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NUMERICAL ANALYSIS FOR EVALUATING THE PERFORMANCE OF BEAMS WITH LONGITUDINAL HOLES

Entesar ALMASYABI

Master's Thesis

Supervisor

Prof. Dr. Tuncer ÇELİK

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The thesis titled “NUMERICAL ANALYSIS FOR EVALUATING THE PERFORMANCE OF BEAMS WITH LONGITUDINAL HOLES” prepared by ENTESAR ALMASYABI and submitted on 05/12/2022 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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ABSTRACT

NUMERICAL ANALYSIS FOR EVALUATING THE PERFORMANCE OF BEAMS WITH LONGITUDINAL HOLES

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The study of the reinforced concrete is effective procedure in the building design. The weakening of these elements can reflect severe problems to the design of the constructions. The shape of the longitudinal holes and the position with respect to the cross sections geometrical design can impact the available internal strength of the element toward the formation of the stresses leading the problems of cracks to be happened. The study aimed to analyze the RC beam with cases of longitudinal holes by identifying the cracking stress and as well the cracking loading according to available compressive strength of the concrete. The study procedure of analysis takes four cases of the longitudinal holes. The cases were rectangular hole in compression zone, rectangular hole in tension zone, circular hole in compression zone, and circular hole in tension zone. The maximum strength for untracked section was identified based on the four cases. The study took into account the area of the hole and the place according to the neutral axis for each case. The longitudinal hole in compression zone is so important as these cases can still impact the overall strength of the member after the stresses passed the cracking section threshold. The study the two shapes of holes presented close impact of the internal strength of the member in the case of uncracked and cracked section. The study derived two equations based on the area of the hole and the available reinforcement in which each case of hole shape supported by one equation to find out the internal strength of the member. The equation for the rectangular hole was: $Mcr=-0.0002\ Ao+ 0.0015\ As+18.957$ for rectangular and $Mcr=-0.0002\ Ao+0.0015\ As + 18.908$ for circular shape. For the case of cracked section, the equation was: $Mu=-0.0002Ao+0.0281As+71.77$ for rectangular hole and $Mu=-0.0008\ Ao+0.028\ As+70.893$ for circular hole. The simulation of the cases was made using the procedure of finite element that provided inside ANSYS workbench program. The study showed in images the stresses behavior and deformation for RC beams that included longitudinal hole in case of rectangular and circular shape.

Keywords: Flexural Analysis, Bending Moment, Longitudinal Holes.

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ABBREVIATIONS

Ac	:	Area of Cross section
At	:	Area of the Transform section
As	:	Area Steel
FEM	:	Finite Element Modeling
WSD	:	Working Stress Design
NFEM	:	Non-linear Finite Element Model
MR	:	Modulus of Rupture

LIST OF SYMBOLS

T : Tension

C : Compression

M_{cr} : Cracked Moment

I : Moment of inertia

d : Depth of beam

h : Height of beam

b : Width of beam

1. INTRODUCTION

1.1 OVERVIEW

In structural engineering, a concrete is a massive amount connecting item that can handle both and vertical loads. These beams are made by wrapping metal bars, plates, or natural fiber within concrete. They are also known as reinforced skin of concrete beams or bolstered cement concrete (RCC) beams. Steel reinforcing strengthens the element, enabling the beam to endure tension forces and resist bending. Once exposed to the applied loads above it, the concrete beam without reinforcing steel may become fragile and crack. Cinderblock beams are commonly used in numerous building projects, especially in road bridge design. Pre - cast concrete beam carcasses are frequently used it for bridges [1]. Such beams are made by stretching high-strength steel tendons, pouring concrete on top of them, and then going to release the tendons while the cement cures. In steel structure building, rectangle and ubiquitous beam cross - section have been commonly used. An I-beam, a broad beam, or a widespread column are other names for the universal beam [2]. Technicians must assess how much trying to load a tangible piece could indeed safely bear and the types of forces that will exercised on it in order for a building to be extremely durable. Girder deformations are similarly decided to seek for structural purposes in a secure environment, such as reducing beam contact when accompanied by brittle construction materials. Beam deformations can also be employed to make the architecture more visually appealing by ensuring that there are no sags inside the beams [3].When carrying a connecting moment, a body of concrete beam of rectangular section is strengthened exclusively on its tensile side. This is the most basic and simple reinforced concrete member, for which the mechanical process and responses have been thoroughly tested and reported. When the beam is easily supported on all ends and more than one concentrated load is symmetrically acted above its span, the middle part of the span is of pure joining and the major responses during testing include giving out of average strain, position of actual axis, strain (stress) of reinforcement, and curvature of the section [4].

When an element is subjected to a positive bending action of moment, it develops a concave-upward curvature. Intuitively, this suggests that the element towards the top of the element is compressed along the x axis, while the bottom portion is tensioned. The stress reaches zero in the condition of transition between the compressive and tensile areas; this is the neutral axis of the beam. If the failure occurred in tension, it will do so in the future due to crack initiation and growth from the lower tensile surface [5]. If an element is strong in tension but weaker in compression, this will fail at the top compressive surface; this may be seen in a piece of wood by compression buckling of a outer fibers. Cracks are a common type of defect and damage to reinforced concrete structures. They can be found in both the manufacturing and operating classes [6]. Excessive tension of the reinforcement in pre-stressed constructions, an insufficient protective layer of concrete, shrinkage of concrete, and a high heat during welding in which of mating element units could all be causes of cracking. The occurrence and upgrade of cracks in bearing reinforced concrete structures occur as a result of their deformation inside the impacts of loads, temperature changes, and uneven sinking in which of buildings and structures. The emergence of cracks in connected elements does not imply that its carrying capacity has been exhausted. It results in increased efforts in the parts accompanied by a crack, which diminishes the element strength. Furthermore, as a result of crack opening, the corrosion of reinforcement rises, reducing the structure's endurance. The standards govern the extent of crack opening based on the force condition in the portion having a crack. Because cracks exist in all reinforced concrete structures, determining the pressure state in a cross section accompanied by a crack is critical for understanding the reliable state of the structure under operation [7].

1.2 COMPRESSIVE STRENGTH

The ability of a material or structure to resist or withstand internal compression is referred to as compressive strength. A material's compressive strength is determined by its capacity to withstand failure in the form of cracks and fissures. Concrete checking aids in focusing on the compressive strength of concrete because it allows us to quantify the body's ability of concrete to resist compressive stresses among constructions, while other applied stresses such as together across axis stresses and tensile stresses are catered for by reassurance and other implies [8]. Concrete is a mixture of sand, cement, and aggregate. The strength of a concrete body is determined by a number of elements, including the individual compressive strength of its constituents (cement, sand, aggregate), the validity of the materials used, air entrainment mix proportions, water-cement ratio, curing procedures, and temperature impacts. Compressive strength provides a sense of overall strength and the elements stated above. By doing this test, one can simply determine the concrete strength psi and the legitimacy of the concrete produced [9].

1.3 FACTORS INFLUENCE COMPRESSIVE STRENGTH

1.3.1 Coarse Aggregate

Concrete is homogenized by blending aggregates, cement, sand, a certain amount of water, and varied in not as admixtures. However, even with correct mixing, some micro cracks may form because to variations in the thermal and mechanical properties of coarse particles and cement matrix, resulting in concrete failure. Concrete scientists developed theoretical notions based on aggregate size, with aggregate size being the primary contributor to compressive strength. As a result, increasing the size of the aggregate may result in enhanced compressive strength [10].

1.3.2 Air-Entrainment

Entrapped air in concrete was one of the methods used by cold areas to avoid damage from freezing and thawing. Later, experiments demonstrated the multiple benefits of air entrainment, as well as improved the workability of concrete at a low water/cement ratio. As a result of achieving the desired workability at a lower water content, one was able to generate a body of concrete with a higher compressive strength, which in turn caused a lighter body of concrete with such a compressive strength [11].

1.4 COMPRESSION AND TENSION STRESSES

Once weight is placed on a beam above its stage, the poundage causes the light to divert attention in bending looking. Comparatively tiny weights on rigid beams cause essentially no deflection, whereas large weight lifting on flexible beams cause significant deflection. The diversion of the element causes the two events to happen: This same beam's top surface is condensed and tries to shorten, whereas the bottom surface is clenched and tries to lengthen[12].Compression is the inverse of tension in that as one proceeds down the element from the top to the bottom, the compressive stress gradually reduces to zero and then the applied load reverse, go out of tension, and start increasing towards the bottom of the beam. The stress switch happens at the midpoint between the upper and mini faces of an unreinforced beam with a symmetrical cross-section (such as a rectangle). This is significant, because there is no subjected to compressive load at the midway of a countertop, placing reinforcing steel there helps nothing. The actual axis is the location where this switch happens, and it can be thought of as an imagined line that runs perpendicular to the beam [13].

1.5 PROBLEM STATEMENT

The construction project requires in cases the workability of concrete beams to be used as the convey lines of other building requirement like the electricity wire bands or cooling system tubes. The creation of longitudinal holes along the beam span can lead to weaken the internal strength of the concrete body under the formation of stresses. The problem can lead to the formation of cracks and to increase the possibility of large deflection or at last the case of failure.

1.6 CONTRIBUTION

The study had built its route to analyze the effective of flexural capacity of concrete beam when casting longitudinal holes inside its body along the span length. The analysis can give figurative view on the possibility to do so and how to avoid any extra problem in the flexural performance of the concrete member under these conditions. The analysis and the simulation can help the designer to detect the allowable external loading and the available strength for better durability of concrete member.

1.7 OBJECTIVE

a) Specifying the initial data like the geometrical behavior of the concrete beam including its width, effective depth, steel area, span length, and number and size of holes.

b) Driving the flexural analysis equation by using ultimate stresses design method and including the influence of holes.

c) Variation of the data to build systematic model that can defining the strength of member with longitudinal holes under different conditions.

d) Simulation of the case study by using ANSYS WORKBENCH program in which built on finite element analysis.

Explaining the result in tables and graphs for better illustrating the impact of the holes on the flexural analysis result

2. LITERATURE REVIEW

2.1 STRESS AND STRAIN BEHAVIOR IN CONCRETE

The stress-strain curve of a concrete body is a graphical representation of the behavior of a concrete body under load. It is provided by graphing the body of concrete compress strain for the different intervals in which concrete compressive forces act stress. Because concrete is usually employed in compression, the compressive stress strain in curve is of particular relevance. The force and strain of concrete are acquired by testing the body of a concrete cylinder specimen for 28 days using a compressive test equipment. This stress strain inside the curvature in concrete allows designers and engineers to predict the behavior of the concrete body used in building constructions. Ultimately, the force strain curve connection and the type of stress to which the body of concrete is exposed in the building determine the performance of the body of concrete structure [14]. Strain-stress higher curves indicate a stronger concrete body. The contour of the concrete body's stress strain in curvature changes depending on the loading. Despite the fact that the speed of testing and the density of the concrete body influence the shape of the stress-strain curve, it can be seen that all curves have almost the same character. In other words, they go through the identical motions when loaded [15]. At first, all stress strain contours are indeed very linear; pressure and tension are roughly proportional. If the load is taken away throughout this time, the material could keep its original shape. The elastic values on the concrete force strain graph continue rising to 0.45fc' (maximum concrete compressive strength). The gradient of the elastic body of both the strain curve is the body solid concrete modulus of elasticity. As the concrete's strength increases, so does its elasticity modulus. The ACI Code includes formulae for calculating the elastic concrete elastic properties[16].

When the elastic morals are surpassed, the concrete exhibits plastic behavior (Nonlinear) even as load increases. The in curve begins to horizontalize after the elastic range, resulting in the greatest condense strain (maximum compressive strength). In typical concrete mixtures, maximum stress is reached at push values in the range from 0.1 to 0.003. Along either hand, the stress concentration obtained for said stress of lightweight concrete ranges from 0.003 to 0. 0035. The greater the strength, the higher the strain results on the both curves. This same ACI Code stipulates that the highest strain that normal body weight concrete can achieve is 0.003, and this value is used in the design of a body of the tangible structural element [17].

After reaching maximum strain, all the curves show a declining trend. The testing procedure determines the variables of the force stress curve in the downward part. A lengthy stable having fallen part is achieved by using a particular test method to ensure a coherent stress distribution as cylinder strength decreases. In any case, if the specific test method is not used, the unloading after sharp peak will be rapid, and the downward section of the curve will be different [18]. The typical behavior of strain-stress curve for concrete explained in figure 2.1

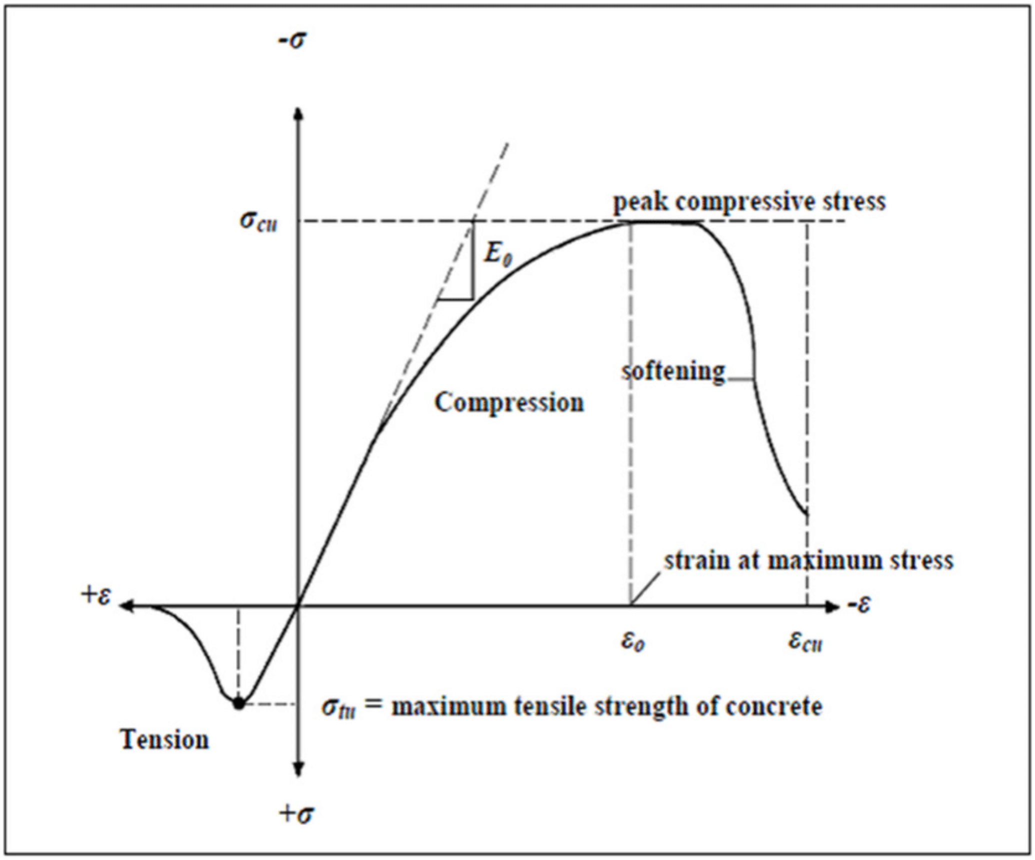

Figure 2.1: Typical Stress-Strain Curve For Concrete [19]

2.2 IMPACT OF HOLES IN RC BEAMS

Gaps and cut - outs in beams decrease the effective area open to fight back shear or joining point in time and must be taken into account. Inside the case of large openings, the lost area must be compensated for by trying to install plates or stringers in the vicinity of the hole or notch. Any material that is removed will undoubtedly deteriorate the structure [20]. Because of its location or size as shown in figure 2.2, the effect of penetration may be minimal in some circumstances. In other circumstances, though, the loss of strength might be severe, necessitating routine strengthening.

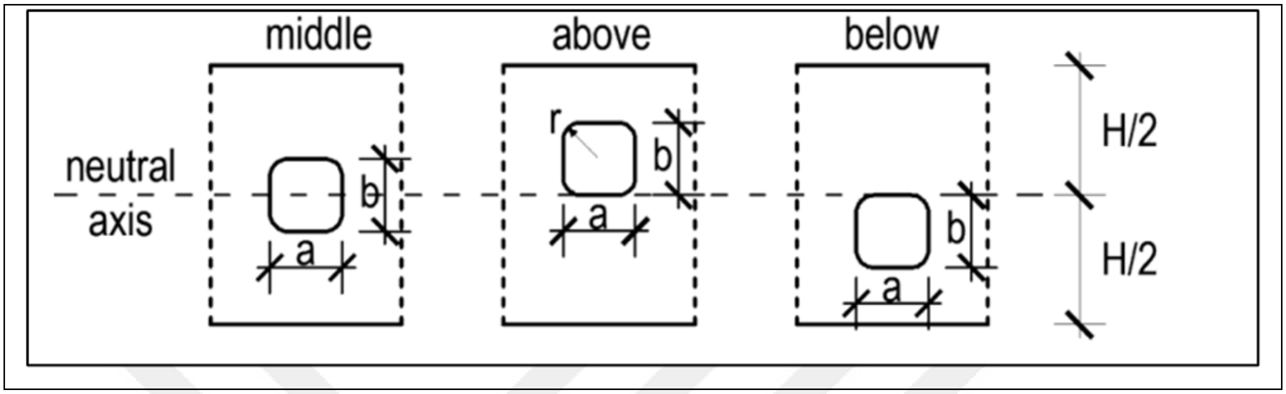

Figure 2.2: The Behavior of Hole Position With Respect To Stress Regions

Two related elements must be considered to determine whether a specific penetration is significant in terms of beam strength. These are [21]:

a) The location of the penetration.

b) The size of the penetration.

To capture the consequences of which notch is prominent, five criteria must be considered [22]:

a) Concentrations of power and strain.

b) Stress gradients.

c) Stress gradients.

d) Local yielding.

vi Crack growth and development.

To locate the holes as well as notches, examine both the cross - sections and the span place. When a position just on section with the least bending force for the pivot point is chosen, it's also the point with the greatest shear force. Correspondingly, bending stress and strain are frequently low near the endorses and higher above them. Each nation must be put to test in regards to the construction element and the forces that act on it. Notches or holes inside the flanges or links of beams, studs, as well as slabs could compromise an element's structural stability [23]. Because the quantity of steel in the flanges resists the majority of the bending moment, future holes or notches in them will affect the element's bend resistance. As a result, flange penetrations are crucial at areas of high bending moments, which are frequently found inside the middle of readily supported beam and in the region of internal aids for beams. The susceptibility of a steel beam to shear force is governed mostly by the area of steel in its web, and so penetrations in the web of a beam are likely to alter its shear strength [24].

A volume of shear in the beam at the position of the penetration determines the impact of a web puncture; shear are strong near the anchors which of the beam, regardless of whether they are simply assessed or continuous. Shear forces are typically low or negligible in the center of beams, increasing towards to the supports [25]. To assess the impact of a permeation on a web, try comparing the shear again for permeation to the sheer and utter ability of the component with part of a web deleted; if beam strengthening is required, add an area equivalent to that deleted as close to the cut out hole as possible; and a qualified systemic designer must be consulted for details. Before performing the incision, the beam should usually be supported up. This will prevent the element from becoming overly stressed or distorted when in a weaker state [26].

2.3 CIRCULAR HOLES IN RC BEAMS

Circular holes are preferred because square holes can cause stress concentrations, increasing the danger of cracking. Long rectangular holes are not advised since they can have a considerable effect on the structural act of the component. Furthermore, holes could be placed distant from points of significant bending action of tension or shear. Except for very small holes, entire holes should be 'framed' by link and transverse steel [27]. Scholastically, it should be allowed to punch a hole in the tension zone of a concrete element because the body of cement is not directly transferring the tensile stress, however if the hole is large enough, it may propagate a visible fracture all the way to the top of the beam. A will weakened confidence in the structure's safety. It is preferable to drill a hole directly above the N-axis, insert a steel sleeve, and grout it as quickly as feasible [28].

2.4 CONCRETE BEAM STRUCTURAL REQUIREMENTS

Structures must adapt and transfer external loads to the ground, as well as deal with the equivalent internal factors (normal force, shear force and moment). This creates stresses and deformations in the structure, which must be controlled so that they do not exceed the specified strength and deformation limitations. A full cross section with little damage and correct element grades is expected when constructing new structures. However, when constructing timber buildings, the cross section and/or qualities of the material/product in which the members can be lowered to avoid mechanical and biological deterioration [29]. All types of injuries have an impact on the loads carrying capacity and serviceability of single-state components or the entire structure. Damage or failure must be recognized and assessed during the assessment of timber structures in order to determine the resistance and serviceability of the timber structure. The observed net cross sections at failures and damages must be compared to the planned cross sections [30].

2.5 THE VALUE OF CONCRETE STRENGTH

Concrete strength improvement methods or equipment are constantly being improved. Testing methodologies, like data interpretation, are evolving and becoming more sophisticated. But the quality in which of concrete is majority based on it is strength. It is also the strength of the concrete body that determines whether or not concrete should be used in a construction. Give commands are used to identify the same thing in different structures. First-floor columns in high-rise buildings, for example, are more structurally essential than nonbearing walls. A lack of sufficient strength can result in costly, risky, and difficult repairs or, in the worst-case scenario, a catastrophic failure [31]. Clearly, the overall quality of any construction is critical, but the degree is determined by its in-construction state aspects. Consideration of the strength specifications is also required for estimating the finalized mix, as the predicted proportions are dependent on the assumed strength for finalizing the ingredients' qualities [32].

2.5.1 Concrete Compressive Strength

Compressive strength is a commonly acknowledged measure of a certain body of concrete mixture's performance. Considering this component of the concrete body is significant since it is the fundamental metric determining how effectively the concrete body can withstand forces that impact its size. It expressly states whether or not a specific blend is suitable to meet the criteria of a specific project [33]. Concrete is extremely resistant to compressive loading. This is why it can be used to build arches, columns, dams, foundations, and tunnel linings. The compressive strength of concrete is determined using cylindrical specimens constructed of new concrete. It is then compressed and tested for various ages. The indicated strength may also be affected by the size and appearance. Additional tests are carried out in order to gather detailed information on the competency of strength growth [34].

2.5.2 Concrete Tensile Strength

Tensile stress is an object's resistance to a force with the possibility to tear it apart. It is calculated using the highest strain that result could indeed withstand without trying to tear and is evaluated in N/mm2, though it was previously specified in tons/inch2. Stress is defined as the force applied to each unit area of a material, as follows: Tensile Force divided by cross-sectional area equals stress. Tensile strain measures the strength of a material; thus, it refers to the a pressure that tries to rip apart or broaden the material. Numerous mechanical characteristics of a material can be determined using a tensile test. Tensile stress is similar to ordinary stress or tension. When the applied stress is less than the material's tensile strength, the material returns to its previous shape and size, either totally or partially. Even as force reaches the scale of the tensile strength, the element begins to flow plastically and soon creates a confined region is called a neck, which is where it fractures [35]. The tensile strength of a concrete body is its ability to withstand cracking or breaking under internal tension. Although the body of concrete in a construction is rarely loaded at pure stress, determining the tensile strength is needed to determine the degree of the probable damage. Cracking and cracking occur when tensile forces exceed tensile strength. Traditional body of concrete has relatively high compressive strength in comparison to tensile, which really is significantly lower in comparison to ultra-high act concrete. This means that any concrete construction that may be subjected to tensile force must first be reinforced with high tensile strength materials such as steel. The understanding of the tensile strength of concrete is expanding due to its importance in regulating crucial cracking [36].

Nevertheless, assessing the tensile strength of concrete is fairly difficult there is no field test for direct assessment. However, indirect methods such as splitting are extremely beneficial. According to studies, the tensile strength of typical concrete ranges between 300 and 700 psi, or 2 to 5 MPa. That means that, on average, the stress is around 10% of the compressive [37].

2.5.3 Concrete Flexural Strength

Concrete's flexural strength determines its capacity to endure bending. It is an approximate measure of tensile strength. Let's look at a classic illustration of flexure strength – Many constructions, including pavements, slabs, and elements, as well as their components, are prone to bending or flexure. When it comes to beams, they might be loaded in the center or supported at the ends. Its lower fibers are tense, while its upper fibers are compressed [38]. Whether this beam is made of concrete, it will experience tensile failure in the micro fibers due to the body's lower tension. However, incorporating a few steel bars in the lower region in the future will sustain a greater amount of substantial load of the reinforcement bars has great specific strength. The beam will stay robust if the reinforcing steel is pre-stressed in cement. Its flexural of a concrete body is typically measured by testing a simple beam at each of the third points with concentrated loading. Following that, the numbers are given as a Modulus of Rupture (MR) in psi. Flexural strength should be between 10% and 15% of compressive, dependent on the concrete composition [39].

2.5.4 Concrete Strength Influencing Factors

If asked what adds to the strength of a concrete body, the response is almost everything. However, the following are frequent parameters [40]:

a) Cement variety

b) Cement quantity, quality, or brand

c) Accidental cement substitution

d) The aggregate's cleanliness and grading

e) Proportions of water

f) The admixtures

g) Handling and placement

h) Temperature

i) Curing circumstances

j) The age of concrete when formed and tested

2.6 ULTIMATE STRESS DESIGN TECHNIQUE (STRENGTH DESIGN)

After the 1960s, the ultimate stress design methods became widespread. Prior to then, working force design was extensively utilized to design reinforced bodies of concrete members. When compared to the stress design approach, the ultimate force design method yields a more sensible and inexpensive result. Furthermore, the ultimate stress design methods employ a greater quantity realistic component in which of safety. The steel and concrete structure has been designed beyond the elastic area using this technology. The operational dead loading or live loading are compounded with the use of a safety factor. the portion intended to fail at a calculated load Failing under factored load indicates that the segment has exceeded the elastic region to ultimate strength following that failure [41].

2.6.1 The Benefits of Strength Design

Strength design methods take into account the non - linear system shape which of stress-strain designs, resulting in a more accurate prediction of load carrying capability. Different factors of safety are used in strength design approaches for different types of loads. Dead load and active loading will have distinct safety factors. Dead loading for structures can be anticipated to be more beneficial than live load. As a result, the safety value for dead load will be lower than the safety parameter for active load. The strength derive approach generates a greater number of economic structures. Steel's high strength is used in the strength design process. Using stress design methods makes use of a portion of steel strength. The strength design approach is more adaptable than the working pressure design method. For example, a large portion can be utilized with a small amount of steel, while a tiny section can be used with a large steel bars [42].

2.7 CURRENT WORK

The study examined the state of construction reinforced concrete beam with holes that penetrated along it span. The problem of built-in holes that take portions from the overall strength of the concrete member was investigated and analyzed. The analysis covered the behavior of the holes including the shape and the position of the hole with respect to region of tension and compression in the beam cross section. The structural analysis method was included by the effect of the holes in the study to explain the impact of these conditions on the design output of the member. The study took the effective parameters like the compressive strength of the concrete, the dimensions of the beam and the quantity of reinforcement inside the analysis steps then simulate the cases by using ANSYS workbench program and explain the results in suitable figures.

2.8 LITERATURE SURVEY

(M. Jeleč, et al., 2014) The study demonstrated that the empirical and theoretical work identified herein is useful for developing simple, generalizable and practical design trends and standards. However, glulam beams are difficult to design, and several theoretical techniques for such beams produce widely varying results. Furthermore, many properties affecting these beams have yet to be investigated. Because of these complexities and uncertainties, major timber construction standards have completely defined slotted glulam beams, leaving room for further research. Since the reproducibility of experiments on miniature samples is questionable, further experiments on real dimensional beams are required, especially for beams with wide areas (above 8 m), which have limited experimental data. Furthermore, there are limited experimental data under beams with large height-to-width ratios, whose behavior would be closer to wall shear than beam girders, and whose effect on stability could be essential in establishing the collapse process. There is very little information about beams of different cross-sections, such as trapezoidal (single and double-taper) beams, which already have a complex stress state. The study found that experimental research kept the clip width constant, so more experiments are needed to understand how it affects amplitude. Furthermore, studies have largely determined the loads dependent in semi-periods, thus experiments that expose the beams to long-term loads, assessing the additional effects of creep and humidity changes, are required. Finally, while most studies have focused on simple evaluated packages, the actual constructions are often not statically defined, and include additional overheads whose outcome is unknown [43].

(M. Jelec, et al., 2016) The study found that for CLCLT beams with holes where the greatest variance relates to the distribution of shear stresses over the crossing interactions for each height in any CLT beam, the largest size is determined at the center of the beam height, contrary to some assumption. Except for the torsional shear stresses over the transverse plate crossing region near the hole, the results obtained for CLT beams with holes are in good agreement with the analytical values. Analytical estimates were smaller in all cases because they were calculated by b, which does not account for force concentrations. The second reason for the observed discrepancy is the actual configuration of the longitudinal and transverse plates with respect to aperture position. Analytically determined equations are based on perfect keel models, which cannot represent a random hole position. The tensile load of the glulam beam with holes in the case of tensile strength perpendicular to the axis of the element was calculated using German NA to EC5. Due to the different failure mechanism of the glulam bundles and the perforated CLT, the combined equations must be validated on a larger number of CLT models. Even at large stress concentrations for the angle at which the holes were obtained, the agreement between the mean values for a specified number of models is satisfactory. There are currently no restrictions on how to create such packages; Therefore, further experimental and numerical investigations are planned[44]. M. Al-Kannoon and H. Al-Thabhawee (2018) The study showed that the cast steel girders are those members that are made from I-section hot-rolled steel by first cutting the mesh in a zigzag pattern and then fusing more than two halves by welding together to form a cast hexagonal girder, which increases the depth of the section. In general, web openings are hexagonal in shape; However, octagonal web slots are usually obtained by providing a spacer plate, which is used to result in greater beam depth. Cast beams are becoming increasingly popular in building construction due to their advantageous characteristics such as ease of choice, strength and low cost. The research aims to improve the performance of hexagonal and octagonal cut elements with spacer plates. The strength of the original (original) I-section beam increases to cause its depth to increase. However, increasing the depth of the polished beam leads to another bend in its lattice as well as many other types of failures when loading these beams. Hexagonal or octagonal cantilever beams made of the original first section (IPN140) were studied using finite element modeling (FEM). The results of the investigation revealed that the efficient use of toroidal stiffeners around the edges of the holes contributes to the strength of the web. It has been discovered that the use of toroidal steel stiffeners may reduce the concentration of force near the edge of the holes and improve the behavior of those beams by increasing the final strength and decreasing deflection. Based on the numerical results (FEM) obtained with ANSYS14, it is concluded that adding a spacer plate and annular stiffeners above the web hole can improve the final strength of the polished beam. Moreover, the results showed that the absolute strength of an octagonal steel element could be increased by up to (54%) over the main girder (IPN140) while using only (12.0%) of the weight of the steel (spacer plate plus circular steel stiffeners)[45].

(M. Ardalany, et al., 2013) The study shows a design strategy for perforated LVL beams that relies on regulating the tensile stress applied to the hole margins in order to restore their original capacity. Tests over LVL girders show that screws and plywood can be used to reinforce the holes. Proven samples are presented for designs that use fasteners and wood to strengthen the openings. Screws and plywood can be used to strengthen beams that have holes. For perforated LVL girders, plywood sheets glued and nailed on both sides are the preferred method of reinforcement; However, screws can be used for a limited range of aperture size to beam depth ratios [46].

(H. Al-Thabhawee, 2017) The study demonstrated the evaluation of the effect of cutting a circular hole in an existing steel beam grille on the stiffness response and maximum load capacity (ULC), as well as how to strengthen this hole using annular steel stiffeners. The experimental investigation focused on four steel I-beam cases subjected to concentrated site loads. The first sample was tested using an I-shaped steel beam accompanied by a rigid mesh for a reference (control) case, and the other three samples were tested with the help of a circular hole cut in a steel beam mesh with and without steel ring reinforcement. The test results reveal that the ULC and hardness of the I-shaped steel beams are significantly reduced when making a hole in the web. According to the results of the experiments, the behavior of steel I-girders together with rigid opening gratings using steel grommets is consistent with the behavior of steel beams combined with rigid gratings (before the hole cut). In this study, a non-linear finite element model (NFEM) using ANSYS proportional software was used to simulate all experimental cases. The statistical solutions for all of the above and the stress distribution along the studied beams were compared with the experimental tests. In general, there was good agreement between (NFEM) and experimental results. The objective of NFEM was to perform a parametric analysis to study the effects of three parameters: size, location of the opening mesh, and thickness of the annealed steel ring. It was discovered that the ULC of steel I beams with the opening mesh decreased almost linearly as the mesh hole diameter increased for the hole diameter to element depth (D/H) greater than 1. (0.5). As a result, it is advisable to use annular steel stiffeners with diameters greater than half the girder depth (0.5H) to strengthen steel beams with grating holes) [47]

(M. Bochenski, et al., 2021) The study showed that the effects of hole diameter and position over the dynamic response of a thin-walled cantilever beam made of carbon-epoxy sheets and Eigen frequencies associated with global or common eigen patterns were examined, where the beam wall distortions were predominant, with no significant distortion of the beam line. The research focused on beam arrangement of circumferentially uniform stiffness (CUS). In the numerical case tests, a finite element approach was used with the Abaqus software package. Moreover, the lower numerical results in which the behavior of the structure, with or without perforation, has been experimentally verified. Actual eigen frequencies and related patterns were produced using an empirical model analysis that included a LMS system and a modular hammer. The study discovered that hole size and location had an effect on eigen frequencies and patterns. Moreover, even a small hole in an element can greatly affect the shape of one of its local modes. It was observed that the qualitative matching of the numerical and experimental data is high [48].

(Y. Liu, et al., 2021) The study relied on the Ohmic Heating (IH) method, an advanced technology to increase the strength of steel by up to three times. The study proposed a unique strengthening method over the steel component with the web opening, making full and flexible use of IH technology to partially strengthen the area around the web opening. First, Vickers hardness tests were carried out to study the effect of IH, and it was discovered that the hardness of the induction heating region (IH region) was increased by 1.87 times compared to the untreated normal strength region. The structural representation was then determined by performing monotonous loading tests on four types of normal-section steel beams without mesh opening, non-reinforced section, plate-reinforced section and IH-reinforced section. Compared to the standard package, the non-reinforced member had a pronounced reduction in load resistance of 28 percent and 38 percent. Sheet and IH reinforcements have been shown to be successful in ensuring load resistance, with to-normal ratios of 1.18 - 1.27 and 0.84 - 0.85, respectively, while maintaining an impressive deformation capacity. Despite the fact that the low ductility of the IH region eventually resulted in hole-edge cracking of the IH-reinforced beam at a relatively large displacement, the image data processing system successfully observed the stress-focus dispersal around the web aperture of the IH-reinforced beam. Finally, several equations based on the SCI derivation approach are summarized to capture the experimental results. Deformation capacity: deformation ratios for any and all samples that were greater than 3.0, indicating that they all had a high deformation ability according to the AIJ criteria. Except for the plate-reinforced beam, which failed in apparent edge shearing, normal light, unreinforced beam and IH-reinforced beam failed in massive shear deformation with torsion of the web. The shear load was easily handled by placing the hole along the load path, in addition to the strain tending to focus on the edges of the four holes along the load path. For the most part, the IH-supported element succeeded in dispersing the stress concentration around the web aperture, although the reduced ductility of the IH region finally led to the cracking. Beam stress variations were related to the way they failed[49].

(D. Jabbar, et al., 2021) The study showed the applications of casting concrete joists of the resistance body of square cross section and testing them until failure under the influence of three-point loads in the current experiment. Three of them were built to have non-large web apertures of various shapes, square, rectangular and circular, while the fourth had no openings (control beam) for the purpose of comparing results. The traces of load deviation for the tested samples were obtained successfully. The results showed that the perforation of reinforced concrete beams with small mesh holes leads to a slight decrease in the final forces and an increase in the final deflection. Furthermore, it was determined that beams with circular mesh holes have greater shear resistance than the other shapes chosen here. Previous research revealed that only minor attempts were made to explore the shear analysis of reinforced concrete beams with different configurations of narrow mesh holes. The study aimed to give empirical data to help understand the shear behavior of these beams. Four reinforced concrete girders with three-point bearing were built and tested. All parameters of the respective materials were successfully obtained, and a comprehensive discussion of the final loading capacity and final mid-beam deflection was provided. The controller failure mode was also introduced and troubleshooting. Finally, the following guiding conclusions can be drawn: The results of the experiment showed that the circular aperture beam was the best choice because it had a higher final load capacity and smaller deflection when compared with other opening forms. All tested beams have bilinear charge curves with significant ductility. Further research is needed to investigate the effect of in not as parameters that may influence the shear behavior of perforated RC beams, such as the effect of slot strengthening with iron rods as well as the effect of slot central deflection. The initial stiffness of the drive beam was slightly higher than that of the perforated beams [50].

(V.Senthil kumar, et al., 2019) The study investigated the analytical behavior of a concrete beam enclosed in a steel polished girder as a composite member with different sections to open the lattice of the polished girder as a section optimization with the help of its maximum load or deflection. Ansys Workbench 16.2 was used to analyze the model and Finite Element. Concrete beam with section size 150mm x 170mm x 1500mm sheathed with ISMB100 structural steel with 1400mm span is trialed for the cast element with various appearances of web holes. The numerical model showed the transforming and carrying capacity of several sectional beams to a hexagonal slot (included in a radius of 25 mm) which has a higher load bearing capacity and lower deflection when compared with other segments which have a circular internet slot (25 mm radius), aperture Hexagonal wide web (25mm with 1:1:1 web ratio), rectangular web opening (25mm x 50mm). Ansys workbench 16.2 is used to do an alternate plugin loading [51].

(J. Liu & X. Cui, 2021) The study used the combination of two technologies, fiber bonding - reinforced composite panel (FRP) and externally reinforced steel plate concrete frame, fiber reinforced composite materials and steel plate reinforced concrete masonry technology, can greatly improve the strength performance of the always tangible body. To investigate the effect of modern technology of steel plates fastening FRP sheet concrete beams and the effect of different damage stages on the reinforcement effect, the author created 3 FRP reinforced beams with damage rates of 20%, 40% and 60%, 1 RC beam with FRP panel only, and a beam Ordinary RC to solve the checking effect of modern steel plate anchored FRP pl. These same results show that the modern FRP plate strengthening technology can effectively prevent the development of early time peeling failure, improve the ductility and carrying capacity of the reinforced girder, and greatly increase the use of FRP plate; As the damage rate increases, the final load of the booster beam decreases, but the ductility increases [52].

3. METHODOLOGY

3.1 ANALYSIS WORK

For analysis the case studies of the beams that based on longitudinal holes size, shape and position in cross section. The working stress and the ultimate stress design method were used to build the initial moving for the analysis progress. The method based on the following:

3.1.1 Working Stress Design Method

This was the old-style technique of design not only for armor-plated real , but too for structural strengthen and timber project . The technique basically assumes that the structural physical behaves as a linear elastic way , and that adequate safety can be ensured through suitably restricting the stresses in the material induced through the expected working loads on the construction . As the specified permissible pressures are kept healthy below the physical strength, the assumption of lined elastic behavior is considered justifiable. The ratio of the strength of the material to the permissible pressure is often mentioned to as the factor of care . However, the main supposition linear elastic conduct and the unspoken assumption that the stresses under employed loads can be kept within the 'permissible pressures' are not originated to be realistic. The Working Stress Design (WSD) method derives RC sections assuming them to be within their elastic limits, where applied stresses are proportional to strains. Large margins or factors in which of safety are considered on material resists to ensure like behavior. It is equally, if non more important to predict the ultimate strength of RC sections so in that they can be designed to resist the largest forces anticipated during their design lives. The materials are non-expected to stay within their elastic limits at like high stresses. More realistic methods in which of analysis, based above actual inelastic performance rather than considered elastic behavior in which of materials and above results of extremely extensive experimental study, have been performed to predict the ultimate strengths [53], figure 3. 1 showed RC beam and stress types.

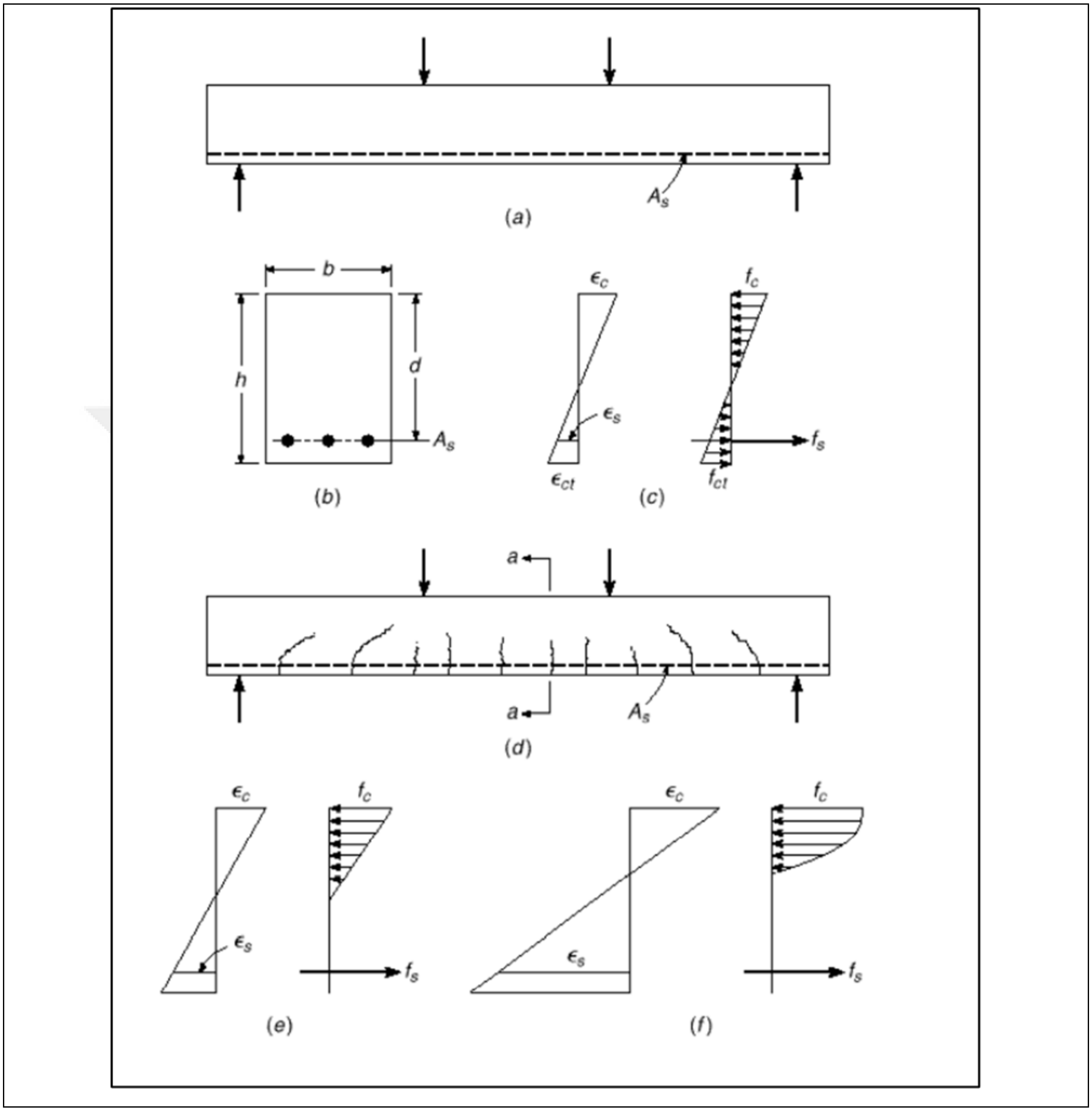

Figure 3.1: (a) RC longitudinal section (b) Cross section of the beam (without openings) (c): Tension and compression stresses (d) Longitudinal section of beam with cracked cross section (e): Stresses behavior in cracked section elastic relationship (f): Stresses behavior in cracked section (plastic relationship) [54].

3.2 ANALYSIS CONCEPTS

For the design consideration, the stresses that formed on the cross section of the beam. The forces that formed by the stresses act in tension and compression zone. The compression force (C) and the tension force (T) is considered in equilibrium, in other word:

C= T

3.2.1 Beam with Rectangular Longitudinal Holes

3.2.1.1 Beam with rectangular longitudinal holes in tension zone (uncracked case)

The cases of longitudinal holes that covered by the study, the cases depend on the position of the hole in the cross section of the beam, and the cases were illustrated in the following figure (3.2).

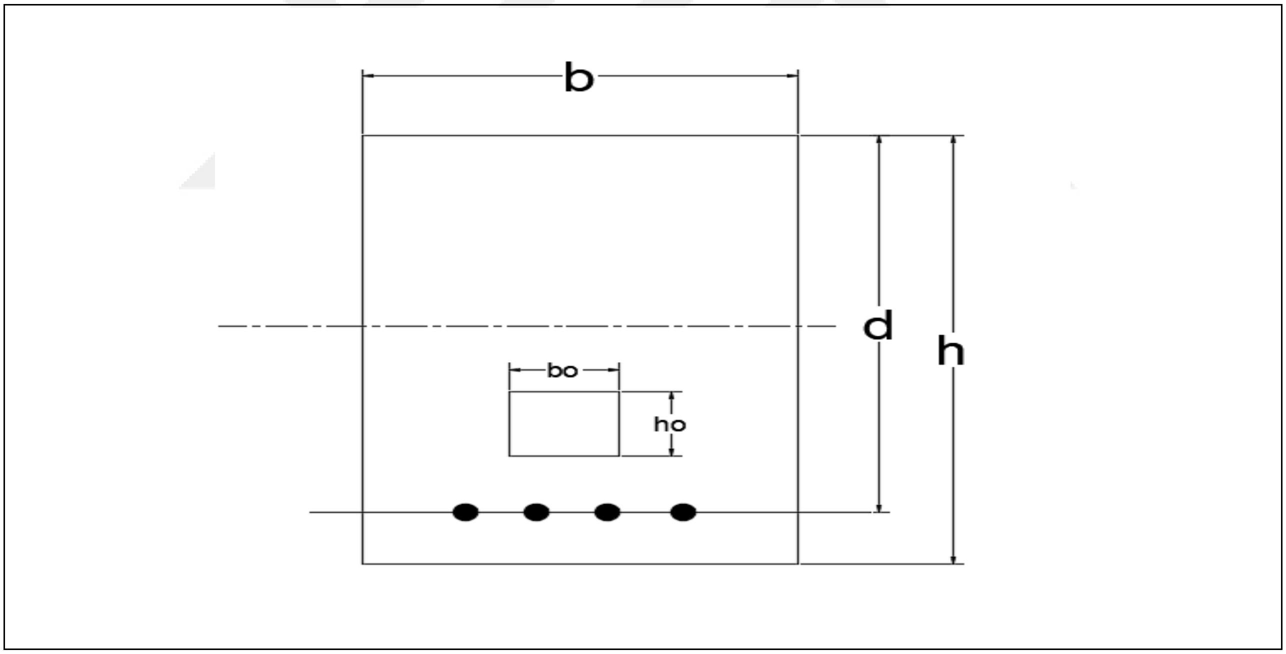

Figure 3.2 : Uncracked Reinforced Concrete Beam With Rectangular Opening In Tension Zone

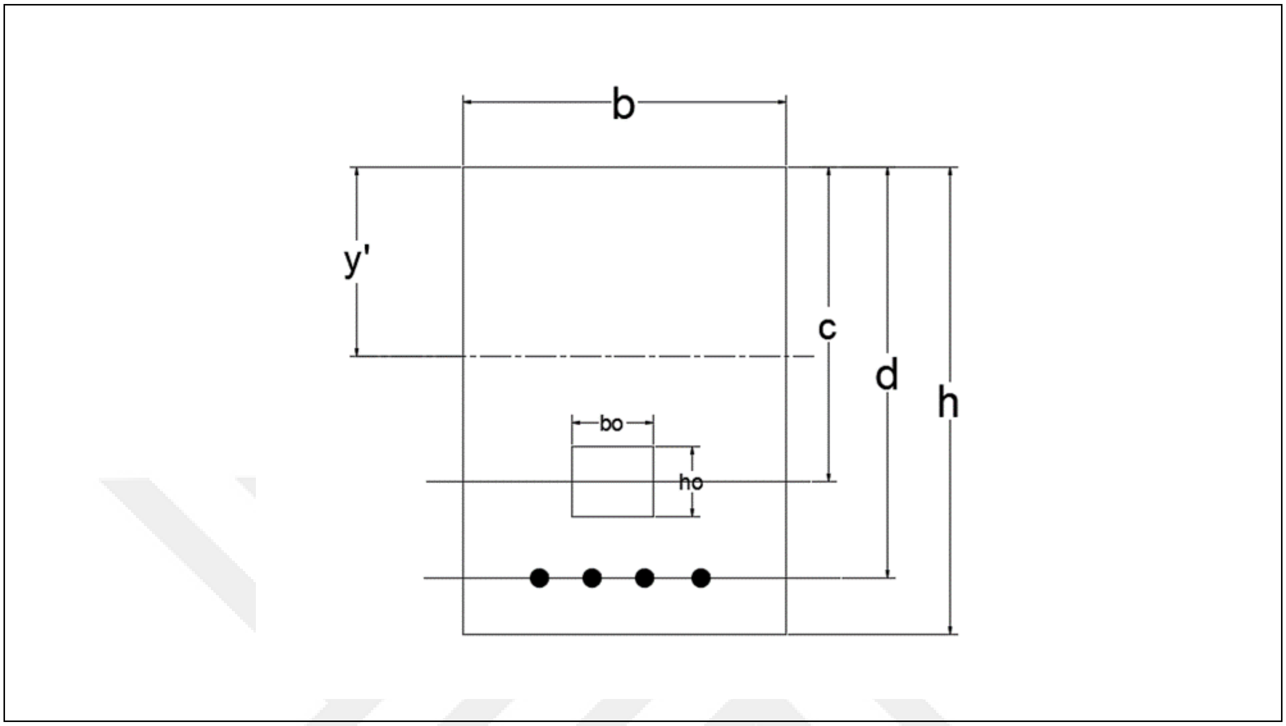

Figure 3.3: Assigning of The Neutral Axis And The Effective Depth For The Opening In Uncracked Reinforced Concrete Beam With Rectangular Opening In Tension Zone

The area of cross section (Ac) is evaluated by the following:

$$Ac = bh - bo\ ho \qquad (3.1)$$

While the area of the transform section (At):

$$At = bh - bo\ ho + n\ As - As \qquad (3.2)$$

$$y' = \frac{bh\left(\frac{h}{2}\right) - bo\ ho\ (c) + (n-1)As\ d}{bh - bo\ ho + n\ As - As} \qquad (3.3)$$

$$I = \frac{b\ h^3}{12} + bh\ (\ y' - \frac{h}{2})^2 + (n\text{-}1)\ As\ (d - y')^2 - \frac{bo\ ho^3}{12} - bo\ ho\ (c - y')^2 \qquad (3.4)$$

3.2.1.2 Beam with rectangular longitudinal holes (cracked case)

In the case of cracked section, the hole in the tension zone can be ignored as the whole body of concrete in tension zone considered without strength and the strength carried by the reinforcement in tension region so that:

$$b\, y' \frac{y'}{2} = n\, As\, (d - y') \tag{3.5}$$

$$I = \frac{b\, y'^3}{3} + \text{n As (d – y')}^2 \tag{3.6}$$

3.2.1.3 Beam with rectangular longitudinal hole in compression zone (cracked case)

For the case of the hole found in compression part of the cross section with the cracked case, the effect of the hole the determination of the distance to the neutral axis and also when the moment of inertia been calculated:

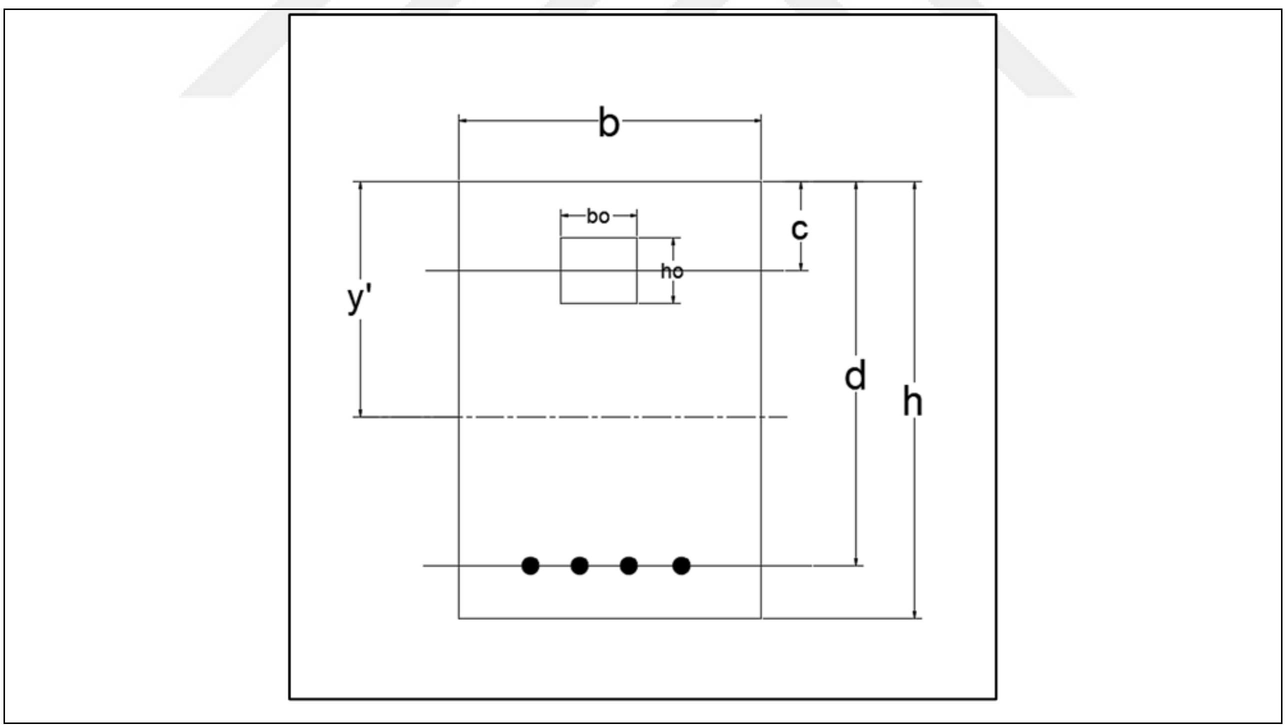

Figure 3.4 : Rectangular longitudinal hole in compression zone

$$b\,y'\,\frac{y'}{2} - bo\,ho\,(y' - c) = n\,As\,(d - y') \qquad (3.7)$$

$$I = \frac{b\,h^3}{3} + n\,As\,(d - y')^2 - \frac{bo\,ho^3}{12} - bo\,ho\,(c - y')^2 \qquad (3.8)$$

3.2.2 Beam with Circular Longitudinal Hole

3.2.2.1 Beam with circular longitudinal holes in tension zone (uncracked case)

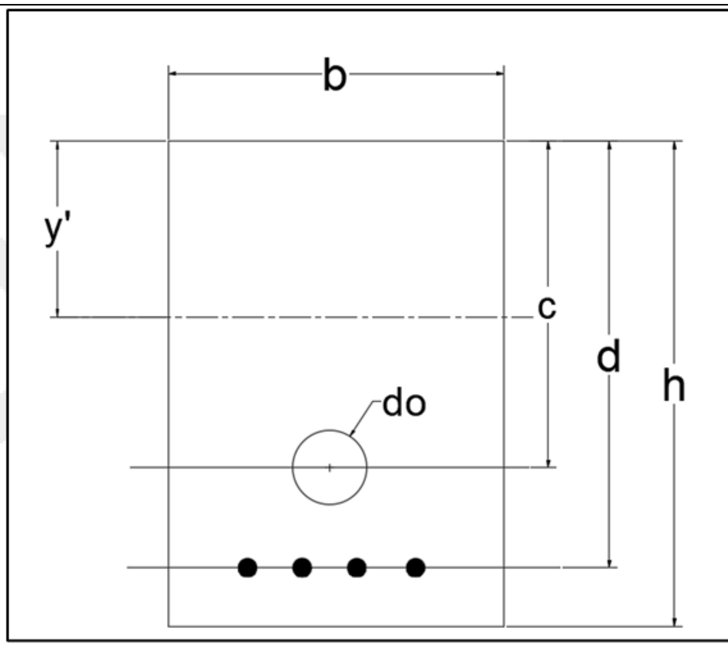

Figure 3.5 : Circular Longitudinal Hole In Tension Zone

The area of cross section (Ac) is evaluated by the following:

$$Ac = bh - \frac{do^2\,\pi}{4} \qquad (3.9)$$

While the area of the transform section (At):

$$At = bh - \frac{do^2\,\pi}{4} + n\,As - As \qquad (3.10)$$

$$y' = \frac{bh\left(\frac{h}{2}\right) - \frac{do^2\,\pi}{4}\,(c) + (n-1)As\,d}{bh - \frac{do^2\,\pi}{4} + n\,As - As} \qquad (3.11)$$

$$I = \frac{b\,h^3}{12} + bh\,(y' - \frac{h}{2})^2 + (n\text{-}1)\,As\,(d - y')^2 - \frac{do^4\,\pi}{64} - \frac{do^2\,\pi}{4}\,(c - y')^2 \quad (3.12)$$

3.2.2.2 Beam with circular longitudinal holes in compression zone (cracked case)

For circular longitudinal holes in tension zone

$$b\,y'\,\frac{y'}{2} = n\,As\,(d - y') \quad (3.13)$$

$$I = \frac{b\,y'^3}{3} + n\,As\,(d - y')^2 \quad (3.14)$$

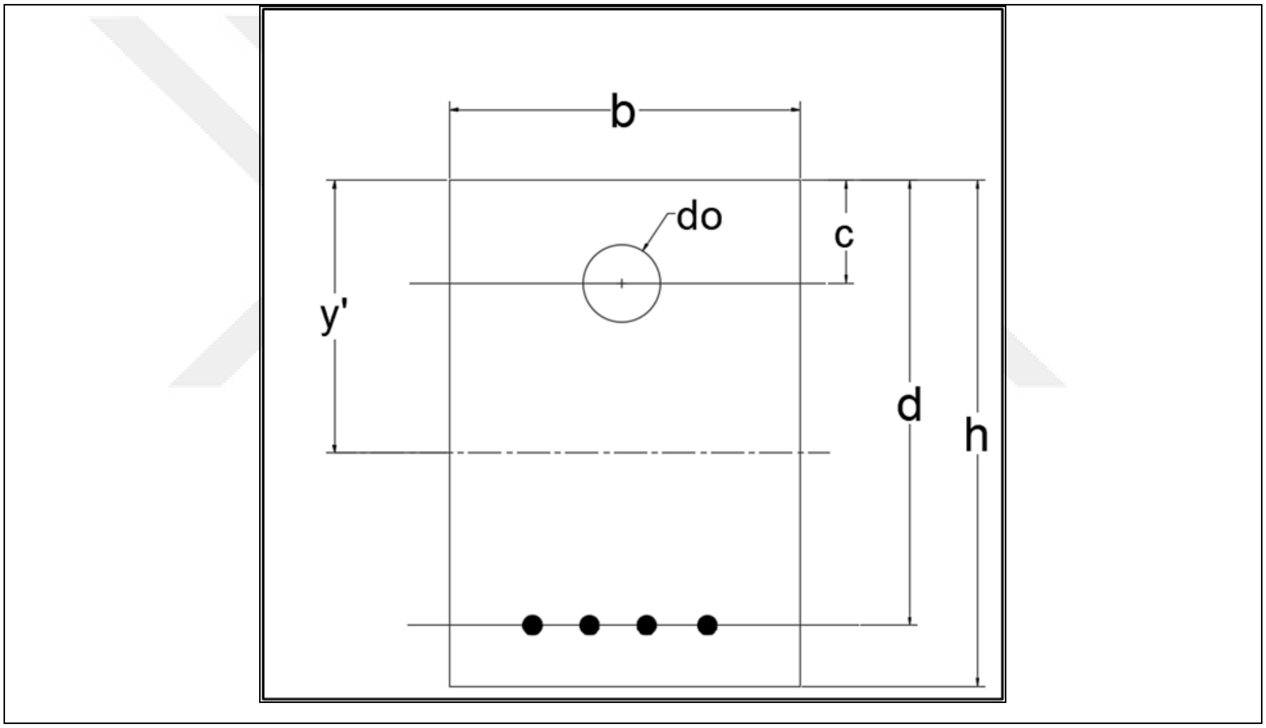

Figure 3.6 : Circular Longitudinal Hole in Compression Zone

$$b\,y'\,\frac{y'}{2} - \frac{do^2\,\pi}{4}\,(y' - c) = n\,As\,(d - y') \quad (3.15)$$

$$I = \frac{b\,h^3}{3} + n\,As\,(d - y')^2 - \frac{do^4\,\pi}{64} - \frac{do^2\,\pi}{4}\,(c - y')^2 \quad (3.16)$$

3.3 SIMULATION WORK

For analysis the situation of reinforced concrete beams with longitudinal holes, simulation action was carried out by using ANSYS workbench program. The simulation was made by assigning initial properties and loading to specific cases of beams that contained hole in rectangular and circular cross section at the region of compression.

The simulation work was based on the condition that summarized in table 3.1:

Table 3.1: Simulation Data In Ansys Program

Item	Value in ANSYS
Width of beam	400 mm
Effective depth for reinforcement	290 mm
Effective depth to the center of the hole	80 mm
Width of rectangular hole	80 mm
Height of rectangular hole	80 mm
Dimeter of circular hole	80 mm
Compressive strength of steel	450 MPa
Compressive strength of concrete	25 MPa
Area of steel	804.2 mm^2 (4 Ø12)

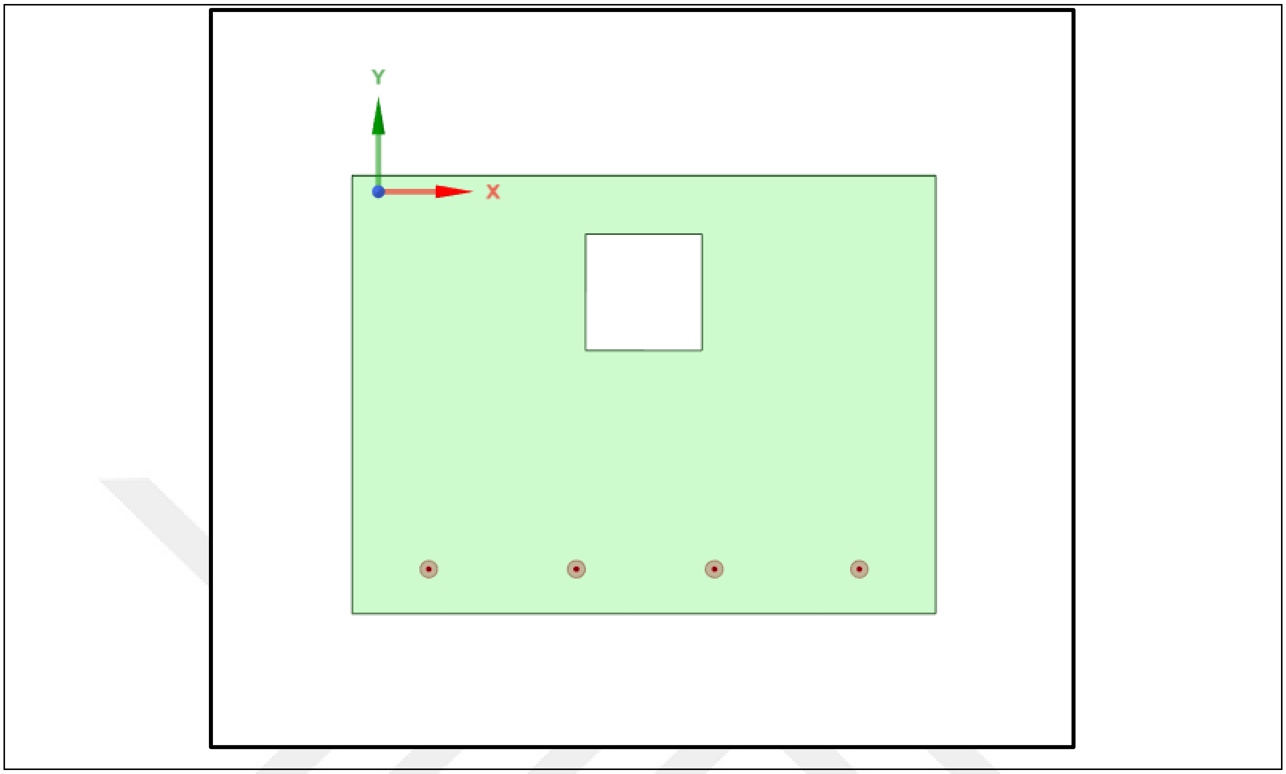

Figure 3.7: Geometry Work In ANSYS For Beam With Rectangular Hole (Cross Section View)

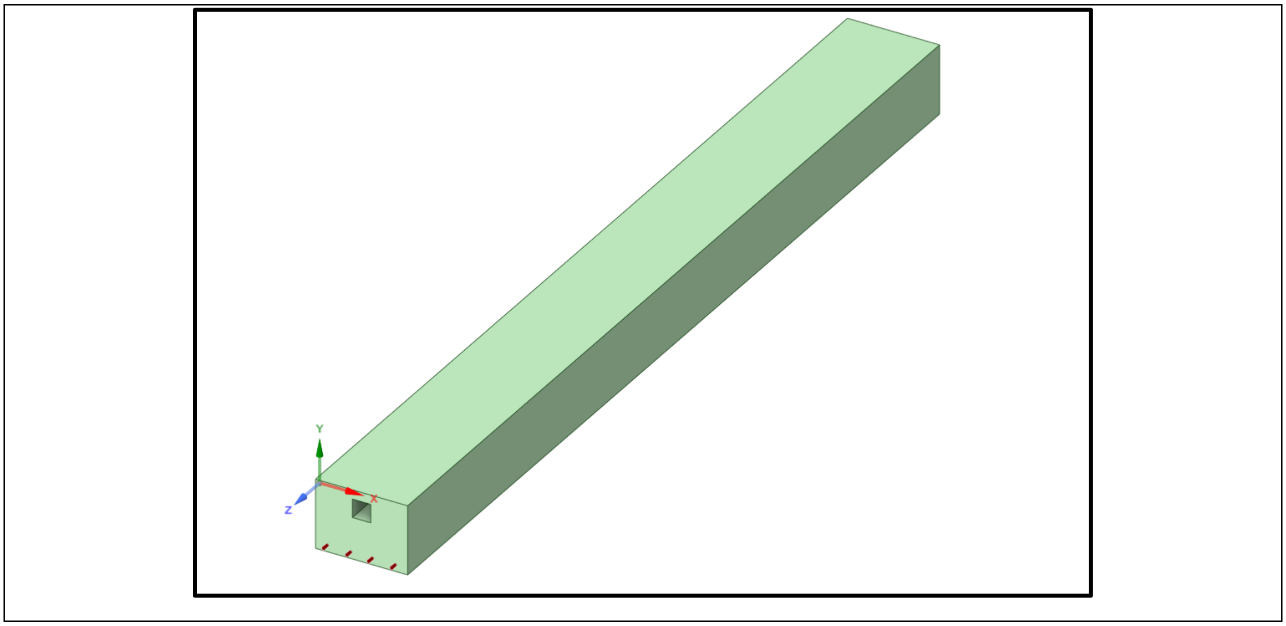

Figure 3.8 : Geometry work in ANSYS for beam with rectangular hole (longitudinal section view)

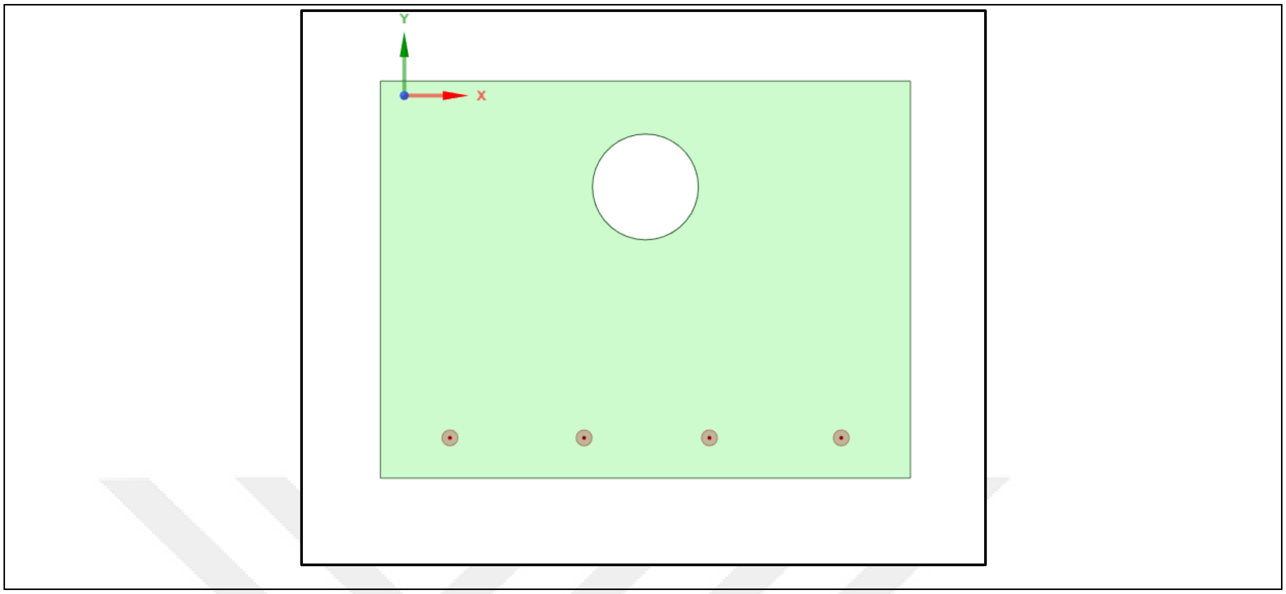

Figure 3.9: Geometry Work In ANSYS for Beam with Circular Hole (Cross Section View)

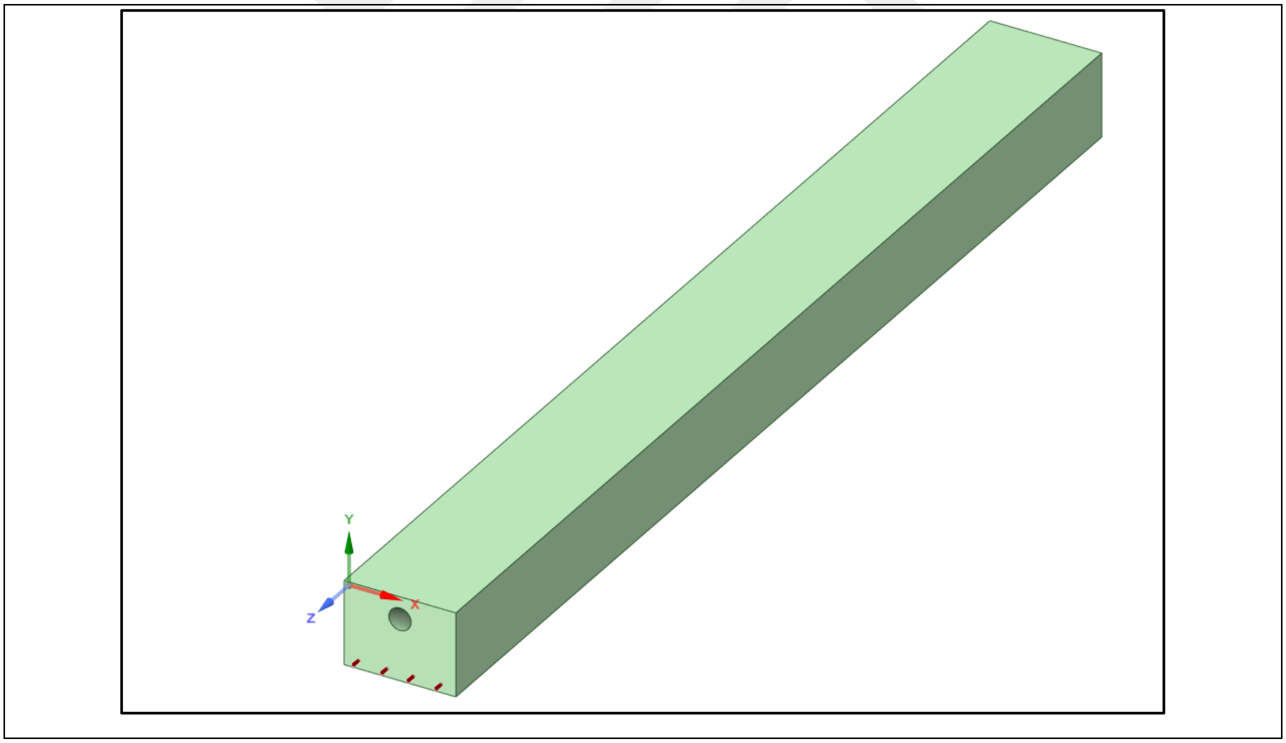

Figure 3.10: Geometry Work In ANSYS For Beam With Circular Hole (Longitudinal Section View)

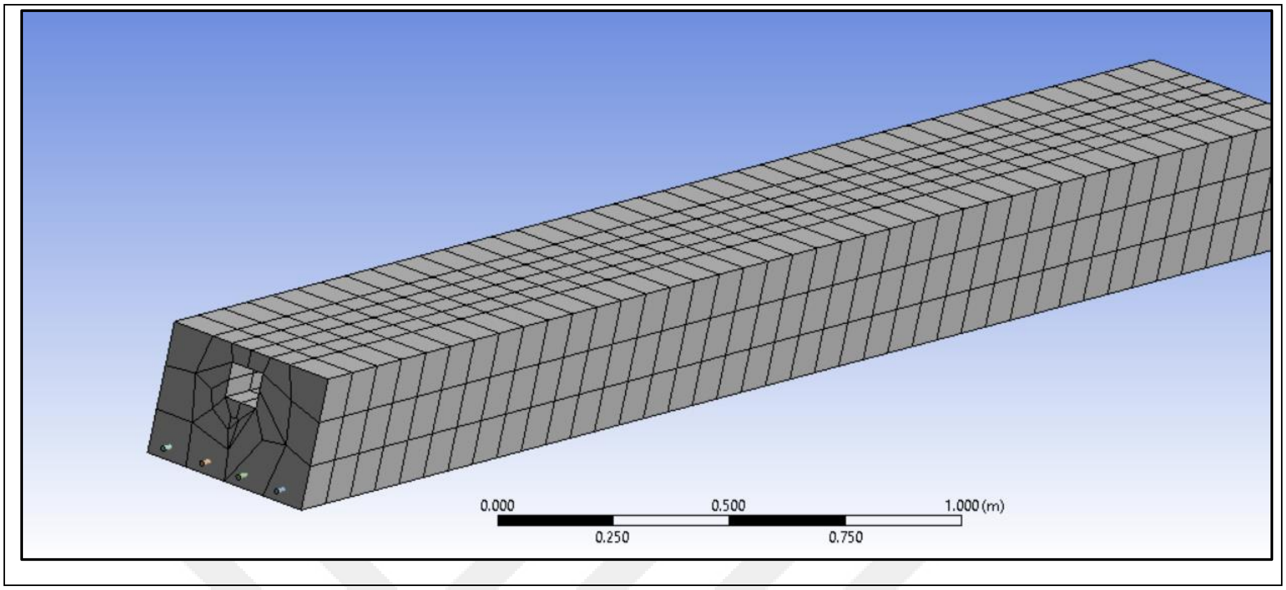

Figure 3.11: Meshing Work In ANSYS For Beam With Rectangular Hole (Longitudinal Section View)

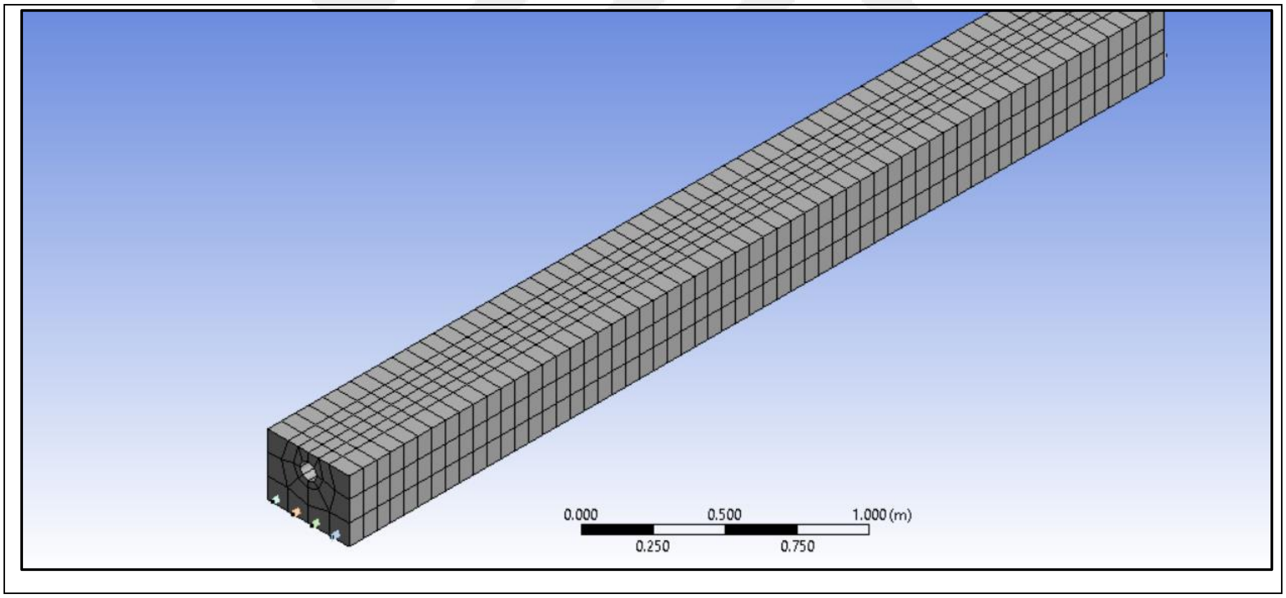

Figure 3.12 : Meshing Work in ANSYS for Beam with Circular Hole (Longitudinal Section View)

4. RESULTS

4.1 CALCULATION AND RESULTS

The analysis of the RC beam was implemented using various values of the ho and for the rectangular hole and do for circular hole, the results of the untracked and cracked section were explained in the following tables and figures

4.2 UNCRACKED SECTION

Table 4.1: The Cracked Moment Variation With The Height Increment Of Rectangular Hole

ho (mm)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
20	156.7	1009141761	19.96
30	156.8	1007931734	19.92
40	156.9	1006687930	19.88
50	157.1	1005400332	19.84
60	157.2	1004058922	19.80
70	157.3	1002653681	19.76
80	157.4	1001174591	19.71

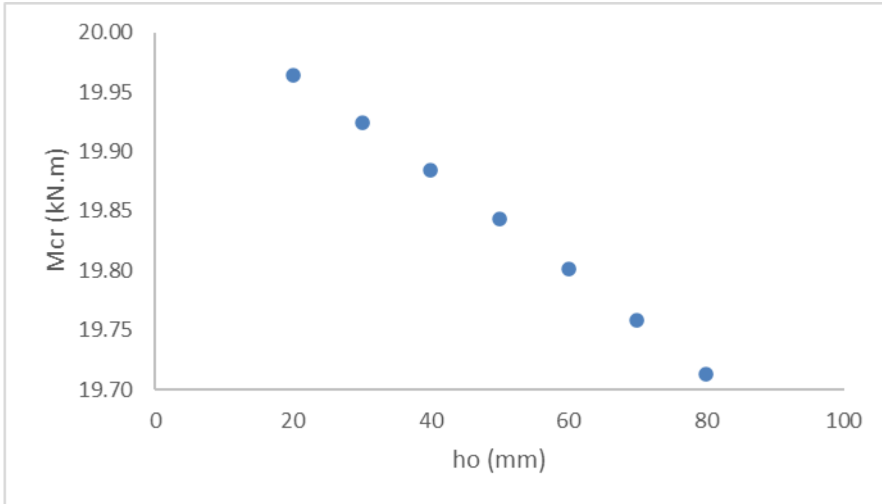

Figure 4.1: The Cracked Moment Variation With The Height Increment Of Rectangular Hole

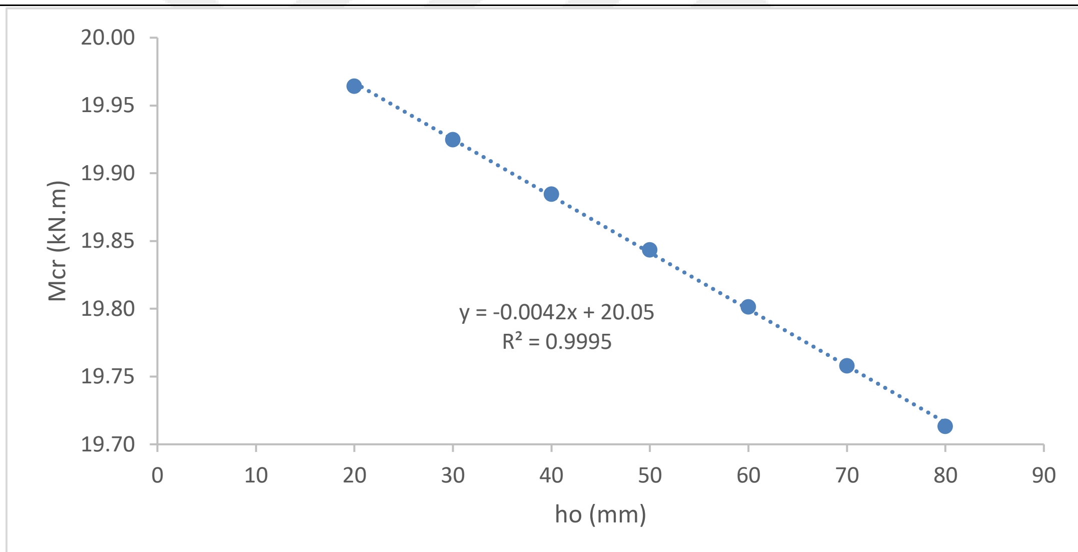

Figure 4.2: Linear Fitting for the Cracked Moment Variation with the Height Increment Of Rectangular Hole

Table 4.2: The Cracked Moment Variation with the Width Increment Of Rectangular Hole

bo (mm)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
20	156.7	1009141761	19.96
50	157.1	1005575332	19.85
80	157.4	1001974591	19.73
110	157.8	998339037	19.61
140	158.2	994668160	19.49
170	158.6	990961441	19.37
200	159.0	987218348	19.25

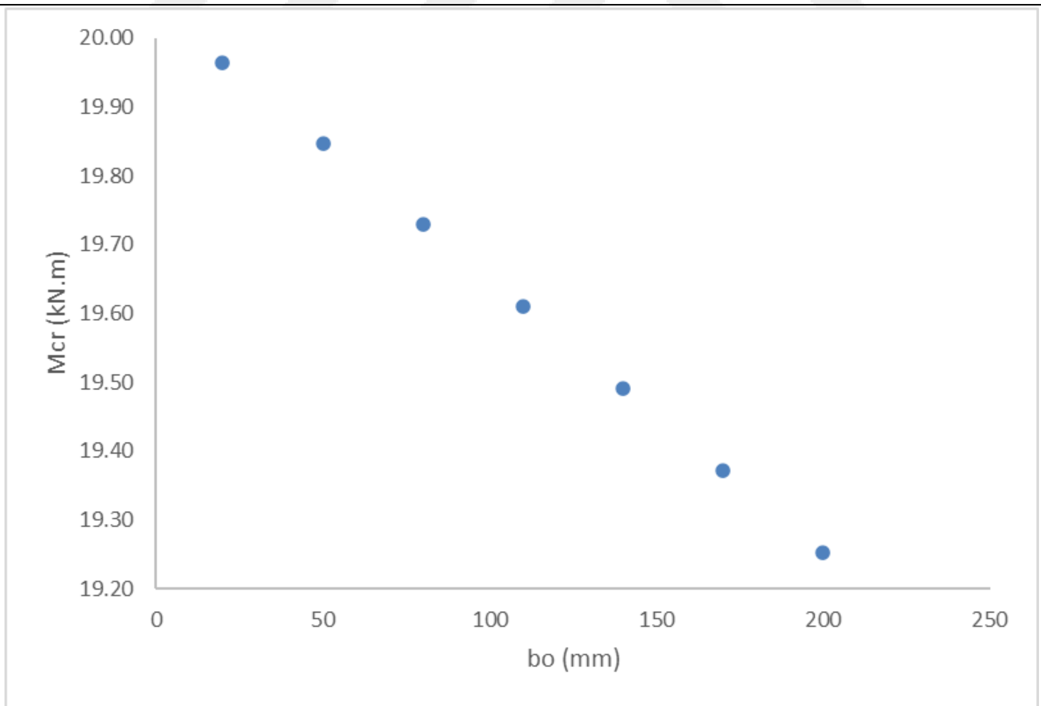

Figure 4.3: The Cracked Moment Variation With The Width Increment Of Rectangular Hole

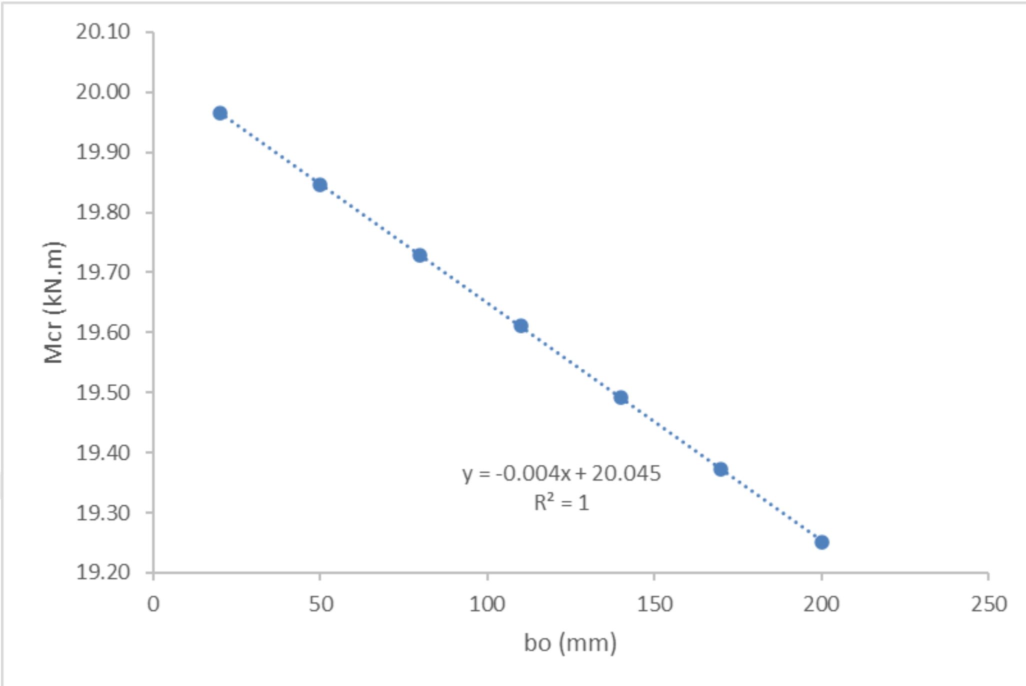

Figure 4.4: Linear Fitting The Cracked Moment Variation With The Width Increment Of Rectangular Hole

Table 4.3: The Cracked Moment Variation With The Area Increment Of Rectangular Hole

Ao (mm^2)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
400	156.7	1009141761	19.96
1500	157.4	1002514618	19.75
3200	158.5	991881029	19.41
5500	160.0	976735406	18.93
8400	161.9	956364503	18.31
11900	164.5	929808043	17.53
16000	167.6	895798393	16.57

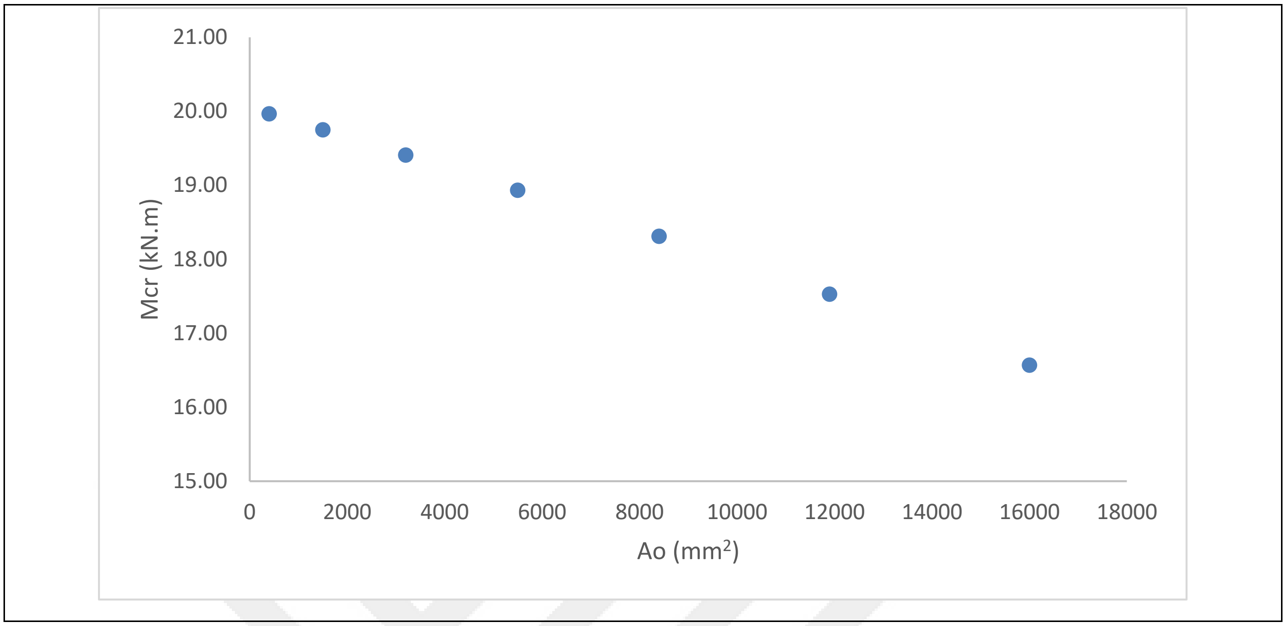

Figure 4.5: The Cracked Moment Variation with The Area Increment Of Rectangular Hole

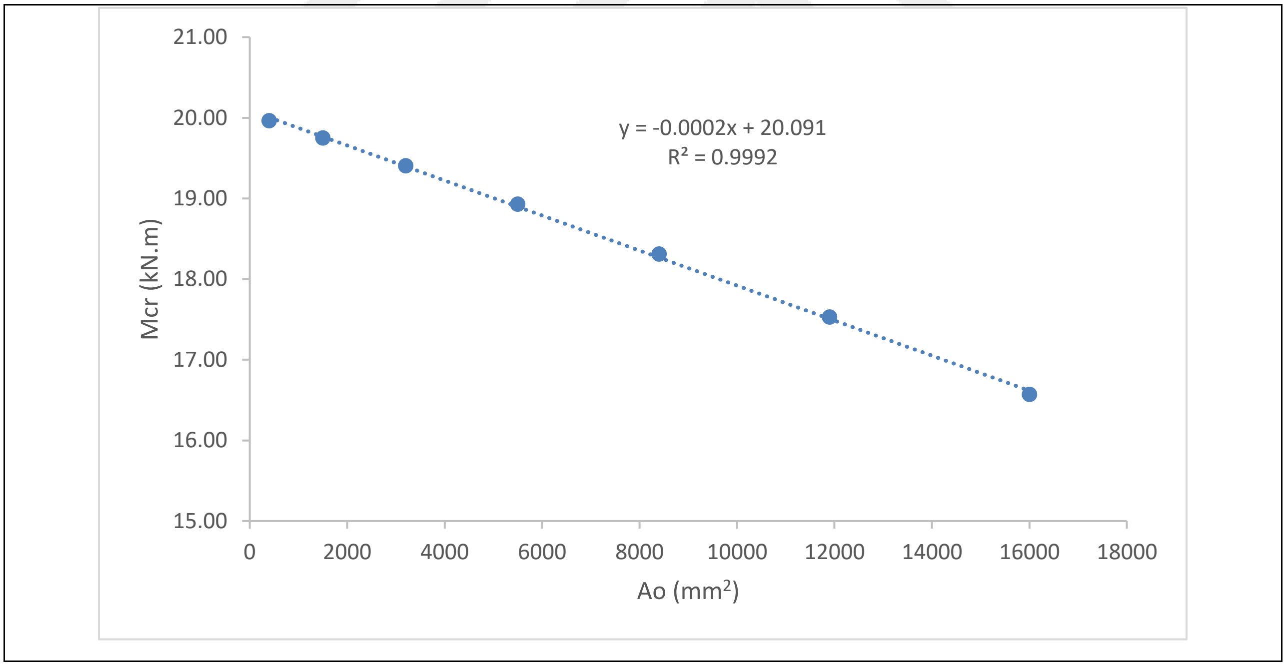

Figure 4.6 : Linear Fitting the Cracked Moment Variation with the Area Increment Of Rectangular

Table 4.4: The Cracked Moment Variation with the Depth to the Center of the Rectangular Hole

C (mm)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
50	157.8	992921886.8	19.50
60	157.7	996210249.5	19.58
70	157.6	999174484.1	19.66
80	157.4	1001814591	19.73
90	157.3	1004130569	19.79
100	157.2	1006122420	19.84
110	157.1	1007790142	19.89

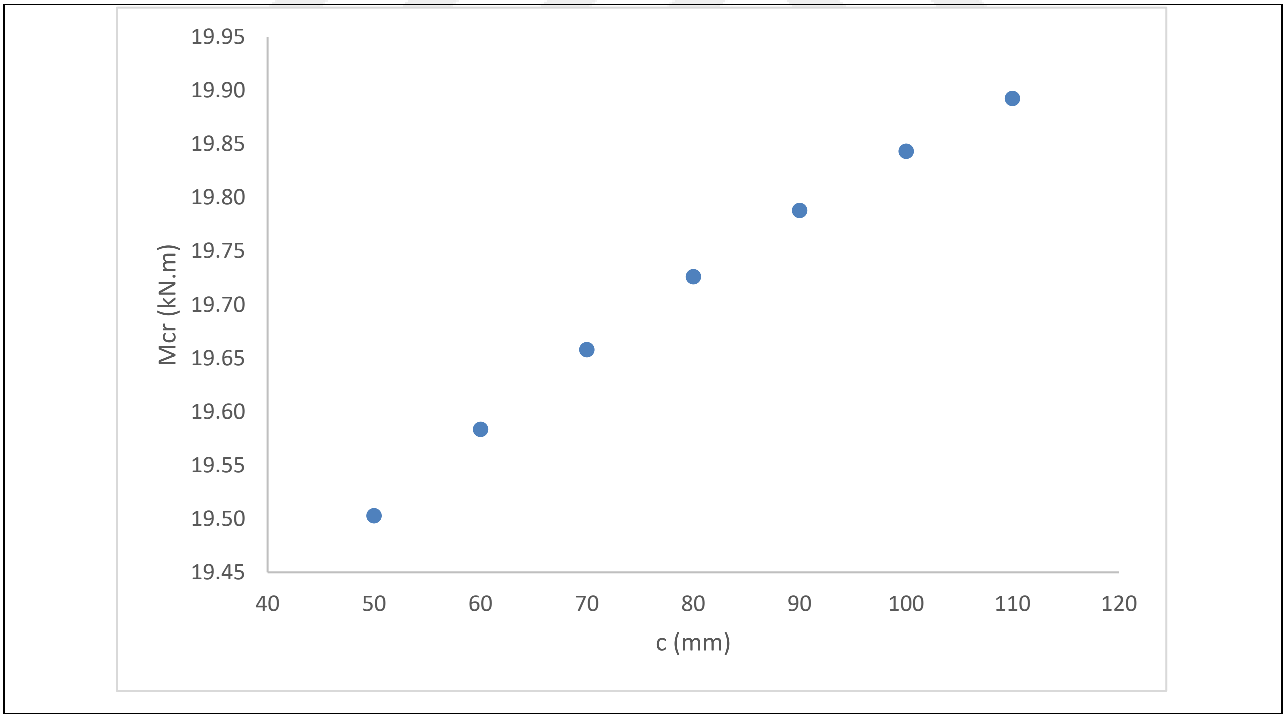

Figure 4.7: The Cracked Moment Variation with The Depth To The Center Of The Rectangular Hole

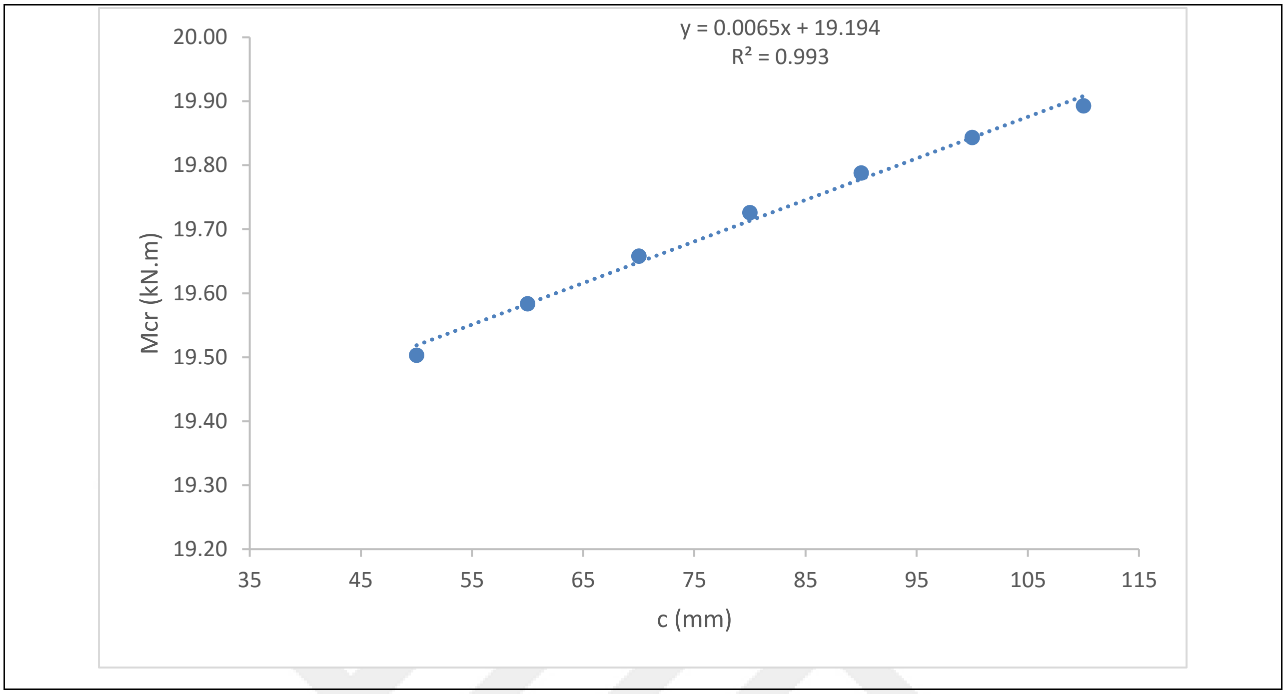

Figure 4.8: Linear Fitting The Cracked Moment Variation With The Depth To The Center Of The Rectangular Hole

Table 4.5: The Resultant Linear Equations for Mcr Based On Rectangular Hole Area When Variation of Depth (C)

As (mm^2)	Linear functions (Ao)
804.2	y = -0.0002x + 20.091
1004	y = -0.0002x + 20.413
1204	y = -0.0002x + 20.721
1404	y = -0.0002x + 21.018
1603	y = -0.0002x + 21.303
1803	y = -0.0002x + 21.577
2003	y = -0.0002x + 21.841

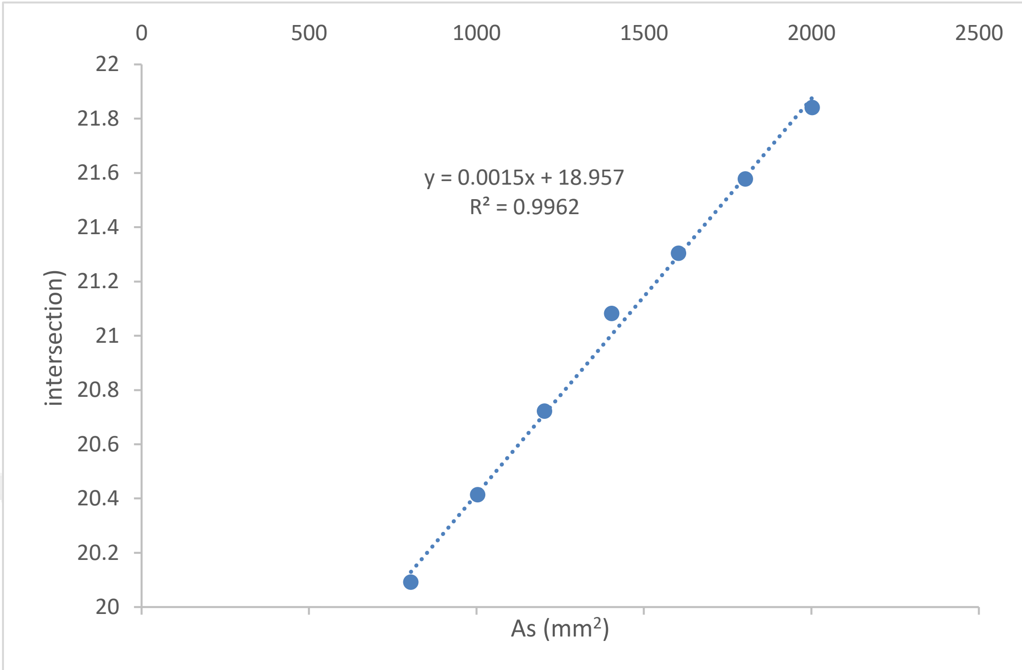

Figure 4.9: Curve Fitting For the Intersection of Linear Equations with Area of Steel

From the polynomial fitting in figure, the equation of Mcr can be written as following:

$$M_{cr} = -0.0002\ Ao + \ 0.0015\ As + 18.957 \qquad (4.1)$$

Table 4.6: The Cracked Moment Variation with the Height Increment Of Circular Hole

do (mm^2)	Ao (mm^2)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
20	314	153.8	958447665.8	19.32
30	707	154.0	956271878.8	19.25
40	1257	154.3	953161336.6	19.14
50	1963	154.8	949051057.3	19.01
60	2827	155.3	943856697	18.84
70	3848	156.0	937473912.9	18.63
80	5027	156.7	929777536.5	18.39

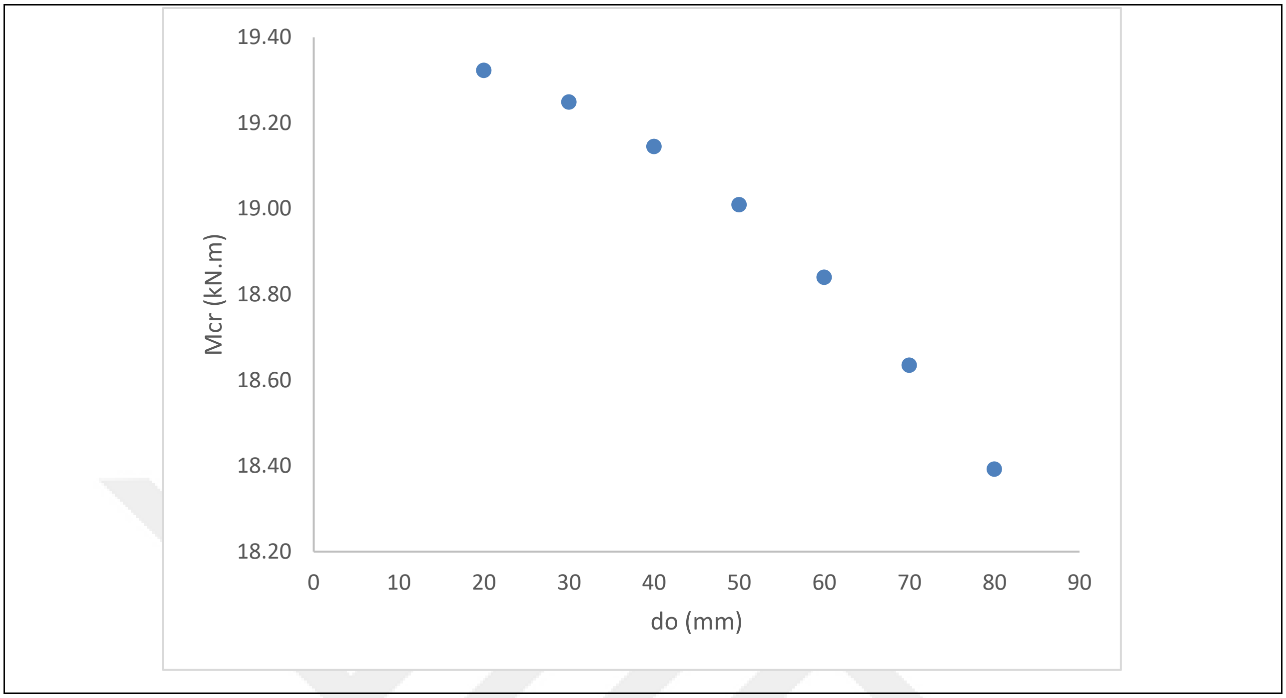

Figure 4.10 : The Cracked Moment Variation with the Height Increment Of Circular Hole

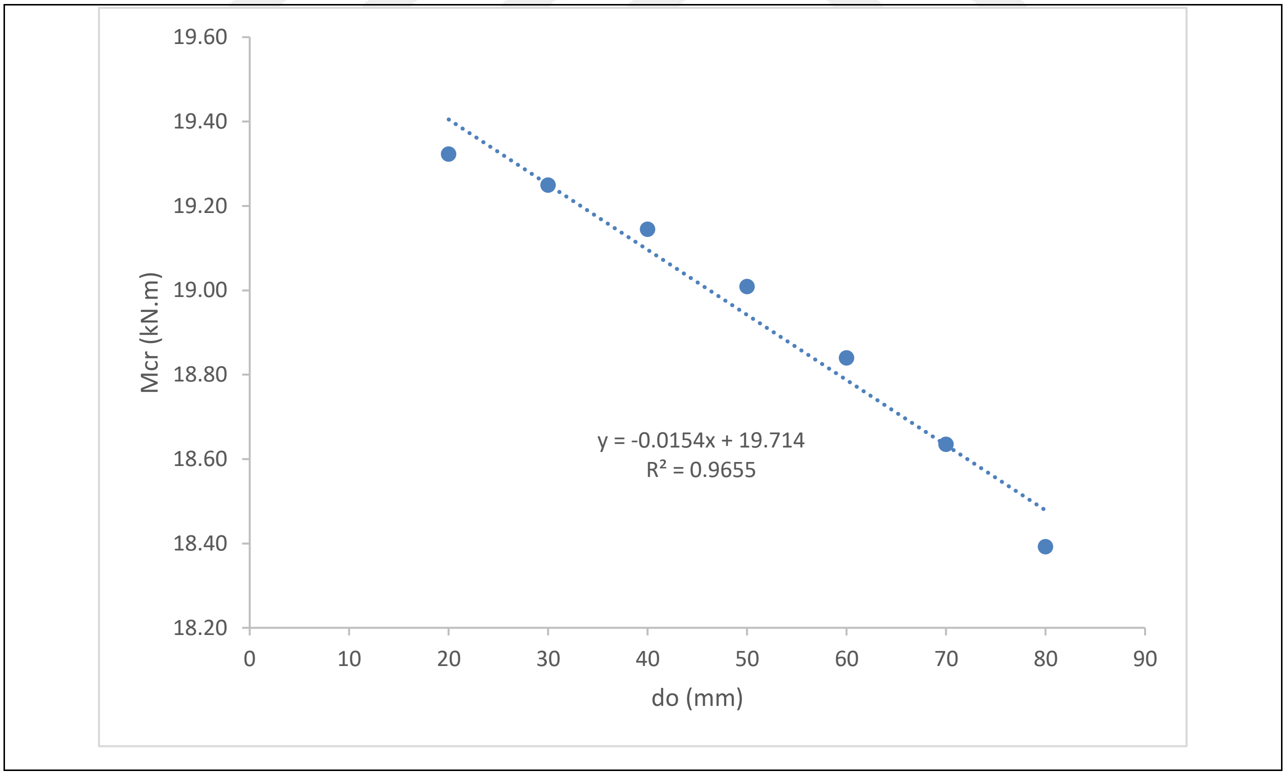

Figure 4.11: The Line Fitting For the Cracked Moment Variation With The Height Increment Of Circular Hole

Table 4.7: The Cracked Moment Variation With The Depth (C) Increment Of Circular Hole

c (mm)	Y (mm)	I_{uncr} (mm^4)	M_{cr}
50	154.75	949873578.9	19.03
60	154.65	952379330	19.09
70	154.55	954631162.7	19.15
80	154.44	956629077	19.20
90	154.34	958373072.9	19.25
100	154.24	959863150.4	19.29
110	154.13	961099309.4	19.33

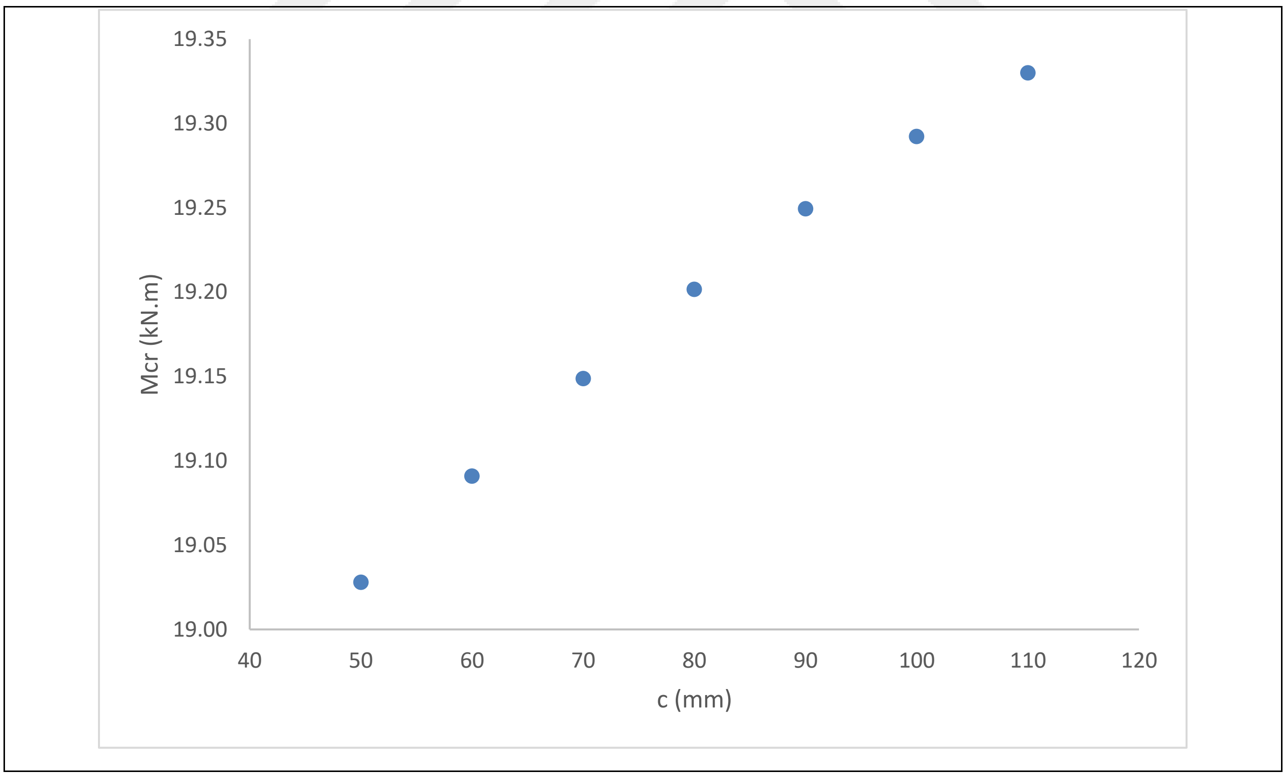

Figure 4.12: The Cracked Moment Variation With The Depth (C) Increment Of Circular Hole

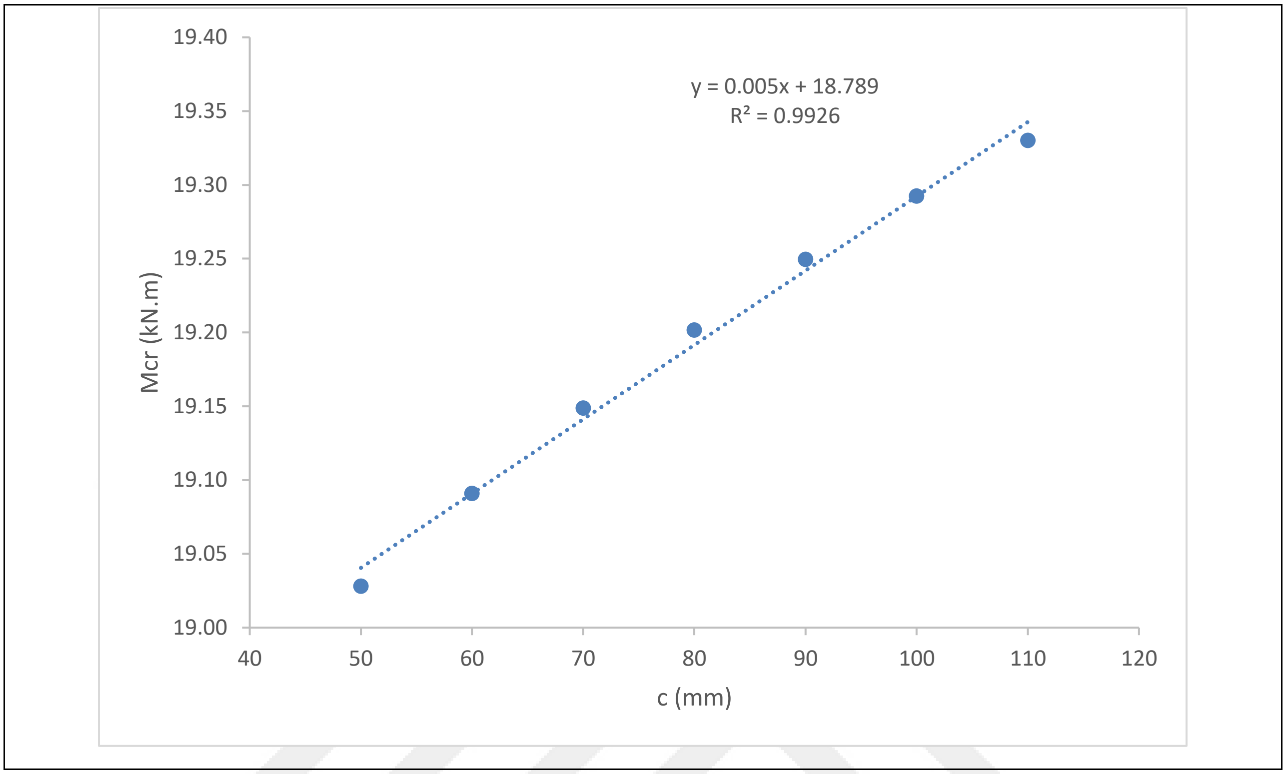

Figure 4.1: Line Fitting For the Cracked Moment Variation With The Depth (C) Increment Of Circular Hole

Table 4.8: The Resultant Linear Equations Based On Circular Hole Area When Variation of Depth (c)

As (mm^2)	function
804.2	y = -0.0002x + 20.052
1004	y = -0.0002x + 20.374
1204	y = -0.0002x + 20.682
1404	y = -0.0002x + 20.979
1603	y = -0.0002x + 21.264
1803	y = -0.0002x + 21.538
2003	y = -0.0002x + 21.803

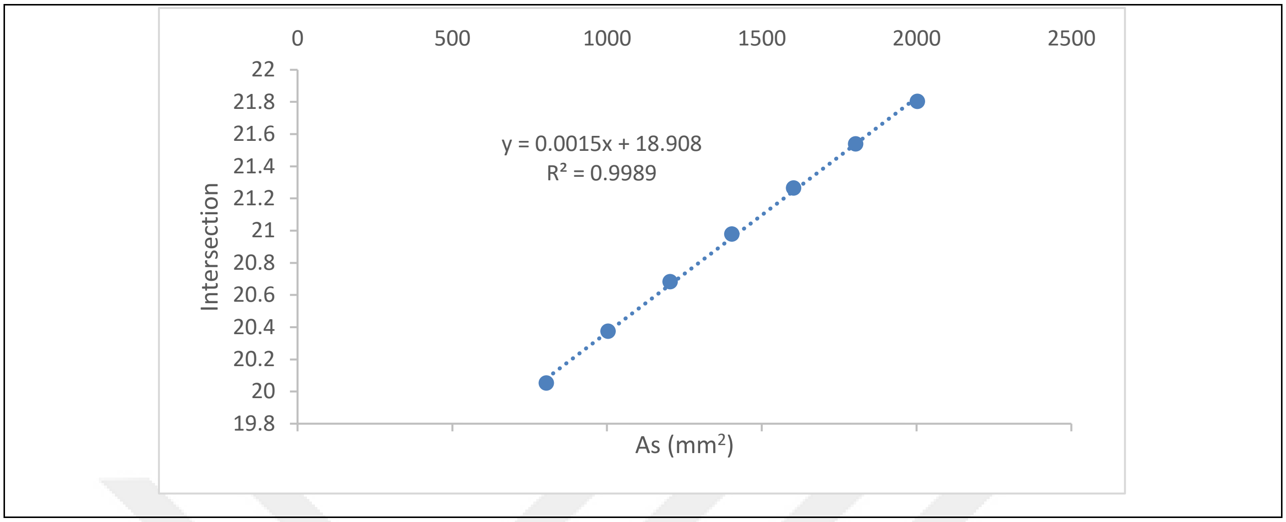

Figure 4.2: Curve Fitting For the Intersection of Linear Equations with the Steel Area

From the polynomial fitting in figure, the equation of Mcr can be written as following:

$$M_{cr} = -0.0002\ Ao + 0.0015\ As\ +\ 18.908 \qquad (4.2)$$

4.3 CRACKED SECTION

For cracked section, the changes of the internal strength of the member were explained in the following figures for the rectangular and circular longitudinal hole.

Table 4.9 : The Internal Strength Variation with the Height Increment of Rectangular Hole

ho (mm)	Y (mm)	I_{cr} (mm^4)	M_u
20	81.8	351773875.4	91.34
30	81.9	351741526.8	91.32
40	81.9	351679171.2	91.29
50	81.9	351576808.4	91.25
60	81.9	351424438.2	91.20
70	81.9	351212060.6	91.14
80	81.9	350929675.4	91.05

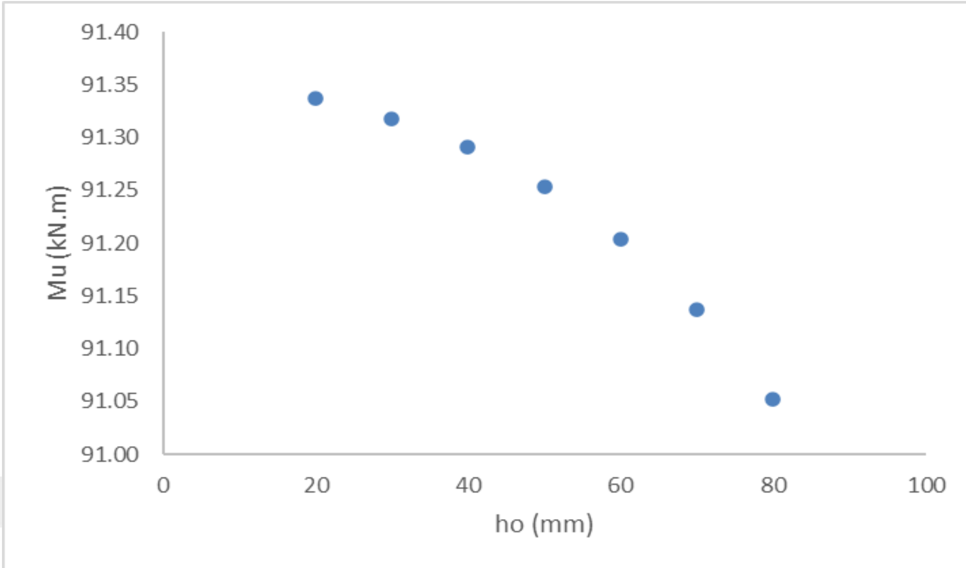

Figure 4.15: The Internal strength variation with the height increment of rectangular hole

Table 4.10: The Internal Strength Variation With The Width Increment Of Rectangular Hole

bo (mm)	Y (mm)	I_{cr} (mm^4)	M_u
20	81.8	351773875.4	91.34
50	81.9	351751808.4	91.30
80	81.9	351729675.4	91.26
110	81.9	351707473.2	91.22
140	82.0	351685198.4	91.18
170	82.0	351662847.4	91.14
200	82.3	351488492	90.77

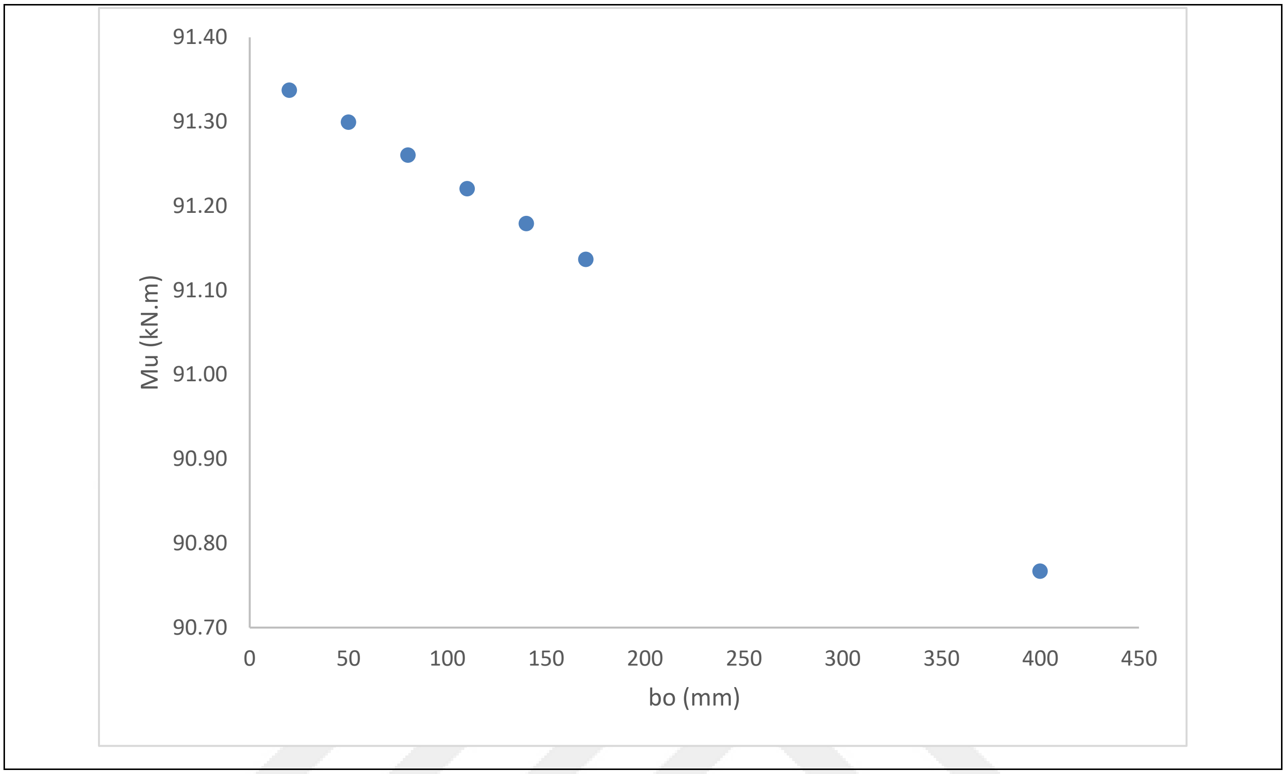

Figure 4.3: The Internal Strength Variation with the Width Increment of Rectangular Hole

Table 4.11: The Internal Strength Variation With The Area Increment Of Rectangular Hole

Ao (mm^2)	Y (mm)	I_{cr} (mm^4)	M_u
400	81.8	351773875.4	91.34
1500	81.9	351670868.9	91.25
3200	82.0	351350306.5	91.07
5500	82.1	350621460.5	90.73
8400	82.3	349233035	90.15
11900	82.6	346872650.4	89.22
16000	83.1	343165589.8	87.79

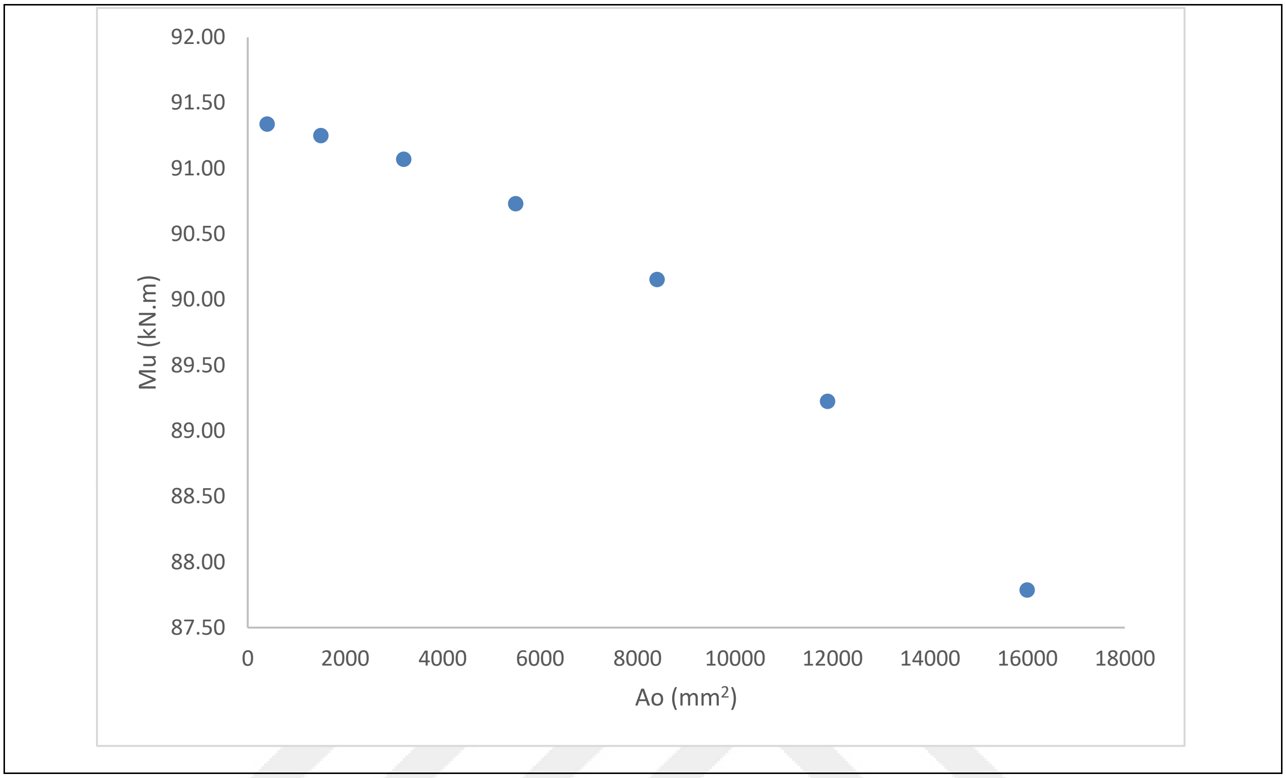

Figure 4.4: The Internal Strength Variation with the Area of Increment of Rectangular Hole

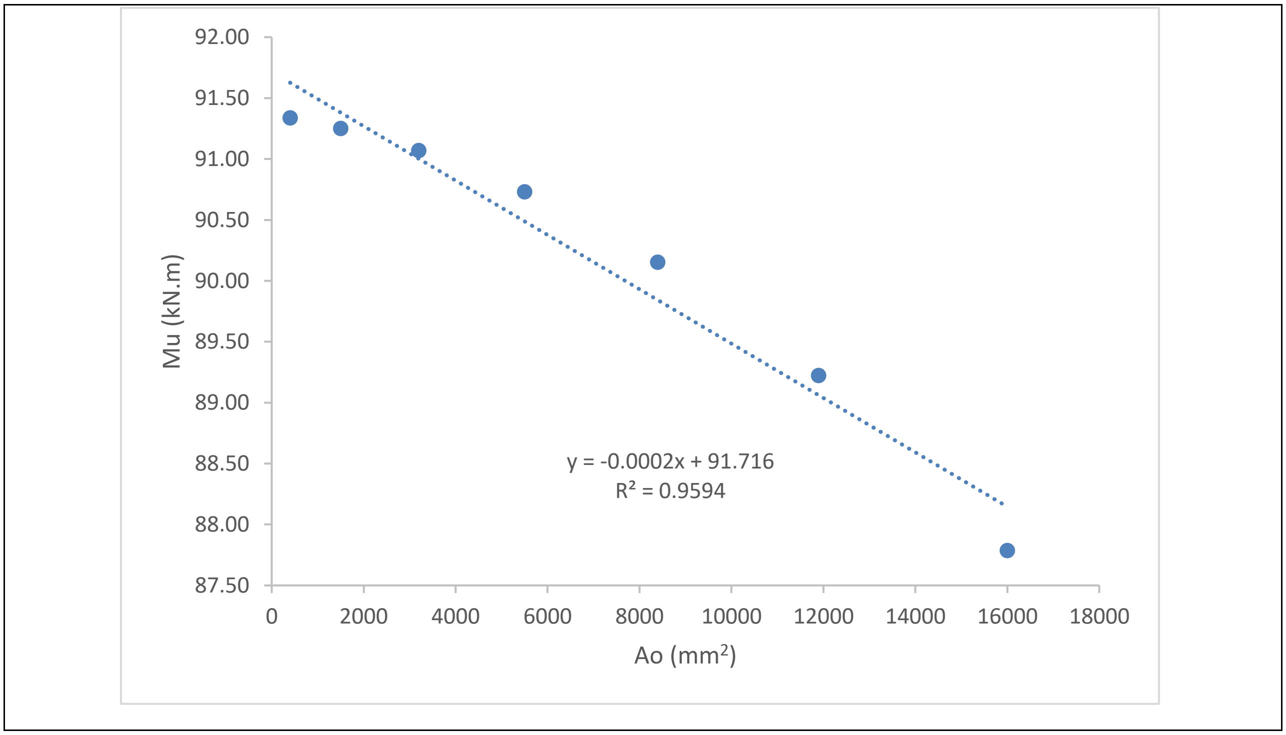

Figure 4.5: Line Fitting For The Internal Strength Variation With The Area Of Increment Of Rectangular Hole

Table 4.12: The Linear Equations Variation with the Depth (C) Increment of Rectangular Hole

As (mm^2)	Function
804.2	y = -0.0002x + 91.716
1004	y = -0.0005x + 99.655
1204	y = -0.0007x + 106.31
1404	y = -0.0008x + 112.07
1603	y = -0.0009x + 117.16
1803	y = -0.001x + 121.71
2003	y = -0.0011x + 125.83

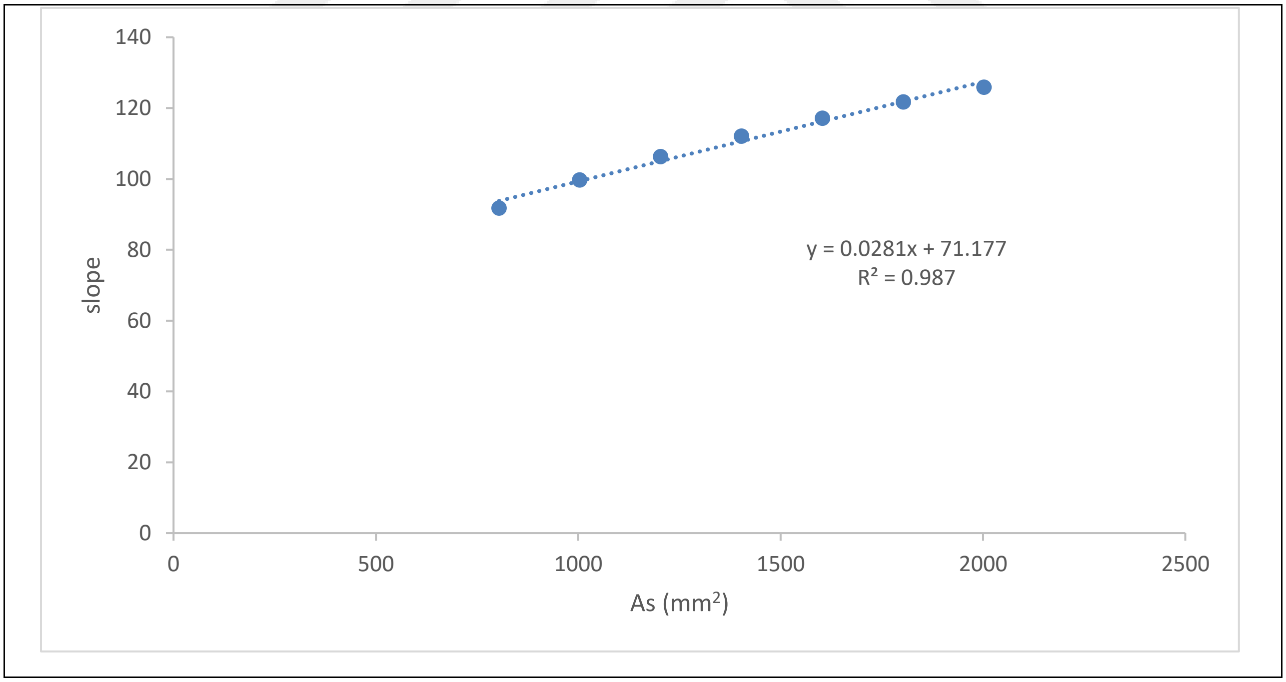

Figure 4.6: Curve Fitting For The Intersection Of Linear Equations With The Depth To The Center Of The Rectangular Hole

From the polynomial fitting in figure, the equation of Mcr can be written as following:

$$M_u = -0.0002Ao + 0.0281\ As + 71.77 \quad (4.3)$$

Table 4.13: The Internal Strength Variation with the Diameter Increment of Circular Hole

do (mm)	Ao (mm^2)	Y (mm)	I_{cr} (mm^4)	M_u (kN.m)
20	314	81.8	351779645.2	91.34
30	707	81.9	351746398.9	91.31
40	1257	81.9	351658573.9	91.26
50	1963	81.9	351474886.9	91.17
60	2827	82.0	351142253.4	91.04
70	3848	82.0	350595783.4	90.83
80	5027	82.1	349758773.3	90.54

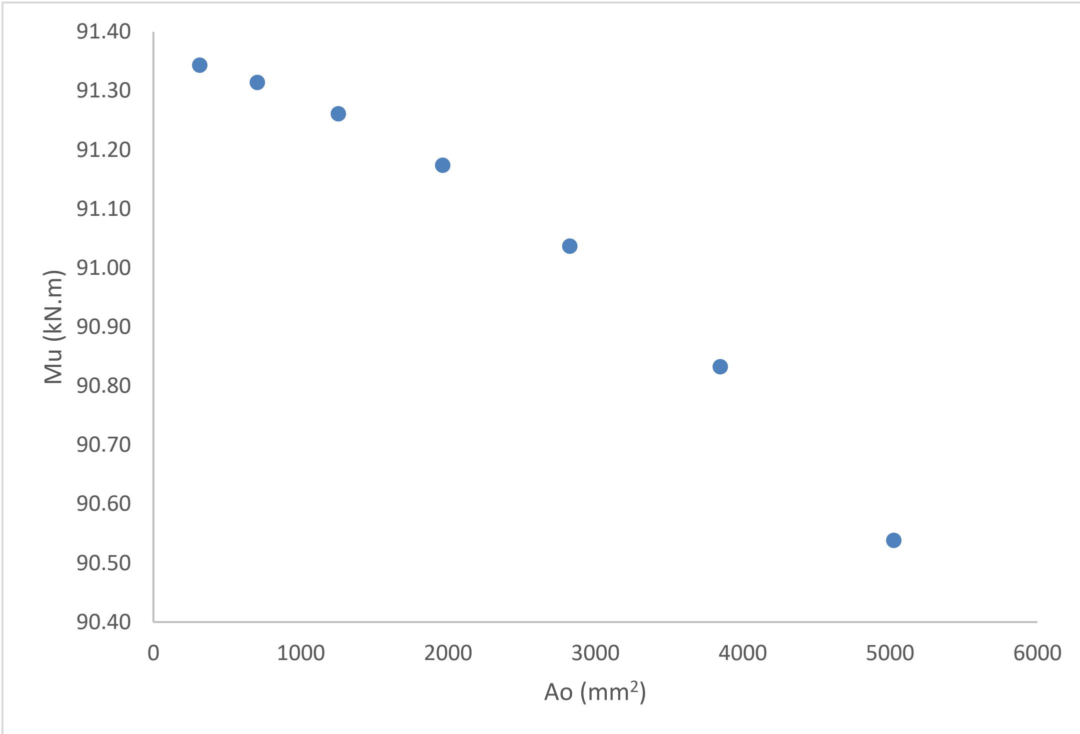

Figure 4.20: The Internal Strength Variation with the Diameter Increment of Circular Hole

Table 4.14: The Variation of Linear Equation with the Depth (C) Increment of Circular Hole

As (mm^2)	Function
804.2	y = -0.0002x + 91.464
1004	y = -0.0004x + 99.257
1204	y = -0.0006x + 105.88
1404	y = -0.0007x + 111.64
1603	y = -0.0008x + 116.73
1803	y = -0.0009x + 121.3
2003	y = -0.001x + 125.42

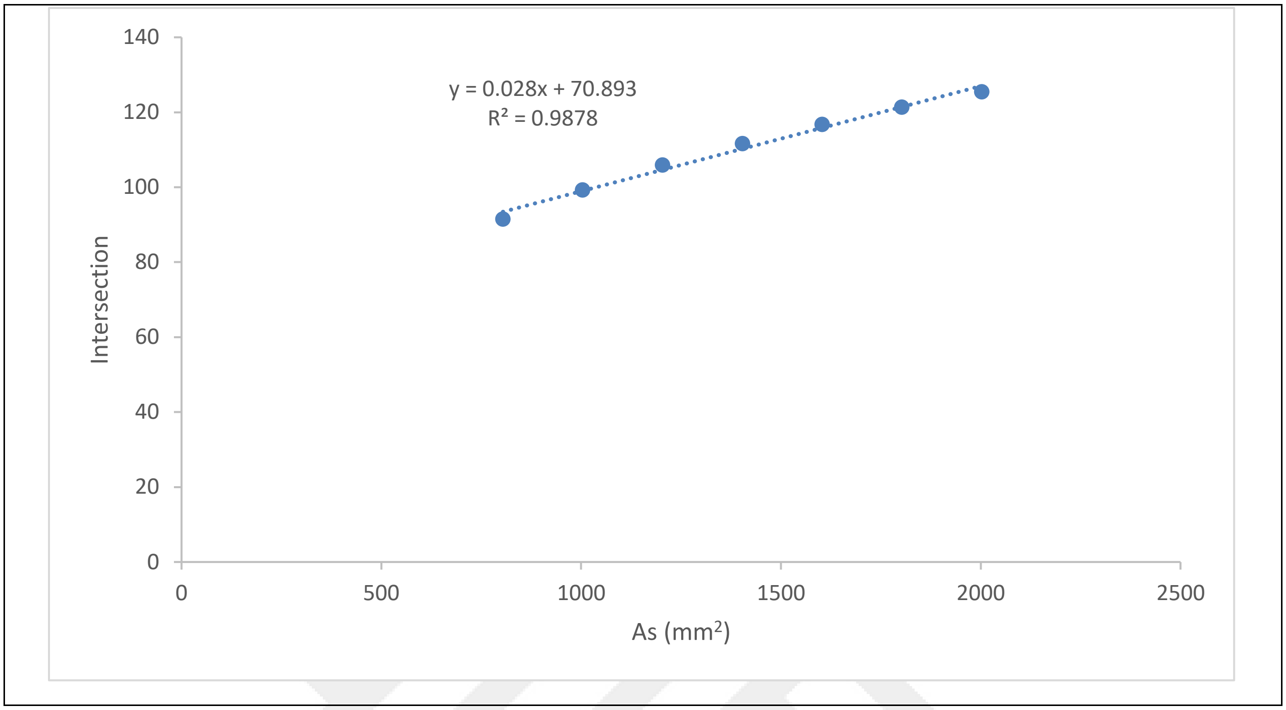

Figure 4.21: The Linear Equation Of The Area Of Steel With The Intersection Increment For Circular Hole

From the linear fitting in figure, the equation of Mcr can be written as following:

$$M_u = -0.0008\ Ao + 0.028\, As + 70.893 \qquad (4.4)$$

4.4 COMPARISON BETWEEN THE RECTANGULAR AND CIRCULAR HOLES

For recognizing the behavior of the concrete beam with variant area of circular and rectangular longitudinal holes, the internal moment strength for the two cases were shown in figure 4.22 and 4.23. The circular longitudinal holes showed higher value in moment cracked and ultimate moment as the moment of inertia for the circular cross section behaved less value than same area of rectangular one.

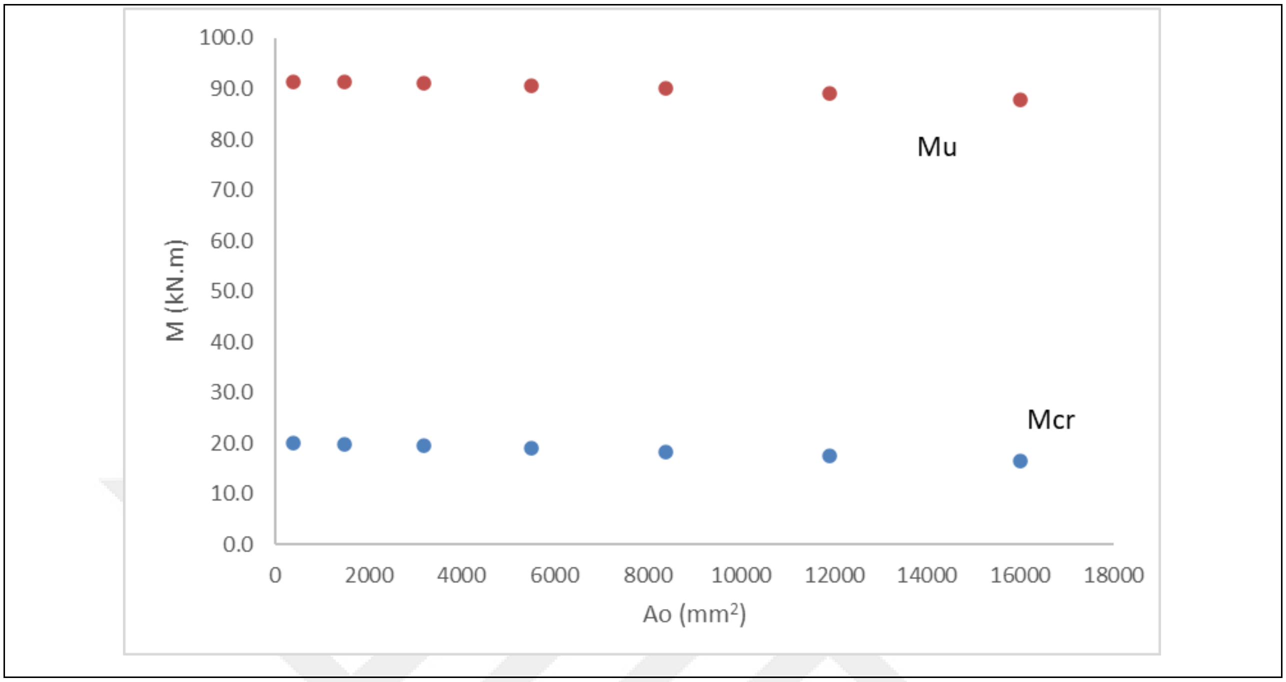

Figure 4.22: The Internal Moment Strength of Rc Beam In The Rectangular Longitudinal Hole Cases

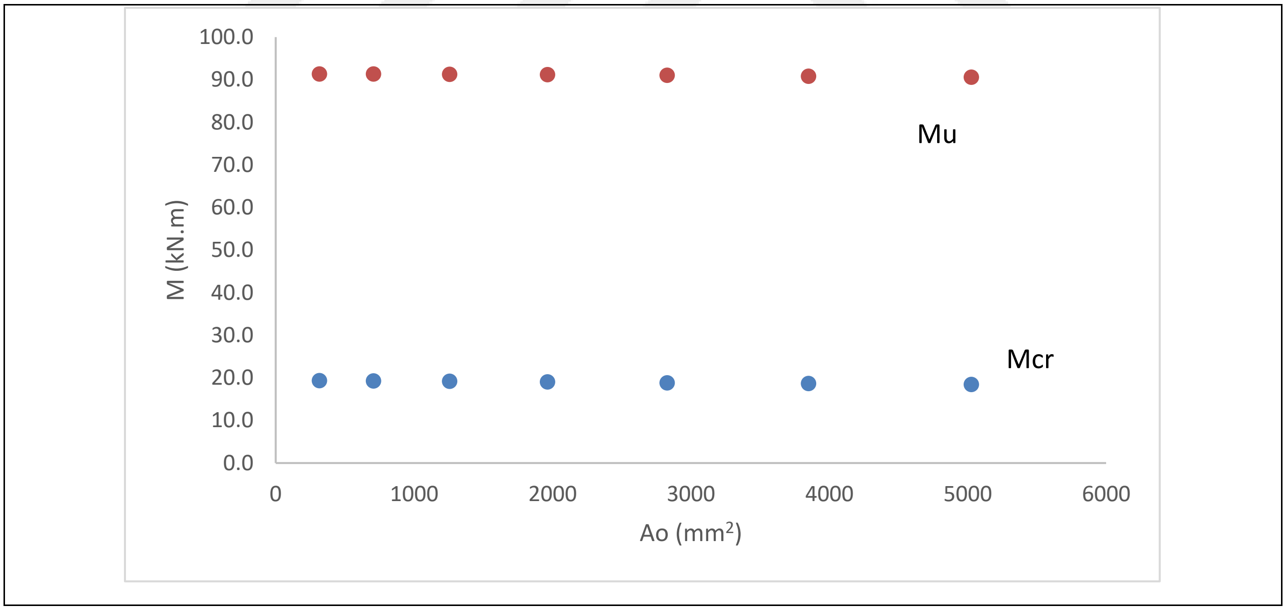

Figure 4.23: The Internal Moment Strength Of Rc Beam In The Circular Longitudinal Hole Cases

Table 4.15: Examining The Results Of Linear Equation For Rectangular Hole And Uncracked Section

Ao (mm^2)	As (mm^2)	M_{cr} (kN.m) by structural analysis	M_{cr} (kN.m) by linearization	ΔM_{cr}
400	804.2	19.96	20.0833	-0.12
1500	1004	20.06	20.163	-0.10
3200	1204	20.01	20.1227	-0.12
5500	1404	19.78	19.9624	-0.18
8400	1603	19.37	19.6821	-0.31
11900	1803	18.76	19.2818	-0.53
16000	2003	17.91	18.7615	-0.85

Table 4.16 : Examining the Results of Linear Equation for Rectangular Hole and Cracked Section

Ao (mm^2)	As (mm^2)	M_u (kN.m) by structural analysis	M_u (kN.m) by linearization	ΔM_u
400	804.2	91.35	93.77	-2.42
1500	1004	98.71	97.73	0.98
3200	1204	104.20	100.80	3.41
5500	1404	107.87	102.96	4.91
8400	1603	109.68	104.23	5.45
11900	1803	109.52	104.59	4.93
16000	2003	107.26	104.05	3.21

Table 4.17: Examining the Results of Linear Equation For Circular Hole And Uncracked Section

Ao (mm^2)	As (mm2)	M_{ucr} (kN.m) by structural analysis	M_{ucr} (kN.m) by linearization	ΔM_u
314	804.2	19.98	20.05147	-0.07
707	1004	20.22	20.27263	-0.05
1257	1204	20.41	20.46237	-0.05
1963	1404	20.55	20.6207	-0.07
2827	1603	20.64	20.74761	-0.11
3848	1803	20.66	20.84311	-0.18
5027	2003	20.63	20.90719	-0.28

Table 4.18 : Examining the Results of Linear Equation for Circular Hole and Uncracked Section

Ao (mm^2)	As (mm2)	M_u (kN.m) by structural analysis	M_u (kN.m) by linearization	ΔM_u
314	804.2	91.35	93.16	-1.81
707	1004	98.95	98.44	0.51
1257	1204	105.18	103.60	1.58
1963	1404	110.31	108.63	1.67
2827	1603	114.45	113.52	0.94
3848	1803	117.75	118.30	-0.54
5027	2003	120.26	122.96	-2.70

4.5 ANSYS WORK

The simulation of the cases was made by using ANSYS program. The results of the simulation were show in figures 4.24 to 4.29, the figures showed various output for the structural performance of the RC beam with circular and with rectangular longitudinal holes. The directional deformation, the normal stress and the equivalent stress explained the behavior of the member when portion of the concrete body missing by the holes, these condition can be notified clearly according to the appearance of mesh in the figures and the overall magnitude of the results. The circular hole indicated better cracked and internal strength values than the rectangular one as the moment of inertial for the rectangle cross section is higher than that for circular cross section with same area.

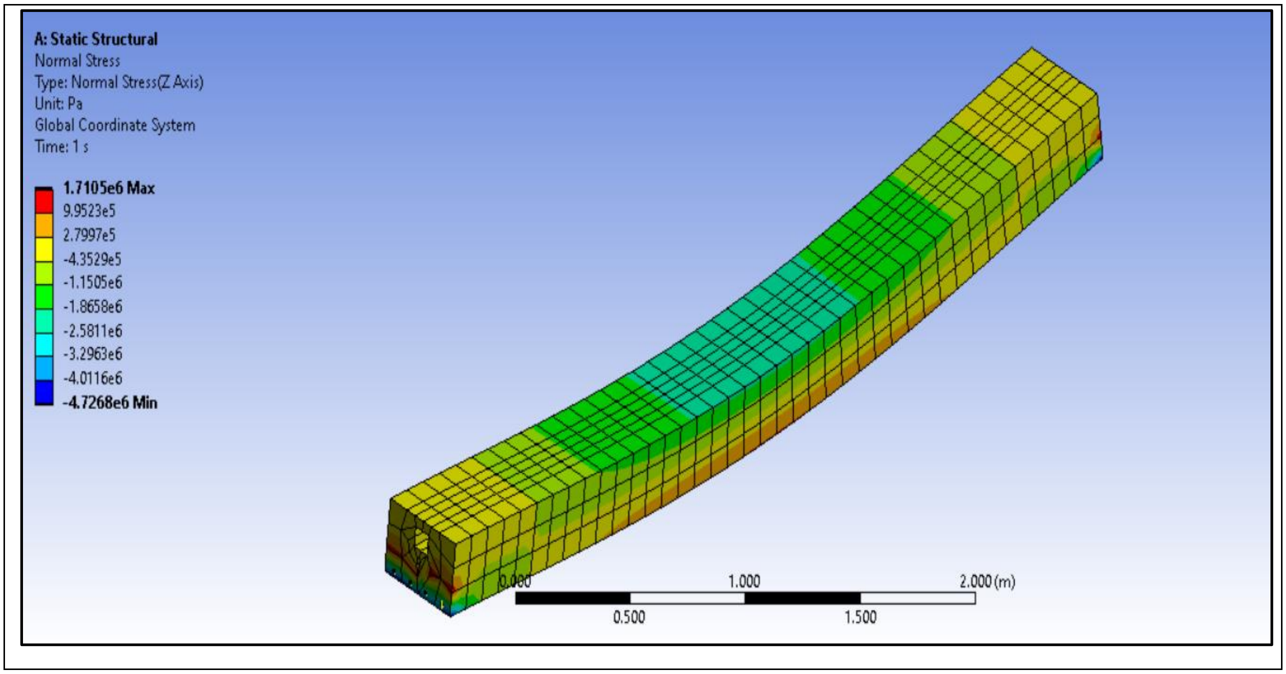

Figure 4.24: The Normal Stress of Rc Beam With The Rectangular Hole Case (ANSYS)

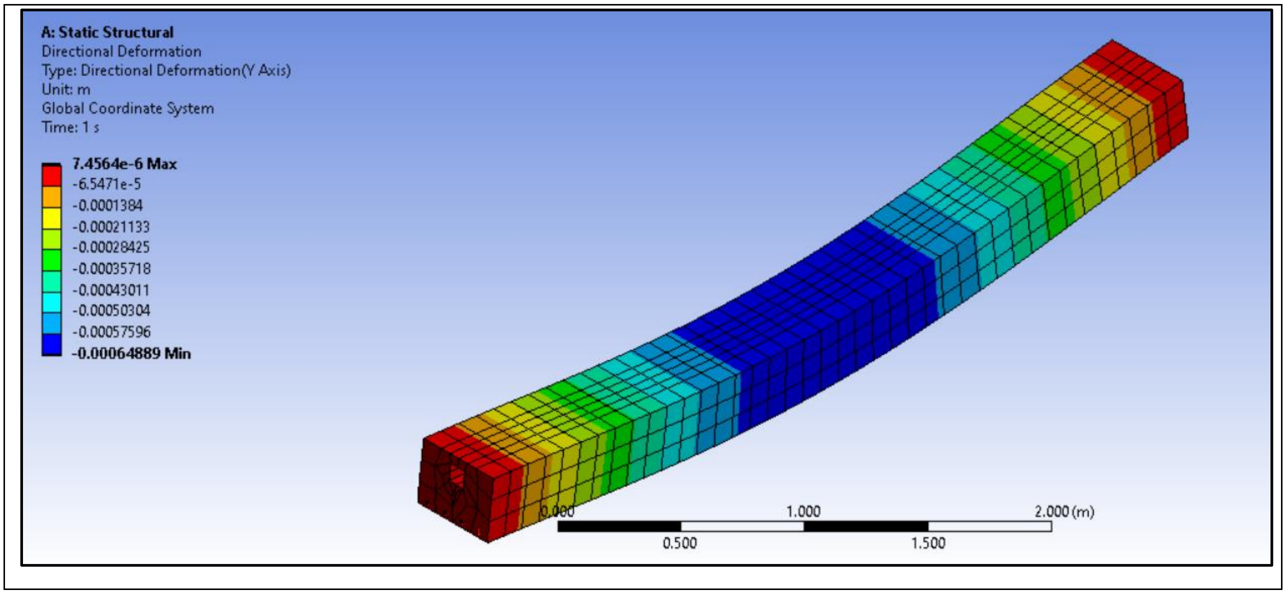

Figure 4.7: The Directional Deformation of Rc Beam With The Rectangular Hole Case (ANSYS)

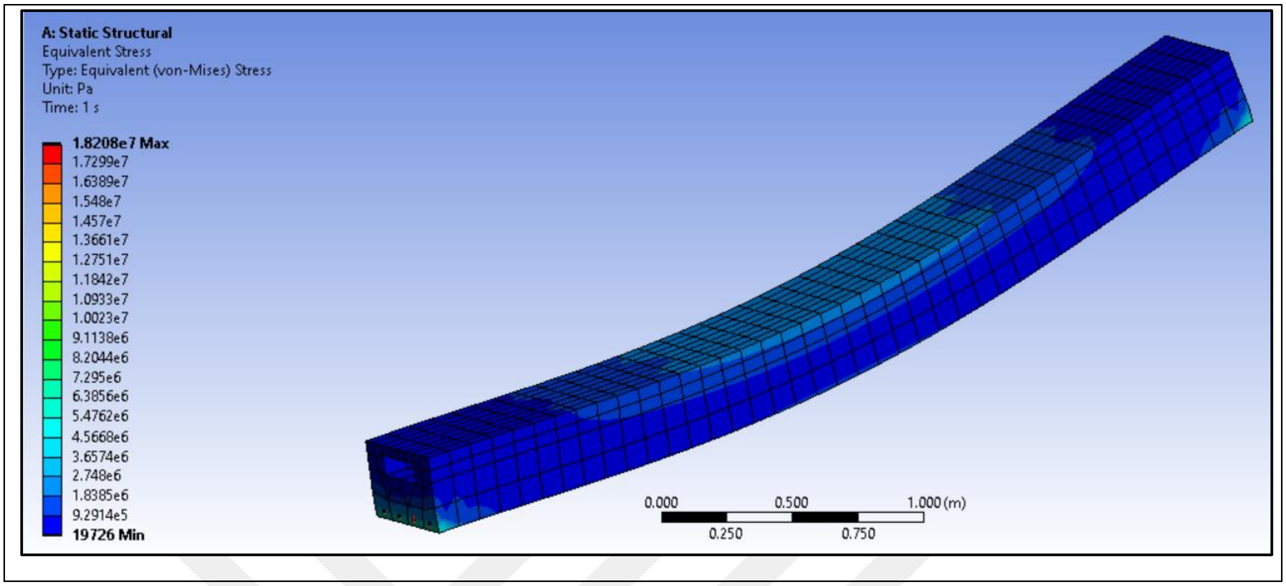

Figure 4.8: The Equivalent Stress of Rc Beam With The Rectangular Hole Case (ANSYS)

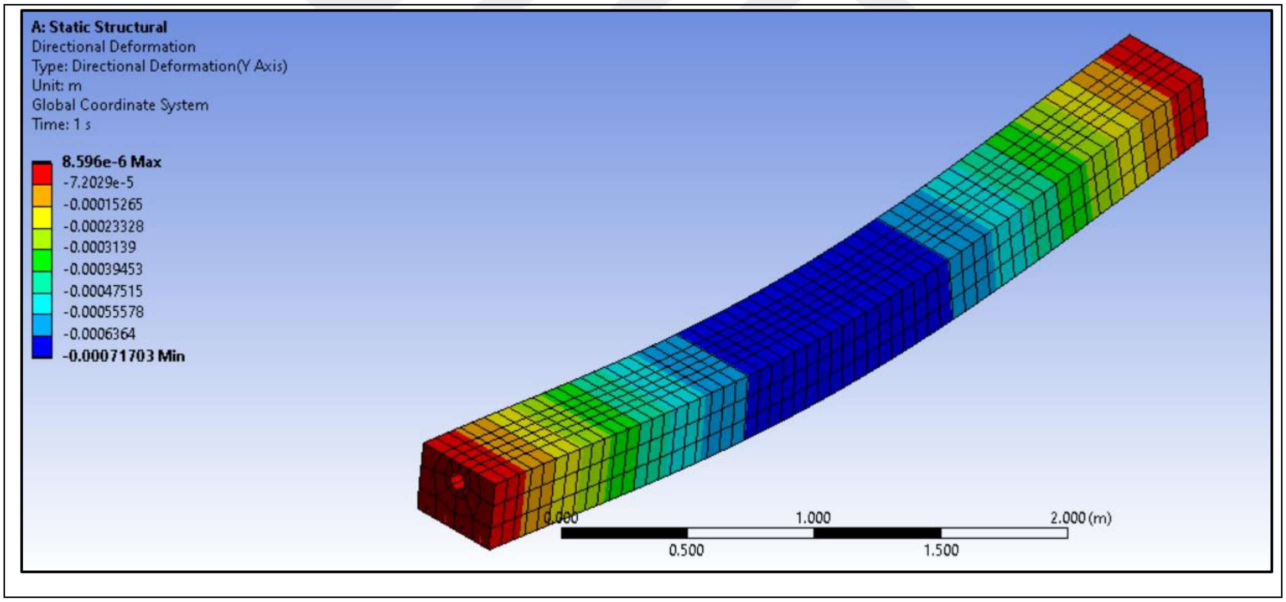

Figure 4.9: The Directional Deformation of Rc Beam With The Circular Hole Case (ANSYS)

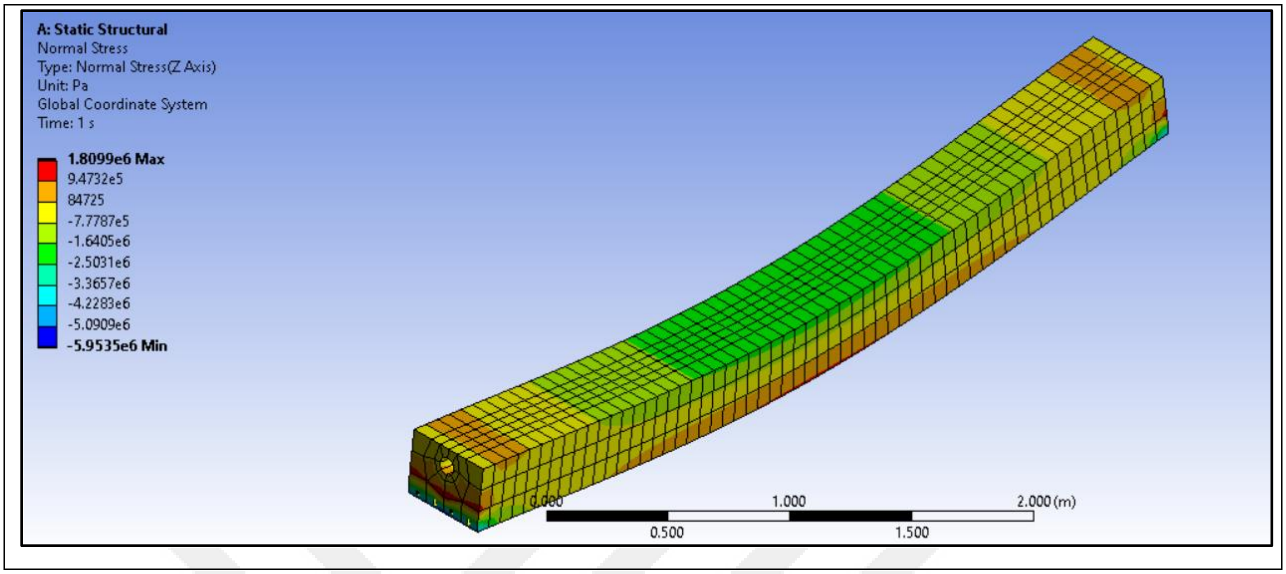

Figure 4.10: The Normal Stress of Rc Beam With The Circular Hole Case (ANSYS)

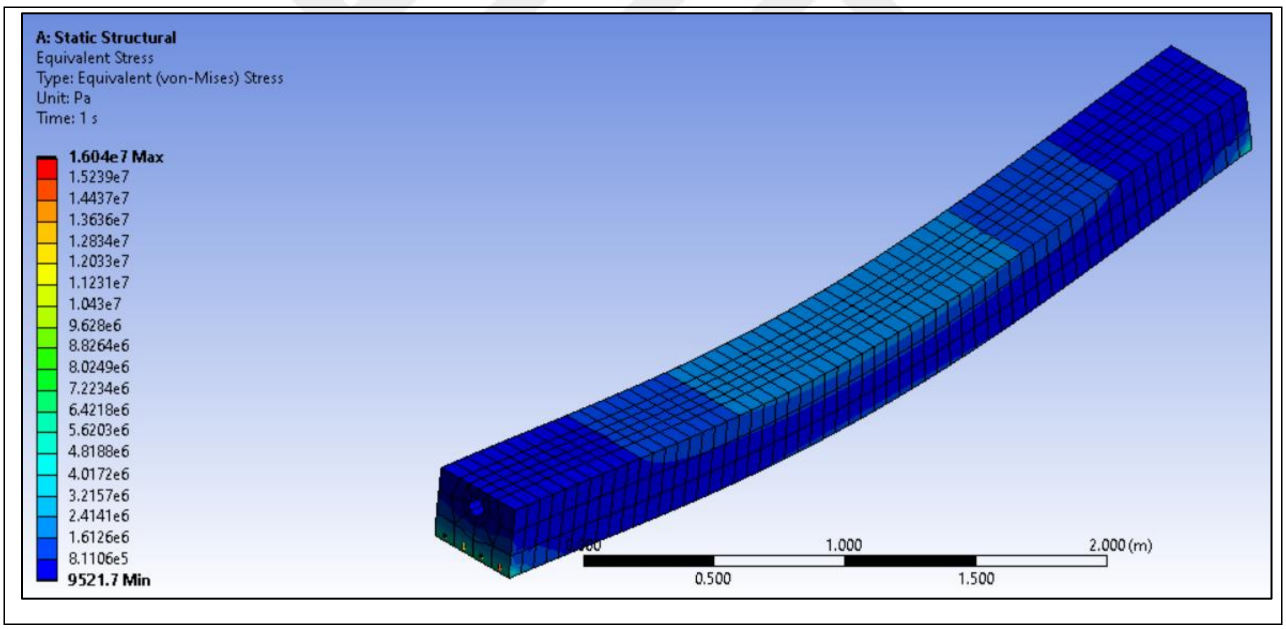

Figure 4.11: The Equivalent Stress of Rc Beam With The Circular Hole Case (ANSYS)

5. DISCUSSION AND CONCLUSIONS

5.1 CONCLUSIONS

The study results aimed to improve the design outline by ease the ways for the designer to choose the better shape of the longitudinal hole and the distance from the neutral axis to save the internal strength of the beam under the predicted loading. The analysis procedures of the RC beams that included longitudinal hole in two shapes, first with rectangular shape and second with circular shape were obtained in the pathway of the study line to examine the affectivity of existence of these holes on the overall strength of the member. The study took the impact of these holes by analyzing the effect of each shape in the cases of untracked and cracked section. The study made simulation for the two cases by drawing the geometrical and the physical properties of the RC beam inside ANSYS program. . The values of stresses were calculated with the rectangular hole 80*80 mm and with circular hole with 80 mm in diameter. The program rendering were showed by the images that solve the deformation and the stresses in the beam with rectangular and circular shapes.

The study made step by step analysis for the influence of the hole area, hole distance from neutral axis, length and width for rectangular hole, and the diameter for the circular hole. For each parameter, the study explained the results in tables and figures. The study showed that the height of the rectangular hole and the diameter in circular hole contributed significantly to the value of Mcr which is the moment that leading to cracked been happened in the tension zone.

a) The rectangular and circular for the cracked moment and for the ultimate moment showed closed values. The equation for the rectangular hole was: Mcr=-0.0002Ao+ 0.0015 As +18.957 for rectangular and Mcr=-0.0002 Ao+0.0015 As + 18.908 for circular shape. For the case of cracked section, the equation was: Mu=-0.0002 Ao+0.0281 As+71.77 for rectangular hole and Mu=-0.0008 Ao+0.028 As+70.893 for circular hole. the values of cracked section for the circular and rectangular section were explained in comparison part of the study.

b) The magnitude of the cracked section was decreased from 20 kN.m to 18 kN.m when the area of the hole is 5500 mm^2.

c) The distance of the center of the hole from the upper line of the cross section play important role in the resultant cracked or ultimate internal moment.

d) The two values of moment increased when the center of the hole be closer to the neutral axis.

5.2 FUTURE WORK

The coming ideas can deal with the effect of holes in prestressed beams and in strengthen beams by the polymers materials. These strengthen can give more flexibility in the longitudinal hole design. The design and the modeling of other concrete members like column and slaps with holes on the facing area toward the loading can be taken for future work. the analysis of the holes in concrete domes can be analysis and modeling as these forms can include openings for ventilation or windows or other useful openings.

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