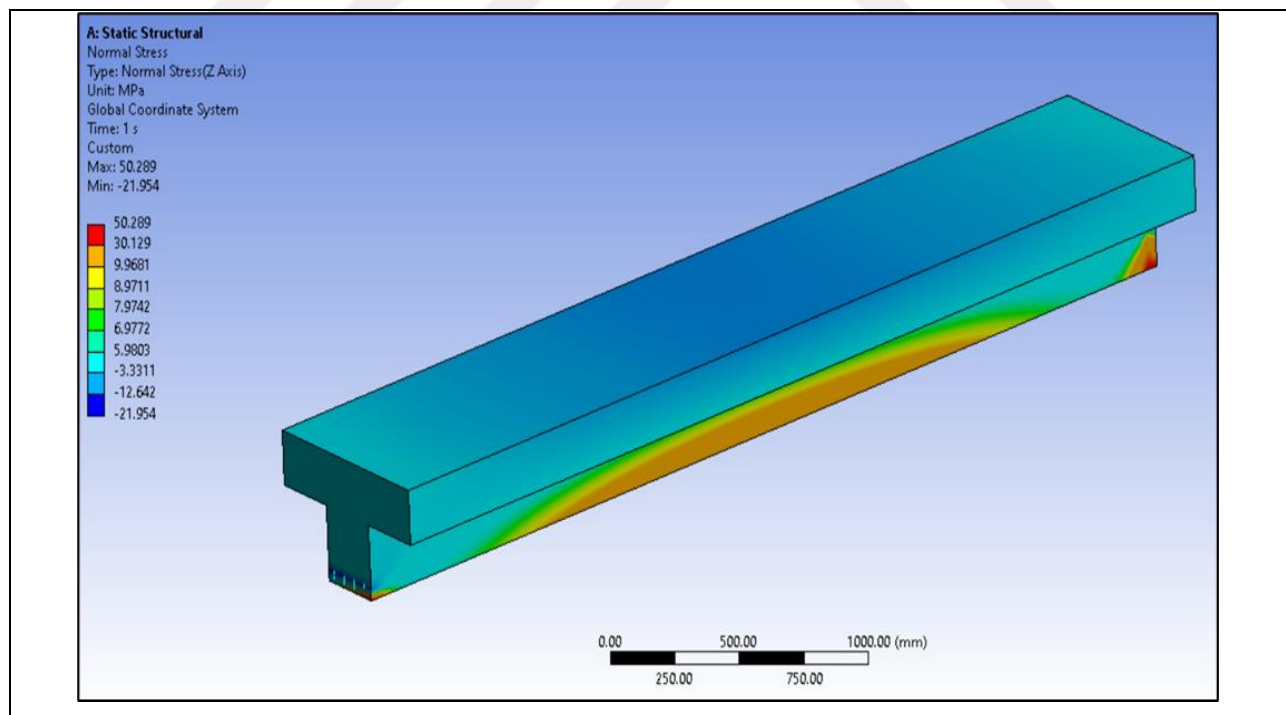


Figure 4.18: Normal Stresses of T-section $h_f = 200$ mm, $b = 7500$ mm and $W = 100$ kN/m

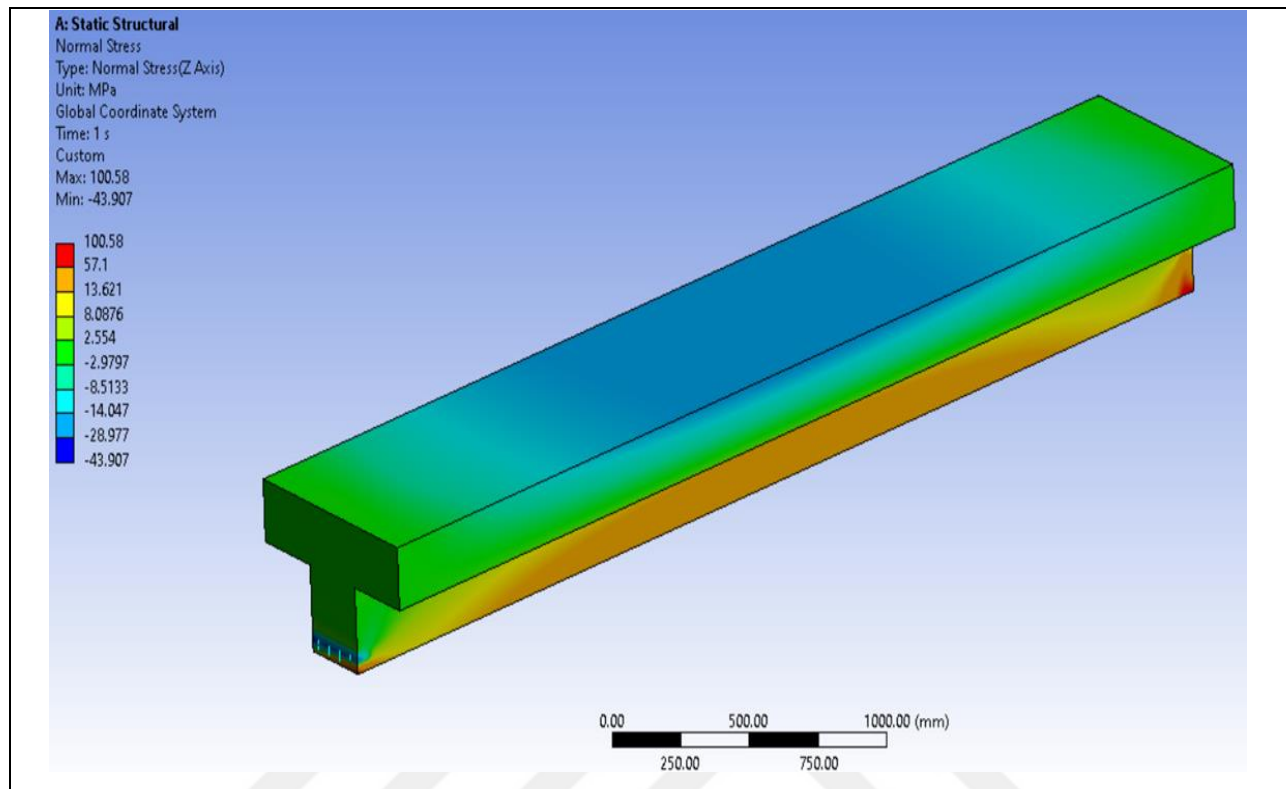


Figure 4.19: Normal Stresses of T-section $h_f = 200$ mm, $b = 7500$ mm and $W = 200$ kN/m

5. DISCUSSION AND CONCLUSIONS

5.1 CONCLUSIONS

The study analyzed the T-section member and processing the stages of design into three main stages:

- a. the first stage included the main structural theory of the T-section design in which the set of the ultimate moment equation based on the depth of flange (h_f), the width of flange (b), the width of web (b_w), the effective depth (d), and the reinforced area (A_s). The study showed the calculation steps when the distance to the neutral axis from the upper level of the section (a) been more the depth of the flange (h_f).
- b. The second stage was included the derived of equations that contained more merged of the main parameters in the output. The derived equation then converted with the ultimate moment magnitude to give the residual strength (R). the residual strength values be in positive when the design strength is more than external stress, while the opposite is get when the R value in negative in which the section cannot handle the applied loading at these condition. For simplifying the matter. The study made many numbers of drawings and curve fittings processes for each parameter and the value of R .
- c. The third stage included the collection of the curve fitting equations and calibrated each equation with percent of affectivity that calculated for each parameter. The study checked the results of R for ordinary and derived way of identifying then corrected the equation by adding a part in which the equation can cover more magnitudes of the uniform loading . The equation can be used to identify the minimum magnitude of each parameter to satisfy $R''=0$ in which the strength in the member equal or close to the external moment applied
- d. The simulation of the cases of T-section inside the ANSYS program was made for number of cases including variation of the depth of the T-section. The load were calculated for $W = 50$, 100 , and 200 kN/m for case 1 and $W= 100$ and 200 kN/m for case 2. The stresses indicated by the program showed increasing in tension and compression magnitudes according the geometry of the sections and the impact of the increment of the applied loading.

5.2 FUTURE WORK

The analysis and modeling of more cross section shapes of beams can be studied through coming studies. The modeling of non-rectangular cross sections or deep beams can be considered to improve the design of these members. The advanced strength of the RC beams and T-section beams can be used as future ideas of study like modeling of pre-stressed RC beams or high strength concrete beams to investigate the effect of updating for the strength portion on the structural performance of that member under various loading conditions .



REFERENCES

- [1] S. Andersson and H. Karlsson, "Structural Response of Reinforced Concrete Beams Subjected to Explosions," p. 236, 2012.
- [2] P. Thanthirige *et al.*, "Flexural Response of Reinforced Concrete Beams Using Various Cementitious Materials," no. August, 2016.
- [3] B. Hamad and O. B. Adnan Masri, Hisham Basha, "BEHAVIOR OF T-SHAPED REINFORCED CONCRETE BEAMS PARTIALLY CONFINED BY STRUCTURAL STEEL." 2011.
- [4] A. Arnesen, S. I. Sorensen, and P. G. Bergan, "Nonlinear Analysis of Reinforced Concrete.," *IEE Conf. Publ.*, vol. 2, no. November, 1979.
- [5] H. Panggabean and N. Pakpahan, "Experimental analysis of T-beam reinforced concrete with holes," *MATEC Web Conf.*, vol. 195, pp. 1–10, 2018, doi: 10.1051/mateconf/201819502006.
- [6] G. Ni, B. Liu, X. Li, and W. Yan, "Experimental Study on Concrete T-Beams Strengthened with Carbon Fiber Reinforced Polymer (CFRP) Sheets on Three Sides," *Syst. Eng. Procedia*, vol. 1, pp. 69–73, 2011, doi: 10.1016/j.sepro.2011.08.012.
- [7] R. M. Abbas and W. A. Fadala, "Behavioral Investigation of Reinforced Concrete T-Beams with Distributed Reinforcement in the Tension Flange," *E3S Web Conf.*, vol. 318, p. 03010, 2021, doi: 10.1051/e3sconf/202131803010.
- [8] H. M. Abdulhusain and M. A. Ismael, "Flexural Behaviour of Hollow Reinforced Concrete T-Beams," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1090, no. 1, p. 012133, 2021, doi: 10.1088/1757-899x/1090/1/012133.
- [9] S. A. Yaseen, "Flexural Behavior of Self Compacting Concrete T-Beams Reinforced with AFRP," *Eurasian J. Sci. Eng.*, vol. 4, no. 2, pp. 178–191, 2018, doi: 10.23918/eajse.v4i2p178.
- [10] A. K. Ajay, A. U. Rao, and N. A. P. Shenoy, "Parametric study on t-beam bridge," *Int. J. Civ. Eng. Technol.*, vol. 8, no. 6, pp. 234–240, 2017.
- [11] A. Husain and M. M. Uddin, "Seismic Analysis of T-Beam Bridge Using Finite Element Method," *Www.Trpubonline.Com*, vol. 1, no. 1, pp. 340–346, 2016, [Online]. Available: www.trpubonline.com

- [12] P. Zhang and X. Wei, "Study on flexural strength and flexural modulus of elasticity of cement stabilized aggregate," *Adv. Mater. Res.*, vol. 287–290, no. July, pp. 990–993, 2011, doi: 10.4028/www.scientific.net/AMR.287-290.990.
- [13] F. H. Wittmann, "Modulus of rupture, tensile strength, and fracture energy: an application of non-linear fracture mechanics," *Restor. Build. Monum. an Int. J. = Bauinstandsetz. und Baudenkmalpfl. eine Int. Zeitschrift*, vol. 11, no. 3, pp. 141–150, 2005.
- [14] K. N. Hong, J. W. Han, D. W. Seo, and S. H. Han, "Flexural response of reinforced concrete members strengthened with near-surfaced-mounted CFRP strips," *Int. J. Phys. Sci.*, vol. 6, no. 5, pp. 948–961, 2011, doi: 10.5897/IJPS10.222.
- [15] I. Merta and S. Kravanja, "COST-OPTIMUM DESIGN OF REINFORCED CONCRETE T-SECTION BEAMS T-SECTION BEAMS Faculty of Civil Engineering," no. September, 2015.
- [16] R. Zhang, P. Hu, K. Chen, X. Li, and X. Yang, "Flexural behavior of t-shaped uhpc beams with varying longitudinal reinforcement ratios," *Materials (Basel)*, vol. 14, no. 19, 2021, doi: 10.3390/ma14195706.
- [17] E. K. Sayhood, N. S. Mohammed, and A. S. Hanon, "Effect of web openings on effective flange width of reinforced concrete T-section," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 737, no. 1, 2020, doi: 10.1088/1757-899X/737/1/012002.
- [18] J. E. Wickline, "A Study of Effective Moment of Inertia Models for Full-Scale Reinforced Concrete T-Beams Subjected to A Tandem-Axle Load Configuration," no. September, p. 117, 2002.
- [19] A. I. Said, A. H. A. Al-ahmed, and D. M. Al-fendawy, "STRENGTHENING BEHAVIOR OF REINFORCED CONCRETE T-BEAMS USING EXTERNAL PRESTRESSED TENDONS," no. November 2016, 2017.
- [20] I. Muhammad and A. Mahmood, "Developing a Computer Program for Analysis and Design of Reinforced Concrete Sections; AD RCS," 2004.
- [21] D. Lavorato, A. V. Bergami, G. Fiorentino, A. Fiore, S. Santini, and C. Nuti, "Experimental tests on existing RC beams strengthened in flexure and retrofitted for shear by C-FRP in presence of negative moments," *Int. J. Adv. Struct. Eng.*, vol. 10, no. 3, pp. 211–232, 2018, doi: 10.1007/s40091-018-0193-1.
- [22] A. El-Megharbel, "Stress distribution for T-section beams made of functionally graded

- mterial.” 2011.
- [23] M. Tazarv, “Development of Alternative Bridge Superstructures for South Dakota Local Roads,” no. April, 2019.
 - [24] “BEARINGS & THEIR CONFIGURATIONS WITHIN BRIDGE SYSTEM,” no. October, 2021.
 - [25] O. Kerokoski and H. Pétursson, “Integral bridge abutment - Approach embankment interaction,” *Large Struct. Infrastructures Environ. Constrained Urban. Areas*, no. April 2020, pp. 462–463, 2010, doi: 10.2749/222137810796025429.
 - [26] A. Nalawade, R. Jadhav, Y. Bharat, A. Phad, S. Tipole, and D. W. Gawatre, “Case Study on Design and Analysis of Simply Supported and Continuous Bridge-A Review,” *Int. J. Eng. Technol. Sci. Res.*, vol. 5, no. 3, pp. 1027–1035, 2018.
 - [27] G. Somani, “A Comparative Study on T Girder Bridge Deck using Grillage Analogy and Finite Element Method,” vol. 10, no. 06, pp. 85–98, 2021.
 - [28] Sekaran *et al.*, “A METHODOLOGY FOR CONDITION ASSESSMENT OF T-BEAM BRIDGES WITHOUT STRUCTURAL PLANS,” *Pakistan Res. J. Manag. Sci.*, vol. 7, no. 5, pp. 1–2, 2018, [Online]. Available: <http://content.ebscohost.com/ContentServer.asp?EbscoContent=dGJyMNLe80Sep7Q4y9f3OLCmr1Gep7JSsKy4Sa6WxWXS&ContentCustomer=dGJyMPGptk%2B3rLJNuePfgeyx43zx1%2B6B&T=P&P=AN&S=R&D=buh&K=134748798%0Ahttp://amg.um.dk/~media/amg/Documents/Policies and Strategies/S>
 - [29] S. Kumar and S. Jyoti, “Analysis of Structure and construction of the R . C . C . T-girder Bridge under Different types of IRC Class Loading,” vol. 9, no. 8, pp. 87–91, 2021.
 - [30] A. Kumar and N. Kushwaha, “A Review Study on Analysis of Concrete T Beam Girder Bridge,” *Int. J. Trend Sci. Res. Dev. Int. J. Trend Sci. Res. Dev.*, vol. 4, no. 6, pp. 93–95, 2020, [Online]. Available: <https://www.ijtsrd.com/engineering/civil-engineering/33305/a-review-study-on-analysis-of-concrete-tbeam-girder-bridge/abhinav-kumar%0AURL:https://www.ijtsrd.com/papers/ijtsrd33305.pdf>
 - [31] A. A. Kokkonda Sricharan, Mohd Ibrahim Hussain, Shaik Laeeq Ahmed, “Analysis and Design of Concrete T-Beam Girder Bridge and Box Girder Bridge: A Comparative Study,” *Irjet*, vol. 8, no. 4, pp. 1541–1544, 2021.
 - [32] R. J. S. Sher, M. Irfan-ul-Hassan, M. T. Ghafoor, and A. Qayyum, “Analysis and Design

- of Box Girder and T-Beam Bridge Superstructure - A Comparative Study,” *Mehran Univ. Res. J. Eng. Technol.*, vol. 39, no. 3, pp. 453–465, 2020, doi: 10.22581/muet1982.2003.01.
- [33] M. S. Kamatagi and M. Manjunath, “Comparative Study of design of longitudinal girder of T-Beam Bridge Using IRC 21-2000 & IRC 112-2011,” *Int. Res. J. Eng. Technol.*, no. September, 2015, [Online]. Available: www.irjet.net
- [34] Manjare Priyanka Balasaheb, “Strengthening of Reinforced Concrete T-Beams with externally bonded FRP Sheets to improve Shear Strength,” *Int. J. Eng. Res.*, vol. V9, no. 07, pp. 1330–1338, 2020, doi: 10.17577/ijertv9is070588.
- [35] R. Concrete and D. R. Beams, “Introduction to T-Beams,” pp. 1–16, 2002.
- [36] S. S. Ghodke, “Experimental Study on Shear Strengthening of RC T-Beams with Web Openings using FRP Composites,” *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 8, no. 6, pp. 1070–1079, 2020, doi: 10.22214/ijraset.2020.6173.
- [37] A. G. Sherif, M. B. Emara, W. Abdel-Raouf, and S. A. Aboul-Magd, “Deflections of T-shaped reinforced concrete cantilever beams,” *Proceedings, Annu. Conf. - Can. Soc. Civ. Eng.*, vol. 2003, no. January 2003, pp. 1254–1265, 2003.
- [38] M. Z. Yousif and L. K. Salman, “Experimental Evaluation of Effect of Flange Dimensions on Shear Behavior of NSC and SCC Double Tee Beams,” vol. 30, no. 17, pp. 3039–3053, 2012.
- [39] A. Ayensa, E. Oller, B. Beltrán, E. Ibarz, A. Marí, and L. Gracia, “Influence of the flanges width and thickness on the shear strength of reinforced concrete beams with T-shaped cross section,” *Eng. Struct.*, vol. 188, pp. 506–518, 2019, doi: 10.1016/j.engstruct.2019.03.057.
- [40] C. Giaccio, R. Al-Mahaidi, and G. Taplin, “Experimental study on the effect of flange geometry on the shear strength of reinforced concrete T-beams subjected to concentrated loads,” *Can. J. Civ. Eng.*, vol. 29, no. 6, pp. 911–918, 2002, doi: 10.1139/l02-099.
- [41] C. C. Ferreira, M. H. F. M. Barros, and A. F. M. Barros, “Optimal design of reinforced concrete T-sections in bending,” *Eng. Struct.*, vol. 25, no. 7, pp. 951–964, 2003, doi: 10.1016/S0141-0296(03)00039-7.
- [42] J. Liu, Y. Yang, H. Song, and Y. Wang, “Numerical analysis on seismic behaviors of T-shaped concrete-filled steel tubular columns with reinforcement stiffeners,” *Adv. Struct. Eng.*, vol. 21, no. 9, pp. 1273–1287, 2018, doi: 10.1177/1369433217739708.

- [43] Y. Zhang, M. Elsayed, L. V. Zhang, and M. L. Nehdi, "Flexural behavior of reinforced concrete T-section beams strengthened by NSM FRP bars," *Eng. Struct.*, vol. 233, no. August 2020, p. 111922, 2021, doi: 10.1016/j.engstruct.2021.111922.
- [44] Ali Sabah Al Amli, Nadhir Al-Ansari, and Sabah Jasim Dahboosh Shejiri, "Repairing of RC T-Section Beams with Opening by CFRP for Cracks and Ultimate Torque," *J. Civ. Eng. Archit.*, vol. 12, no. 2, pp. 83–90, 2018, doi: 10.17265/1934-7359/2018.02.001.
- [45] S. Edlund and D. Thesis, "Buckling of T-Section Beam- Columns in Aluminium with or without Transverse Welds," 2000.
- [46] A. Mahmoud, A. Hassan, F. Khairallah, and H. Mamdouh, "Effect of Flange Openings on T-Section Beams Performance," *J. Eng. Res.*, vol. 167, no. septamper, pp. 1–8, 2020, doi: 10.21608/erj.2020.139815.
- [47] K. Ciesielczyk, M. Szumigala, and J. Ścigallo, "The Numerical Analysis of the Effective Flange Width in T-section Reinforced Concrete Beams," *Procedia Eng.*, vol. 172, no. June, pp. 178–185, 2017, doi: 10.1016/j.proeng.2017.02.047.
- [48] E. Kanthasamy *et al.*, "Web Crippling Behaviour of Cold-Formed High Strength Steel Unlipped Channel Beams," *Buildings*, vol. 12, no. 3, 2022, doi: 10.3390/buildings12030291.
- [49] U. Kytölä, J. Tulonen, and A. Laaksonen, "Longitudinal shear in the tension flanges of composite concrete beams made continuous," *Struct. Concr.*, vol. 23, no. 2, pp. 1100–1117, 2022, doi: 10.1002/suco.202100561.
- [50] N. T. Mascia and E. A. Nicolas, "Concerning timber-concrete panels and T-beams for rural bridges," no. January 2008, 2015.
- [51] M. Z. Al-mulali and M. W. Falah, "T-beam analysis and design," no. July, 2019.
- [52] MacGregor y Wight, "Reinforced Concrete Mechanics and Design," pp. 1–3, 2011.
- [53] H. A. Mohammed, "SPAN CONSIDERATION FOR DESIGNING," no. April, 2020.