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STATISTICAL ANALYSIS FOR THE AFFECTIVITY OF REINFORCEMENT BEHAVIOR ON THE STRENGTH OF CONCRETE ELEMENTS

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Master's Thesis

Supervisor

Prof. Dr. Tuncer ÇELİK

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The thesis titled “STATISTICAL ANALYSIS FOR THE AFFECTIVITY OF REINFORCEMENT BEHAVIOR ON THE STRENGTH OF CONCRETE ELEMENTS” prepared by MOHAMMAD SETAR and submitted on 06/12/2022 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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ABSTRACT

STATISTICAL ANALYSIS FOR THE AFFECTIVITY OF REINFORCEMENT BEHAVIOR ON THE STRENGTH OF CONCRETE ELEMENTS

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The study aimed to find out how the reinforcement in both longitudinal and vertical directions can contribute to the internal strength of the concrete beam according to the ACI code. The study set and analyzed the equations that included the impact of the steel area in both directions and the other properties of the member and programing them so that the resultant cracked moment, ultimate moment strength, shear strength of steel, and concrete shear strength were identified according to each equations and each limitations in the code. The study made many numbers of charts that included the relationship between each strength item and the steel area. The maximum shear strength of concrete according to the longitudinal reinforcement was identified and modeled into more direct equation so that the designer can identified the maximum contribution of the longitudinal reinforcement on all strength items of the beam. The study made the analysis for the cases of RC beam under double concentrated loads and other case under uniform loading. The impact of load magnitude, the study showed the behavior of the two cases according to the steel area used in number of charts that can enhance the design issues. The charts including the impact of the steel areas on strength of concrete and the maximum shear strength (Vc) obtained for various effective depths and widths of beam values. For supporting the outline of the study, simulation was made for each case of the RC beam under the techniques of ANSYS program. The simulation

showed the structures of both the vertical and the longitudinal reinforcement and how the stresses and the strain behaviors along the span length. The simulating also showed the directional deformation of the cases. The variation of the shear force along the section of the beam was showed by diagram that obtained by ANSYS program.

Keywords: Reinforcement, Concrete Elements, Statistical Analysis

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ABBREVIATIONS

AS	:	: Area Steel
FEM	:	Finite Element Method
FRP	:	Fiber Reinforced Polymer
GFRC	:	Glass Fiber Reinforced Concrete
HSC	:	High-Strength Concrete
NRSB	:	Non-welded Rectangular Stirrup Beam
WRSB	:	Welded Rectangular Stirrup Beam
WWTB	:	welded Warren Truss-shaped Beam
RC	:	Reinforced Concrete

LIST OF SYMBOLS

σ	:	Stress in Beam
E	:	Strain in Beam
I	:	Modules of elasticity
M	:	Moment in beam
S	:	Spacing between the shear reinforcement
d	:	Depth
w	:	Weight
f	:	Force applied

1. INTRODUCTION

1.1 OVERVIEW

Concrete is weak in tension due to the presence of a weak link inside the body of the concrete matrix known as the Interfacial Transition Region. Concrete is mostly made up of rock aggregates that are cemented together with the help of a cement paste, which is a cement and water mixture. The outside surface of which of the large stiff aggregates is generally filled with calcium hydroxide, which is a byproduct of the hydration reaction of concrete. This calcium hydroxide coating is weak and porous, contributing to the overall construction's low tensile strength. Tension is just the pulling force exerted perpendicularly and away from the surface. The effect produced by pulling on both ends of a rope in an effective pictorial manner. When tensile stress is applied to rope, it tends to lengthen and expand its length along the axis of implementation while decreasing the cross-sectional area of the material [1].Though it is crucial to note that not all types in the future will elongate and simply return to their initial condition once the imparted load is removed. This is the situation with concrete. The building material would not be able to endure high levels of tension and, if used, would result in irreparable deformation and destruction. On a microscopic level, one might envision that the heterogeneous units of concrete pieces are initially linked to each other in a manner similar to that of a paste or adhesive agent [2].It is reasonable to believe that the ultimate binding strength is proportional to the strength transferred with the aid of the connection inside the concrete materials. In other words, weak linkages lead to poor resistance to external factors such as strain. Concrete has this type of weak link, which limits its resistance to tensile pressures [3].

Tension is described as the pulling force away from the surface of a structure, and compression is defined as the pushing force towards the material. It usually leads in an increase in the cross-sectional area of the element while simultaneously decreasing the length. Concrete, when compared to other building materials, has an exceptional resistance to compression. Its high compressive strength, along with its low cost, make it a popular building material in the industry. However, it is vital to note that, while concrete has a high compressive strength, it is still weak in terms of tensile resistance. The gap between concrete's property is usually filled with reinforcements made of steel, which has a high tensile strength [4].

1.2 CONCRETE STRENGTH INFLUENCING FACTORS

There are various parameters that might affect the total strength of concrete, but the synergistic effects of its component properties have a significant impact on its values, which are mentioned below:

a. Water quantity and clarity

b. Cement (quantity and quality)

c. Quality, purity, and particle size of rock aggregates (grade)

d. Handling Techniques -pouring, spraying Admixtures-presence or absence

e. Temperature and humidity are the curing conditions [5].

Concrete is a complex mixture of three key constituents: cement, sand or rock aggregates, and water. The features of individual ingredients, as well as the processes that occur within the mixture, result in the overall mechanical properties of concrete, which is why understanding the state of function of each component is critical [6].

1.3 REINFORCED CONCRETE

Concrete is extremely strong when crushed, yet it can shatter when bent or stretched. Steel (or plastic) reinforcement is placed inside it to prevent it from bending. Steel is strong and will not bend, yet it is brittle. It is stronger because the body of concrete is formed around steel reinforcement bars. The steel is organized within it, shielded from rust and fire by the concrete, and the two elements work in tandem to handle the loads. Concrete hardens after a few days rather than drying out, it actually absorbs water [7].To counteract these disadvantages and assure the structural integrity of inhabitable structures, most civil engineering projects and some structural bodies of concrete constructions employ concrete reinforcements to ensure the structure's bearing and tensile strength. Bearing strength is defined as a structure's load bearing capacity or ability to withstand contact pressure or weight. Tensile strength is best defined as the ability of concrete to break inside tension bending [8].

1.4 CONCRETE REINFORCED WITH FIBERS

While many concrete applications, often those installed as non-load bearing applications, do not require reinforcement, others require the collected strength to provide a sound and compliant construction that is suitable for use or occupation. The addition of reinforcement to concrete, specifically the use of fibrous elements, dates back to prehistoric times when fibers such as straw and even horsehair were mixed with mud-like cement-based substance. The body of concrete can be reinforced by embedding elements such as steel rods or reinforcing bars, also known as rebar, mesh, wires, and cables in the concrete application, hence the title Steel Concrete. As a result, the installation or construction resists both tension and compression, with the concrete producing compressive strength and the steel producing tensile strength [9].Rebar is made of steel strands that are tightly twisted to generate a rope-like structure that helps to keep it firmly in the cured concrete. Furthermore, steel is frequently a recommended material to use when reinforcing the body of concrete as a result of its inclination to expand and contract much to the same degree as concrete when exposed to both hot and cold environments [10].

1.5 PRE- STRESSED CONCRETE

While strengthened body of concrete is one of the most durable building options available, pre-stressed body of concrete provides an even more effective reinforced concrete choice as well as an effective raveling outcome to prevent body of concrete from cracking or becoming brittle under pressure. Pre-stressing reinforced concrete is accomplished by applying compressive force to the body of concrete prior to its intended use. When pre-stressed concrete is eventually exposed to an external load, the pre-stress or compressive pressure applied to the concrete counteracts the loadbearing stress on the reinforced concrete fitting, providing an extremely durable and robust solution [11].Reinforced concrete is employed in a variety of design projects, both large and small, ranging from fiber reinforced body of concrete or steel body of concrete reinforcements to pre-stressed or pre-tensioned concrete. Reinforced concrete is used in practically any large-scale civil design project, including bridges and sports stadiums, as well as water-based buildings such as dams and piers. It is also used in home features such as foundations, columns, lintels and loadbearing walls, platforms, and balconies [12].

1.6 IMPORTANCE OF STEEL REINFORCEMENT IN CONCRETE STRUCTURES

Steel reinforcement is a spectacular breakthrough from the nineteenth century that has been widely employed to reinforce concrete constructions in the building industry all around the world. Because of the numerous advantages that this method of reinforcement provides, it has become a key component of the construction of big bodies of concrete structures today. Steel bars strengthen the concrete framework and enable for more specialized designs, such as cantilevered constructions (long constructions anchored at only single end). It also allows for the use of thinner, less supported concrete slabs and encourages shorter building periods, to name a few advantages [13].

1.6.1 Summary of Concrete and Steel Properties

1.6.1.1 Characteristics of concrete

a. Poor tensile strength: Concrete's low tensile strength (its resistance to breaking under tension) is most likely the number one reason why it needs to be reinforced.

b. High compressive strength: Because concrete has a high compressive strength, it is appropriate for large constructions that must endure high compressive forces.

c. Moldable: When mixed, concrete may be shaped into almost any shape before it dries and hardens. The attribute makes it excellent for construction because it has few typical shapes and designs, allowing architectural engineers and engineers to work without limits [14].

d. Concrete is a relatively inexpensive ingredient when compared to other materials in construction sector, such as steel.

1.6.1.2 Characteristics of steel

a. High tensile strength: Steel items, particularly steel reinforcement, have a high tensile strength, making them excellent for strengthening concrete buildings. A steel reinforced concrete construction will provide a material with increased tensile strength, which will not easily break under high tension as seen in massive structures.

b. Steel, like concrete, has a high compressive strength and can withstand the tremendous compression pressures found in larger buildings and structures. Steel and concrete, when combined, form the ideal constituent for long-lasting structures such as buildings, bridges, and more.

c. Steel is more difficult to mold and shape than fresh concrete, but it can be molded and shaped at extremely high temperatures. This makes shaping and bending more difficult, but it is still achievable.

d. Relatively costly: Despite the fact that steel is rather expensive, and there will be no material waste in the future [15].

1.7 PROBLEM STATEMENT

The deformation of concrete members can lead to critical problems toward the chance of failure to be occurred. The resistance of the concrete body to the bending stresses is built as the available compressive and tensile strength of the member. The weakness of concrete to handle tension stresses can lead to the problems of cracks and high deflection relatively. The tensile flexural strength is important approach in concrete for assigning the right properties in the desire design .

1.8 CONTRIBUTION

The analysis and evaluating of the influence of reinforcement properties and amount and shapes inside the concrete body can reflect important contribution to the flexibly and precious of design. The detection of the optimum properties of reinforcement can reduce the overall cost and support the member with high strength. The study moved toward the evaluation of the impact of reinforcement with various properties on the structural performance of the members.

1.9 OBJECTIVE

a. Analysis the strength of various shapes of concrete beams with and without reinforcement using ultimate stress design method

b. Input the data inside statistical analysis by using SPSS program and identify the variation and the degree of impact of the reinforcement that added to the concrete beam to the member strength

c. Simulating the cases by using the techniques of finite element under ANSYS workbench program

d. Building applicable figures for explaining the effectivity of reinforcement in structural performance.

2. LITERATURE REVIEW

2.1 INTRODUCTION

Reinforced concrete beams are structural elements that are designed to carry transverse external loads. The loads generate bending moments, shear forces, and, in some cases, torsion along their length. Furthermore, concrete is strong in compression but very weak in tension. As a result, steel reinforcement was tried to take top tensile stresses in reinforced concrete beams. Furthermore, beams assist loads coming from slabs, other elements, walls, and columns. They transfer the loads to the columns that support them. Additionally, beams that can be simply supported, continuous, or cantilevered. They can be designed as rectangular, square, T-shaped, or L-shaped sections.. Beams can be reinforced either singly or twice. The latter are used in this manner if the depth of the beam is limited. Eventually, the design of a rectangular reinforced concrete component will be presented in this section [16].

Concrete wherein steel is embedded in such a way that the resisting force magnitudes of multiple materials interact with each other. In a concrete structure, reinforcing steel—rods, bars, or mesh—absorbs tensile, shear, and sometimes compressive stresses. Plain concrete cannot withstand tensile and shear stresses caused by wind, earthquakes, vibrations, and other forces and is thus unsuitable for major structural applications. In reinforced concrete, the tensile strength of steel and the compressive strength of concrete work together to allow the member to withstand these stresses over long distances. The discovery of concrete in the nineteenth century transformed the construction industry, and concrete quickly became one of the world's most popular construction materials [17].

2.2 TENSILE STRENGTH

By definition, tensile means capable of being drawn outside or stretched. Tensile strength is the ability of steel to withstand tensile tension. It has been attempted to use to specify the point at which steel transitions from elastic (temporary) to plastic (permanent) deformation. It is typically measured in terms of truck full per cross-sectional region. When a piece of steel is tried to pull past its tensile stress point, it splits. Tensile strength of steel indicates how much tensile stress the steel can withstand before failing in one of two ways: ductile or brittle failure. Tensile strength is calculated using the maximum force that the steel can withstand while being stretched or managed to pull before breaking [18].

2.3 TYPE OF FAILURES

a. Ductile failure considers this the stage before permanent deformation, where it is pushed beyond the yield point.

b. Brittle failure this is the final stage in which the tensile strength is measured[19].

2.4 YIELD STRENGTH

Yield capacity is the force that can be applied before it permanently changes shape. This is a close approximation to the steel's elastic limit. If force is applied to the metal but it does not reach the yield point, the metal will return to its original shape once the stress is removed. When the applied stresses exceed the yield point, the steel is unable to rebound. Yield strength represents the maximum load that can be safely applied to metal, making it an important number to understand when designing components [20].

2.5 STRESS- STRAIN RELATIONSHIP

A typical stress-strain relationship for normal strength concrete is present. After an initial linear portion lasting up to about 30 – 40% of the ultimate load, the curve becomes non-linear, with large strains being registered for small stress increments. The non - linearity is caused primarily by the coalescence of micro-cracks at the paste-aggregate interface. The final stress is reached when a massive crack network within the concrete forms, consisting of coalesced micro-cracks and cracks in the cement paste matrix. For normal strength concrete, the strain corresponding to ultimate stress is typically around 0.003. In tension, the stress-strain behavior is similar to that in compression [21].

Figure 2.1 and 2.2 explained the behavior of stress-strain in typical state respectively. A dislocation or strain controlled test machine can obtain the descending portion of the stress-strain curve, or in other words, the post-peak response of the concrete. A constant rate of load is applied to the specimen in typical load controlled machines. Thereby, each additional load beyond the specimen's ultimate capability results in a catastrophic failure. In a displacement controlled device, small increments of dislocation are given to the specimen. As a result, the decreasing load beyond the peak load capacity can also be detected. As shown in Figure 2, the strain at failure for normal strength concrete is typically around 0.005. The post upper point behavior is a function of the stiffness of the testing machine in relation to the stiffness of the test specimen, as well as the rate of strain. As the strength of concrete increases, so does its brittleness, which can be explained by a decrease in the strain at failure [22].

These curves seem to be invariant for various concrete ultimate strengths, specifically the upper point stress as well as ultimate strain. They consist of a relatively elastic portion in which force and strain are closely proportional, followed by a curvature to the horizontal, reaching maximum he, i.e., the compressive strength fc, for a strain of approximately 0.002, and finally a descending branch. They also demonstrate that concrete with low strength is more ductile, failing at higher strains [23].

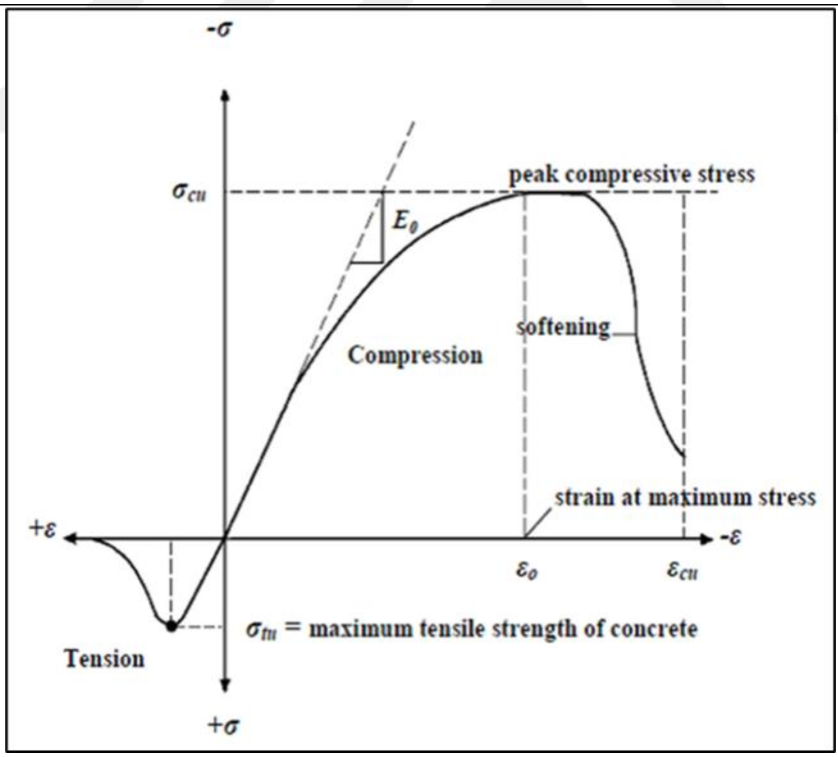

Figure 2.1: Typical Stress-Stain Curve For Concrete Under Loading [52]

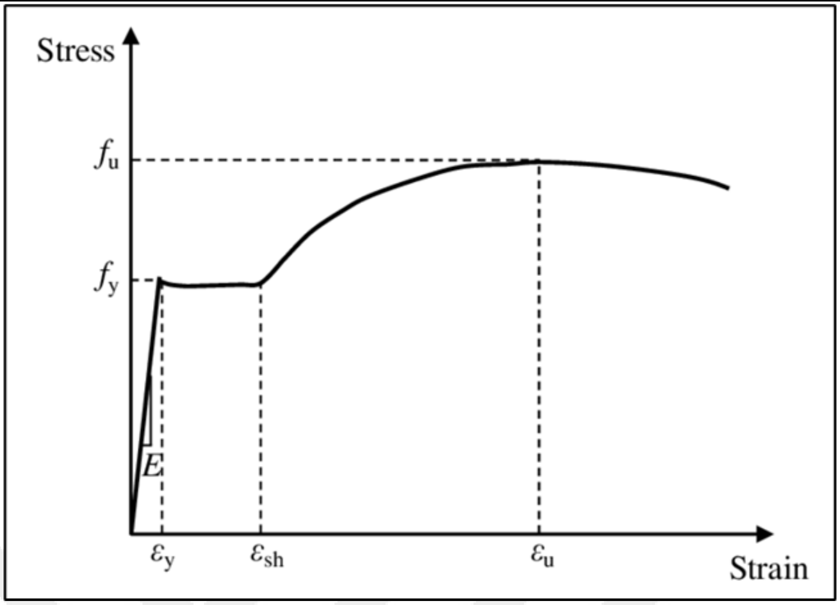

Figure 2.2: Typical Strain-Stress Curve For Steel [53]

The Stress-Strain Curve for Steel as I figure 2.2 is linearly elastic up to a constant stress (known as the proportional limit, fp), after which it reaches the yield point (fy), where the stress remains nearly constant despite strain differences. Beyond fy, the force increases with stress (strain hardening) up to the maximum stress (ultimate strength, fult) and then decreases until failure at a stress (fbrk) close to fy. The typical stress-strain curves for in-service which also shows the decreasing ductility of higher-strength metal due to the disappearing yield area. However, regardless of strength, the modulus of elasticity (Es) remains nearly constant. The elastic-perfectly-plastic (EPP) model for assumes that stress varies linearly with strain up to the yield point (fy) and then remains constant [24].

2.6 REINFORCEMENT DEVELOPMENT IN CONSTRUCTION PROJECTS

Steel reinforced concrete structures are affordable and last a long time, despite being one of the strongest building materials available. However, there is the issue of corrosion. Steel reinforced concrete rusts, and while methods exist to slow the process, it is unavoidable. Steel bars have alternatives, but none have gained widespread acceptance. Glass, basalt, aramid, and carbon are examples of fiber-polymer composite materials [25].

2.6.1 Steel Fiber

The execution and resultant method determine the shape of steel fibers. The greater the bond strength of the fiber, the less magnitude of fiber is required to achieve the same increases in toughness, shear capacity, and so on. Steel fiber aspect ratios are typically in the range of 20 to 100, with lengths ranging from 6.4 to 76 mm. Steel fibers can be placed in the form and then infiltrated to achieve higher fiber fractions than around 2% without compromising workability. This is done in conjunction with conventional reinforcement [26]. The material obtained with such large fractions of steel differs significantly from ordinary concrete. Compressive strength can reach up to 140 MPa, tensile strength around 40 MPa, and flexural strength around 90 MPa. Steel fibers near the body of the concrete surface may exhibit problematic behavior. Because they are exposed to the corrosive exterior environment, they will rust, leaving unsightly stains on the surface. They may also be sharp and dangerous to living creatures or tyres. Steel fibers are rarely in contact with each other for normal volume fractions, so no galvanic circuits can form between different units. Any voltage differential dominant to also be built on top of each non-large fiber. As a result, rust is typically less important in SFRC than in steel reinforced concrete [27].Steel fibers some ways have not been used in greater quantities as the sole reinforcing material in flexural concrete members; the ACI even recommends the somewhat conservative design trend that reinforcement bars are required to resist tensile force magnitudes. This is primarily due to the uncertainty about whether the fibers have been distributed evenly throughout the member. Steel fibers, on the other hand, have been shown to effectively replace shear stirrups and secondary reinforcement [28].

2.6.2 Glass

Ordinary E-glass fibers degrade relatively quickly in the alkaline environment of concrete. This can be accomplished with varying degrees of success by either coating the surface of the fibers or changing the chemical composition of the material. It was discovered about 50 years ago that adding zirconia to the glass melt increased alkali resistance, and this is still the most common addition material in AR-glass. Another method of increasing the durability of alkali-sensitive fibers in the body of concrete is to reduce the alkalinity of the concrete, as previously discussed. Even for the best glass fibers available in the future will worsen and lose strength over time, especially if the concrete participant is exposed to harsh environments. When fully aged, typical remaining capacities of glass fiber reinforced body of concrete (GFRC) are 40% of initial tensile and flexural resists and 20% of initial tensile strain capacity; this is higher than for AR-glass and lower than for E-glass. The loss of strain capacity that can be seen as a result of embrittlement. AR-glass is currently being upgraded to improve its resistance to concrete conditions. Until now, glass fiber reinforced concrete has primarily been used for façade panels and complex geometry applications such as sinks and pipes. Glass fiber reinforced polymer has piqued the interest of researchers in recent years. According to one similar study GFRP and steel rebar, "GFRP reinforcing bar does have higher tensile strength and greater corrosion resistance than steel rebar." The study also concluded that, based on the findings of the researchers, GFRP is a viable alternative to steel in foundations [29].Some argue that while GFRP may be more expensive up front, the life-cycle cost is substantially lower than maintaining and repairing steel reinforced structures. Glass does not rust and is sensitive to Uv damage, resulting in fewer cracks, among other benefits [30].

2.6.3 Basalt

Basalt fibers are derived from the popular rock basalt, which is formed when lava solidifies. During the cold war, the Soviet Union conducted the first tests accompanied by basalt fibers. Basalt as a reinforcement material for concrete, both directly dispersed and in epoxy rods, is a relatively new application that has received less attention than fibers. As a result, some doubts about its mechanical properties and durability remain. In terms of mechanical properties, most information sources place basalt fibers slightly above glass accompanied [31].

Workability as well as balling opposition are slightly better when dispersed in concrete than when combined with steel fiber. According to some, basalt can withstand high alkalinity and deteriorates far less than glass fibers. Other studies have shown that it does lose less volume due to the concrete environment, but that its strength is influenced even more than E-glass. According to one theory, one of the causes of these losses is the presence of alkali sensitive pyroxenes in basalt's chemical composition. Much like with glass fibers, attempts have been made to change the chemical composition of basalt in order to improve its durability properties [32]. In one such experiment, Al_2O_3, MgO, and TiO_2 were added to basalt melt in various combinations. A control batch of unaltered fibers was kept for comparison. Two liquids were used to immerse entire fibers. One is completely alkaline, while the other simulates concrete pore water. Both liquids produced comparable results. The reduction in fiber strength is most noticeable at first and then slows down gradually [33].

2.6.4 Fiber Reinforced Polymer (FRP) Reinforcement

Fiber reinforced polymers (FRP) are composite materials made up of unidirectional fibers encased in a resin matrix. The materials vary greatly within the group due to different fiber and matrix combinations. Overall, FRP performs a group of very different characteristics, and unlike most other materials, it can be designed to meet specific needs. However, there are many similarities, particularly when some of the more unsuitable FRPs for building purposes are excluded. The element is thus evaluated as one in the first part of this section, after which possible variations in each variety are examined further. Composite materials are not a novel concept. Textiles have indeed been reinforced with metal threads, and non-artificial resins and bitumens have been used to glue metal sheets together. In the construction industry, mud and straw are a composite, and masonry is a (macro-scale) composite of well [34]. However, it was not until after World War II that plastics became widely used, and they were soon reinforced with the help of fibers. When fiber reinforced plastics began to behave in a variety of applications involving aerospace, marine, and sports, it took some time before they were seriously considered for use as the body of concrete reinforcement. Due to the increase in motor vehicle traffic, the road network was vastly expanded during the close to adequate period. De-icing salts were first used in areas that experienced snowy and icy winters. However, it was soon discovered that this practice caused infrastructure reinforcement to corrode [35].

2.7 CURRENT WORK

The study aimed to investigate the validity and the right ways to improve the strength of concrete beam by examining the contribution of various reinforced state according to their strength on the overall strength of the member. The study assign the reinforced used with cases relating to the applied loading and the geometrical shape of the beam. The study arranged the input data inside statistical analysis using SPSS program then simulating the cases under ANSYS workbench program for better supporting of the analytical outline.

2.8 LITERATURE SURVEY

(H. Mahzuz, et al., 2021) the study showed that the Torsion failure is an unwelcome brittle failure of a reinforced concrete structure that could be avoided, particularly in earthquake-prone areas. Recognizing this issue, numerous studies were conducted above the torsional strength of bolstered body of concrete using various techniques. The flexure behavior of variant Enhanced Cement Concrete beams was studied in this study using distinct patterns of shear reinforcements to find the best alternative shear additional forces when compared to the conventional Non-welded Rectangular Stirrup Beam (NRSB). In this study, a new shape of warren truss shaped shear reinforcement was tried. With a fixed concrete dimension and the same reinforcement weight and yield strength, three types of beam were tested: non-welded rectangular stirrup beam (NRSB), welded rectangular stirrup beam (WRSB), and welded Warren Truss-shaped beam (WWTB). In all beams, 16 mm bars were used for bottom and top longitudinal reinforcement, and 10 mm bars were used for shear reinforcement. One body of concrete mix ratio, namely 1:2.5:2.5, was considered (by volume). The elastic theory was used to calculate the angle of twist in which of each beam [36].

(O. Aziz & F. Karim, 2008) the study showed that the behavior and the environment experimentally. Inside combined tensile stress, joining, and torsion, the ultimate strength of L-shaped reinforced high strength concrete beams was determined. The experimental program includes casting and testing (13) high strength concrete beam bodies under bending, shear, as well as torsion. The main factors are the effect of compressive strength, quirkiness, and the transverse to longitudinal reinforcement ratio. An rise in cross section to longitudinal reinforcement ratio of (21.43 percent) causes a decrease in ultimate resisting torsional moment of (13.19 percent) for beams under 80mm eccentricity of forces action, and for an eccentricity of 170mm; the decrease in resisting torsional action of moment is (15.14 percent). If all types of reinforcement remain constant, an increase in eccentricity of (112.5 percent) for torsion results in a decrease in load carry capacity of (43.33 percent). By using multiple nonlinear stepwise regression analysis on data from this research and other literatures, formulas for predicting shear strength at cracking and ultimate loads, as well as torsional ability at cracking and tensile properties, are proposed. These summarized equations demonstrated better agreement when compared to equations obtained from practice codes such as (ACI, Canadian, and BS) and demonstrated good relationships. [37]

(Ke Shi, et al., 2021) the study showed that the Steel fiber and NaNano–SiO2 concrete is a novel concrete element that has great potential for use in practical engineering. However, there have been few past research on the flexural behavior of steel fiber and Nano–SiO2 materials reinforced concrete (SFNMRC) beams. As a result, the primary goal of this paper is to investigate this same flexural performance of SFNMRC beams using a combination of experimental and theoretical studies. A total of ten specimens were tested to investigate the flexural behavior and the effect of key parameters such as concrete strength, the size distribution of steel fiber, and the quantity of Nano–SiO2. The loading versus deflection curves of SFNMRC beams were thoroughly examined throughout the loading process. The failure mode was thoroughly discussed, and all of the specimens exhibited intense ductility. Furthermore, the test results revealed that joining cracks and bodies of concrete crushing were formed in the compression zone of all specimens. All cracking loading and ultimate beam loading increased as the body of concrete strength and the volume fraction of steel fiber increased. Above the flexure acting, the amount of Nano–SiO2 had a limited effect. Finally, the measuring formula for predicting the flexural bearing capacity of SFNMRC beams was developed with the effect of steel fiber above the cracked sections within a week of beam cracking in mind. The predicted outcomes are in good agreement with experimental results. The studies may provide a significant reference for designing this type of structure in engineering practice[38].

(B. Mahmood, 2012) the study showed that the goal of this research is to estimate the impact of web openings in reinforced bodies of concrete deep beams using nonlinear finite element analysis. Concrete is represented by eight isoperimetric nodes, serendipity plane stress, and elements. The reinforcement was treated as embedded members and was thought to be elastic and perfectly plastic. New constitutive modelings to simulate the body of concrete material were proposed using a nonlinear regression analysis of many experimental data sets using the SPSS 16 statistical program. To model the compressive performance of high strength concrete, an impression hardening approach was used. In tension, two models were used to simulate the high strength body of concrete in the pre-peak and post-peak states.. A smudged fixed crack approach is assumed, with cracked concrete in tension. Three variables were considered: concrete strength, shear span – to – depth ratio, and the width and depth of openings. The results showed that deep beams with openings have significantly lower ultimate strength than deep beams alone. The experimental results for a reinforced high strength body of concrete deep beam with openings were compared to the finite element results and found to be in good agreement. Deep beam, Finite element, High strength concrete, Non - linear resolving, Openings, New constitutive model are some of the keywords used in this study [39].

(Sethuraman V.S, et al., 2017) the study showed that the goal of this paper is to model and analyze an M60 body of concrete beam using Abaqus for static loading and to validate the results using experiment. Concrete with a compressive strength of 60 MPa or higher has been used for high-rise buildings and long-span bridges in recent years. The introduction of various mineral and chemical admixtures has facilitated the production of high strength to high performance concrete. HSC assists in avoiding the use of unacceptable oversized columns on the lower floors by allowing large column spacing and usable ground space or increasing the number of possible stories without detracting from the lower floor. HSC lowers the dead load on link girders and piers, allowing for wider underpass clearance widths. ABAQUS is a powerful design simulation software suite based on the finite element method (FEM) that can solve problems ranging from relatively simple linear analyses to the most difficult nonlinear simulations. In the this paper, a M 60 beam was modeled with various reinforcement setups and the results were compared [40].

(M. Rashid & M. Mansur, 2005) the study showed that the results of flexural tests performed on 16 reinforced concrete beams to assess the implications of using high-strength concrete (HSC) are reported. Body of concrete compressive strength, tensile and compressive reinforcement ratios, and lateral tie spacing are among the test elements considered. The existing code provisions for conclusion can be drawn of maximum crack width and strength characteristics are found to be adequate up to a concrete strength of approximately 130 MPa. Concerns have been raised, however, about their suitability for cracking activity of moment and provider loading deflection. It is demonstrated that applied stresses caused by concrete shrinkage and creep can significantly affect the cracking moment and service load deflection of reinforced HSC beams. Also, when HSC is involved, part of the detailing requirements for compression reinforcement must be reassessed in order to utilize its full strength potential and ensure adequate ductile response of the beam [41].

(Yasen zy., et al., 2021) the study indeed an exploratory investigation into the layered concrete beam. It includes researching the possibility of using mortar intervention with layers of glass fiber for the tension zone in a loaded backed concrete beam. To produce a lighter element than the element with all Normal concrete and to detect the effect of this substitute above beam properties.

A rectangular beam section (150*200*1000)mm cast with NSC (normal strength concrete) at the compression zone and mortar with layers of 3D glass fiber used as part of the tension zone. The beams produced are layered flares with a lighter weight than a homogeneous RC beam. All beams were tested under two point load until failure at three different levels in which the replaced layers (1/3,1/2, and 2/3 of the element thickness) were studied. The full load capacity result shows an apparent decrease in the beam's loading capacity, but as the lightweight layer increases, this decrease in loading capacity decreases. For (1/3,1/2, and 2/3) of the beam thickness replaced with mortar and 3D textile fiber, the percentage of failure loading is (33.04 percent, 27.18 percent, and 19.73 percent), and the weight is (5.45 percent, 9.07 percent, and 12.92 percent) for the close to sufficient sequence, respectively. Which beams are tested for stiffness, ductility, and toughness? An apparent decrease in stiffness value which of the tiered beams is recorded in conjunction with the reference ones. It shows an increase throughout toughness and tenacity value after a short period of time [42].

(H. Al Saadi, et al., 2017) the study showed that the One of the major challenges and current research in the field of construction state designing is the strengthening of foundational structural elements using readily available market materials. A few studies were done above to strengthen various structural components using traditional and advanced materials. Many researchers attempted to improve the strength of reinforced concrete (RC) beams by using steel plate, glass and carbon fiber reinforced polymers (GFRP & CFRP). Because of the high weight-to-strength ratio and compatibility in strength between FRP composites as well as steel bars, steel plates, and GFRP and CFRP composites, they have not been tried for practical use in strengthening works. As a result, the suitability of using wire mesh for the purpose of strengthening the RC flexural parts is investigated in this job using experimental work.. In this work, a new technique of strengthening system using wire mesh is used to improve structural characteristics and, as a result, flexural strength of RC beams. The results of experimental and theoretical analysis were compared, and it was discovered that there is a good correlation between them. The experimental results show that RC beams reinforced with steel wire mesh are a simple technique for strengthening existing flexural members [43].

(Y. Zhao, et al., 2020) the study showed that the Because of their high strength, light weight, and strong corrosion resistance, fiber-reinforced polymer bars have been widely used for strengthening the body of concrete members. To protect the fiber-reinforced polymer bars from external hazards, a near-surface mounted strengthening system was used. This study concluded that a pre-stressed near-surface mounted steel–basalt–fiber-reinforced polymer composite bar could be used to compensate for the lower stiffness and ductility of fiber-reinforced polymer bar in comparison to steel rebar. The steel–basalt-fiber-reinforced polymer composite bar is created by wrapping a steel rod with a basalt-fiber-reinforced polymer cover.. Nine concrete elements are fabricated and tested, one for control or calibration and the other eight for reinforcement with pre-stressed near-surface mounted steel–basalt-fiber-reinforced polymer composite bars. The findings indicate that the proposed steel–basalt-fiber-reinforced polymer composite bar strengthening methods can improve the overall strength and ductility of reinforced concrete beams. Pre-stressing the steel–basalt-fiber-reinforced polymer composite bars significantly increases the load-carrying capacity of the beams by preventing crack propagation in concrete. The cracking load is correctly predicted by standard-based load analysis, but the ultimate strength of the beams is underestimated. Finite element methods modeling is used to provide a more accurate load-carrying capacity prediction, and a state study is performed to determine the magnitude of the bolstering steel. –polymer composite bar reinforced with basalt fibers [44].

(J. Huang, et al., 2021) the study showed that the used specimens with four different dimensions and concrete beams with six different transverse reinforcement to investigate the properties and flexural behavior of ultra-high-performance fiber reinforced body of concrete (UHPFRC) cured at 20 oC. At a curing temperature of 20 oC, the standard cubic compressive strength of UHPFRC specimens cannot be achieved. The bearing capacity under flexure of UHPFRC beams was improved as the reinforcement ratio was increased. As the reinforcement ratio increased from 1.26 percent to 9.50 percent, the failure modes of UHPFRC beams changed from ductile to brittle. Furthermore, the ductility of UHPFRC beams decreased with an increase in the reinforcement ratio from 1.26 percent to 9.50 percent. The flexural behavior of UHPFRC beams cured at room temperature was consistent with previous studies on UHPFRC beams cured at high heat. Furthermore, the CECS38-2004 framework . the framework underestimated the maximum bending ability of the under-reinforced UHPFRC beams (with reinforcement ratios ranging from 0% to 7.85%) and overstated the bending moment ability of the UHPFRC beams with a high reinforcement ratio of 9.50% [45].

3. METHODOLOGY

3.1 INTRODUCTION

For many problems the solution can be significantly simplified by using already calculated equations or values for the deflection curve. That have listed below the tables with the calculated equations of the deflecting curves for various types of beams and for various loads: these tables you can use in order to simplify the solution of the problems by simply taking the ‘ready to go’ results or in order to control the solution. Since that solution possibility is obvious, that will not be using it in this book for solving the problems. that simply mentioned it as an existing possibility to simplify the solution and that will concentrate later on the other solution possibilities where you actually need to solve the problem, and not adopting the existing table values. Unfortunately not all problems can be solved exactly. For example, for the beam presented in the drawing above, there is no exact solution. One would not be able to determine the bearing forces as well as the equation for the bending moment.

This problem that will solve later in this book, so stay tuned The question now is what to do if the exact solution fails. If this is the case, then one can use one of the approximate solutions: the polynomial solution or the potential energy minimum principle solution. Being approximate solutions, both of the above mentioned solutions are not supposed to deliver the same result as the exact solution (if existed) would produce, but this is completely fine Now we will start with the polynomial solution possibility. In order to do this we need to define the deflection curve in polynomial form.In order to solve a particular problem, we need to choose the correct polynomial form for this particular problem and need to decide which polynomial degree would be appropriate. That needs to keep in mind and find a balance between two things. That would like that the polynomial solution differs not much from the exact solution (ideally it would be identical to the exact solution if those exists). But we would like also that mathematical solution is not overcomplicated.

3.2 THE ANALYSIS PROCEDURE

The stress formation on small part of the beam length according to the internal moment strength was showed in figure 3.1 and figure 3.2.

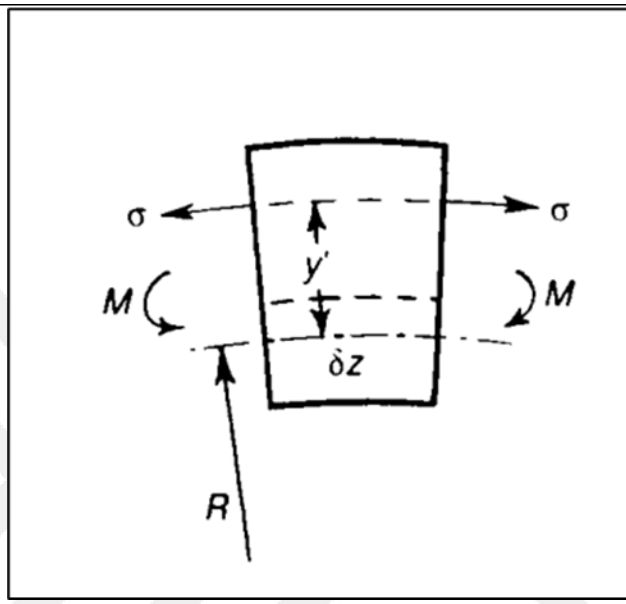

Figure 3.1: The Stress Formation On Beam Element [46]

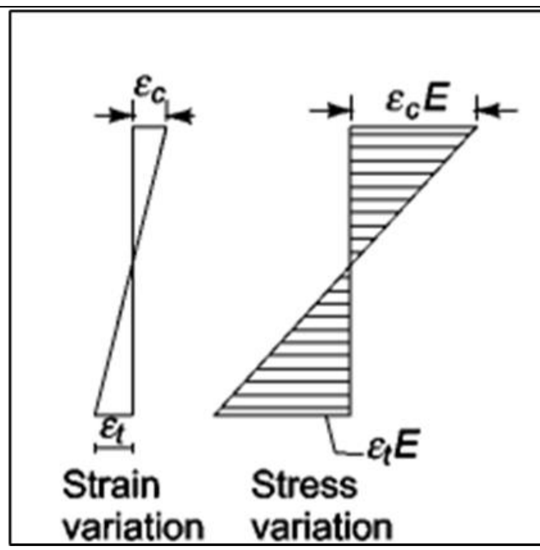

Figure 3.2: The Stress Formation On Beam Cross Section [46]

The linear relationship between the stress strain of the beam indicate the following analysis steps to identify the stresses based on the element modulus of elasticity and place of the neutral axis in the cross section:

$$dx = R\, d\theta \quad (3.1)$$

The change in length = $R\, d\theta - (R - y)\, d\theta = y\, d\theta$ (3.2)

$$strain = \frac{\Delta L}{L} = \frac{y\, d\theta}{R\, d\theta} = \frac{y}{R} \quad (3.3)$$

$$\sigma = \frac{E\, y}{R} \quad (3.4)$$

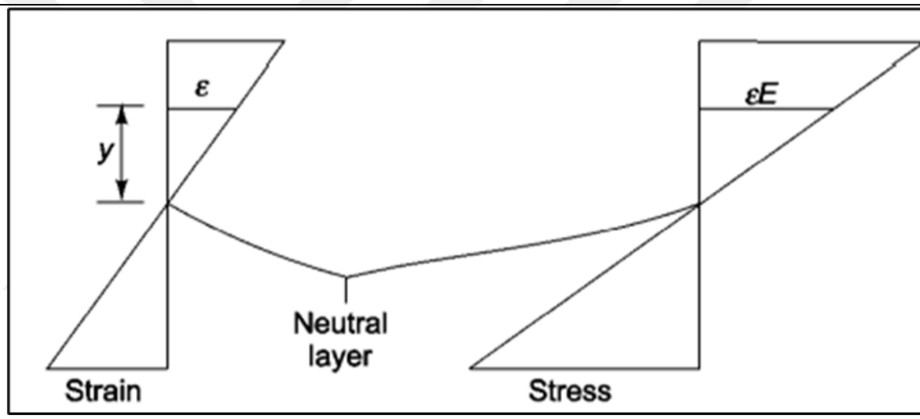

Figure 3.3: The Stress-strain behavior on beam cross section: the stress-strain behavior on beam cross section [47]

If the force element df assigned as:

$$df = \frac{E}{R}\ y\, b\, dy \quad (3.5)$$

$$dM = \frac{E}{R}\ y\, b\, dy\, y \quad (3.6)$$

$$dM = \frac{E}{R}\ y^2\, b\, dy \quad (3.7)$$

From the equation above, the element of bending moment influenced by the moment of inertia in which reflect the part $y^2\ b\ dy$ so that:

$$M = \frac{E}{R}\ I \tag{3.8}$$

From the two equations:

$$\sigma = \frac{M\ y}{I} \tag{3.9}$$

The reinforcement in the concrete beam contribute to both y and I

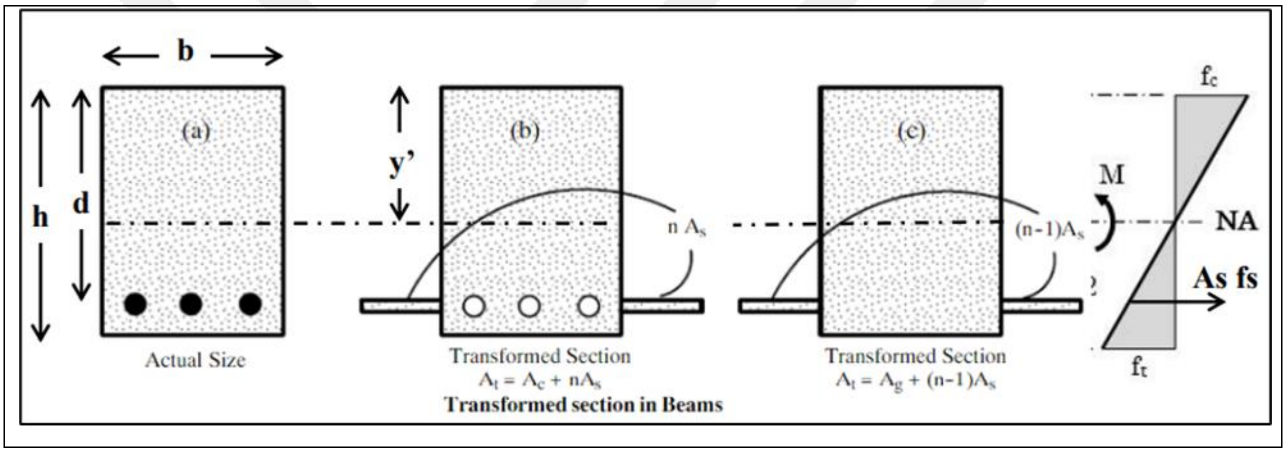

Figure 3.4: Compression Ad Tensions Stress On The Beam Cross Section [47]

The dividing of the modulus of elasticity by that for concrete is n where n:

$$n = \frac{Es}{Ec} \tag{3.10}$$

Distance to the neutral axis y then can be calculated as:

$$y = \frac{b\ h\ \frac{h}{2} + (n-1)\ As\ d}{b\ h + (n-1)As} \tag{3.11}$$

$$I\ = \frac{b\ h^3}{12} + b\ h\ (y-h)^2 + (n-1)As\ (d-y)^2 \tag{3.12}$$

For cracked section:

$$\rho = \frac{As}{b\,d} \qquad (3.13)$$

$$k = \sqrt{\rho^2 + 2\,\rho} - \rho \qquad (3.14)$$

$$y = k\,d \qquad (3.15)$$

$$I = \frac{b\,h^3}{3} + b\,h\,(y - h)^2 + n\,As\,(d - y)^2 \qquad (3.16)$$

3.3 ULTIMATE STRESS DESIGN

For non-linear relationship between the stress-stain of the RC beam, the ultimate stress method give the following analysis procedure in which the reinforcement play important role in the strengthen of the member.

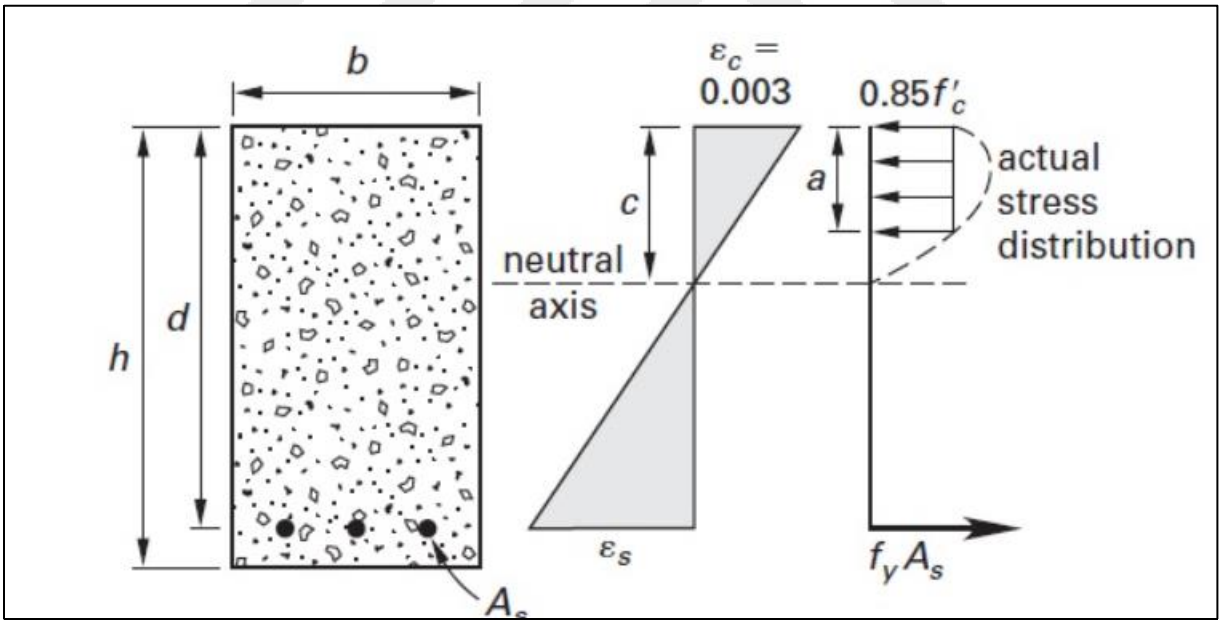

Figure 3.5: The Stress-Strain Analysis According To Ultimate Strength Method [48]

The equilibrium equation in tension and compression lead to the following equation:

$$As\ Fy = 0.85\ fc\ \ b\ a \tag{3.17}$$

$$a = \frac{As\ Fy}{0.85\ fc\ b} \tag{3.18}$$

$$Mn = Fy\ As\ (\ d - \frac{a}{2}) \tag{3.19}$$

3.4 REINFORCEMENT FOR SHEAR STRENGTH

The main portion of the RC beam the resist the applied shear force based on the internal strength of the concrete toward shear Vc and the internal strength of steel Vs. the design shear force section along the beam span showed in figure 3.6.

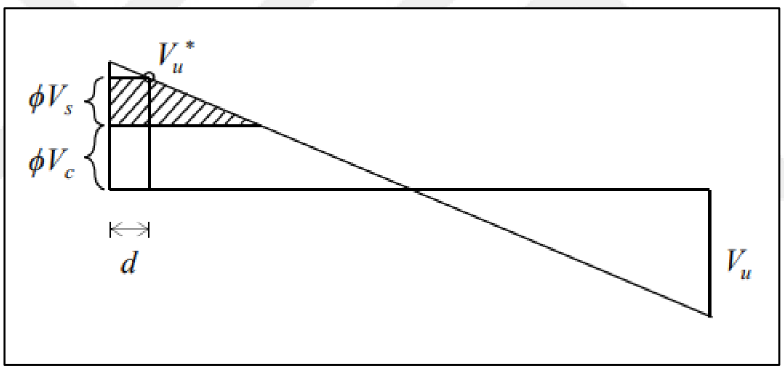

Figure 3.6: The Design Shear Force Section Along The Beam Span [49]

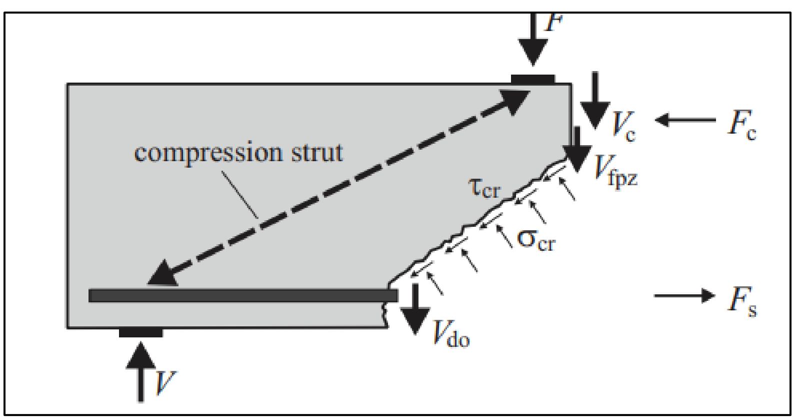

Figure 3.7: The Formation Of Shear Stresses On The Beam Section [50]

The value of maximum force taken at distance d away from the support, the equations that used for calculation the shear strength of a member are summarized as following:

$$Vu \ \leq \emptyset\, Vn \tag{3.20}$$

$$Vn = Vs + Vc \tag{3.21}$$

$$Vc = \ 0.17 \sqrt{fc'}\, b\, d \tag{3.22}$$

$$Vs = \frac{Vu - \emptyset\, Vc}{\emptyset} \tag{3.23}$$

The minimum value for the steel area of stirrups can be calculated for non-prestressed beam the greater of the following two equations:

$$\frac{Av(\min)}{s} = \ 0.062 \sqrt{fc'}\ \frac{b}{fyt} \tag{3.24}$$

or

$$\frac{Av(\min)}{s} = \ 0.35 \ \frac{b}{fyt} \tag{3.25}$$

The magnitude of Vc can be adopted in more detailed calculation as according to the least value of the following equations:

$$Vc = \left(0.16 \sqrt{fc'} + 17\, \rho\, \frac{Vu\, d}{Mu}\right) b\, d \tag{3.26}$$

$$Vc = \left(0.16 \sqrt{fc'} + 17\, \rho\right) b\, d \tag{3.27}$$

$$Vc = 0.29 \sqrt{fc'}\, b\, d \tag{3.28}$$

For the shear strength of the steel Vs, the value can be determined according to the following equation:

$$Vs = \frac{Av\, Fyt\, d}{s} \tag{3.29}$$

3.5 SPACING

The spacing between the shear reinforcement must be as the following:

$$if\ Vc \leq 0.33\sqrt{fc'}\ b\ d \tag{3.30}$$

S not more than d/2 or 600 mm

$$if\ Vc > 0.33\sqrt{fc'}\ b\ d \tag{3.31}$$

S > d/4 or 300 mm

3.6 REINFORCED BEAM CASES

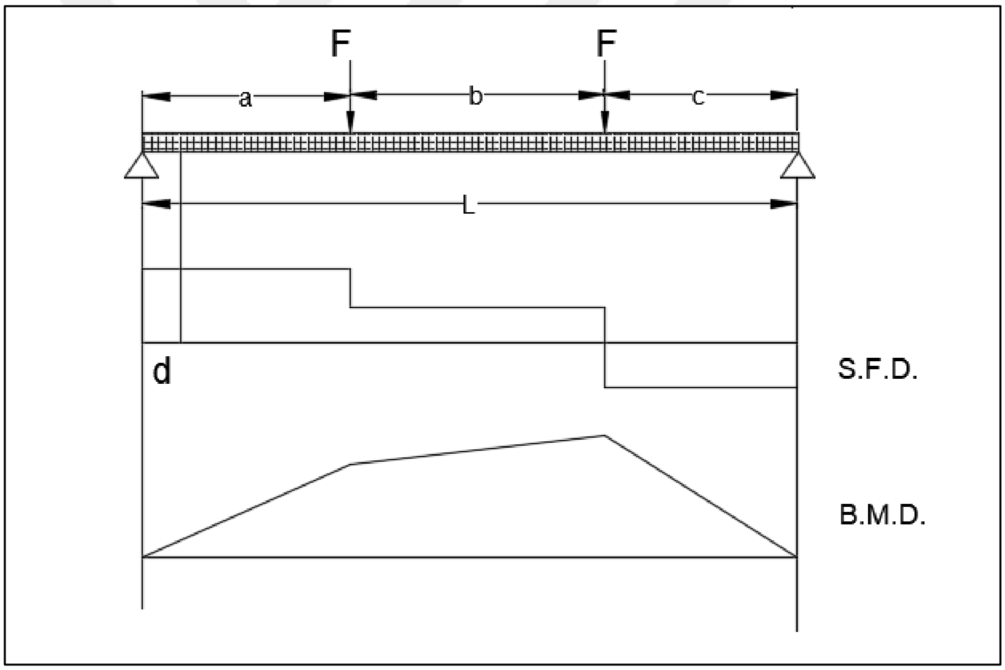

Figure 3.8: Case One: Two Concentrated Loads [51]

$$Vu = \frac{F\ (L-a+c)}{L} \tag{3.31}$$

$$Mu = \frac{F\ (L-a+c)\ d}{L} \tag{3.32}$$

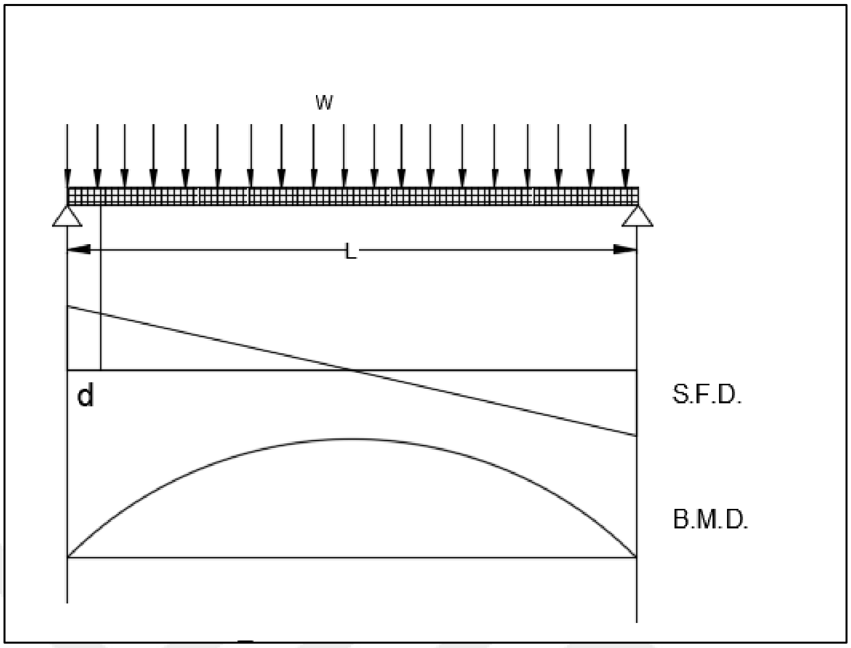

Figure 3.9: Case Two: Uniform Load [51]

$$Vu = w\left(\frac{L}{2} - d\right) \quad (3.33)$$

$$Mu = w\,d\left(\frac{L}{2}\right) - \left(\frac{w\,d^2}{2}\right) \quad (3.34)$$

3.7 INITIAL CONDITIONS

The initial conditions taken for the cases were:

b=h =300 mm

fc =20 Mpa

Fy =400 Mpa

Fyt = 300 Mpa

Asv = 150 mm^2

For concentrated loading:

F=150 kN

For uniform loading:

w= 40 kN/m

3.8 PREPARATION FOR ANSYS

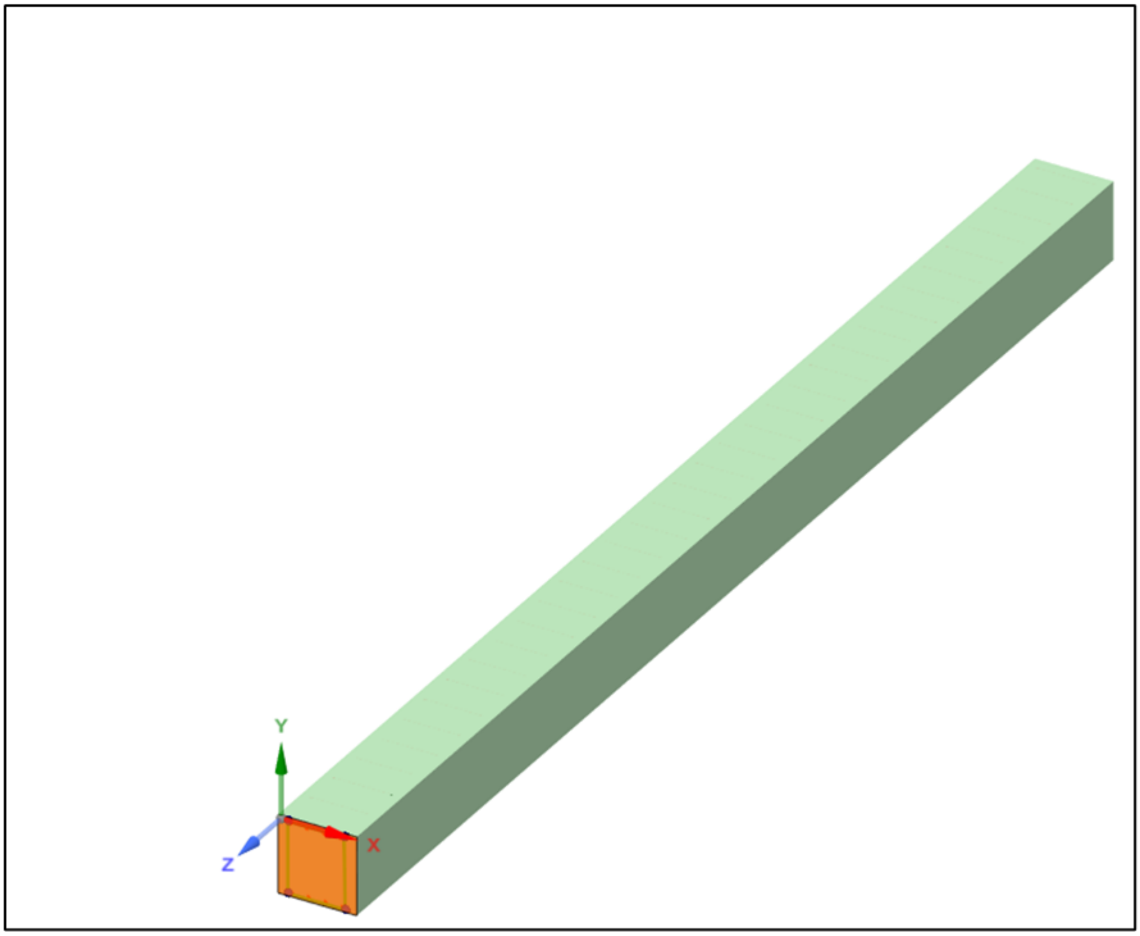

Figure 3.10 : Geometrical Shape of The RC Beam (ANSYS)

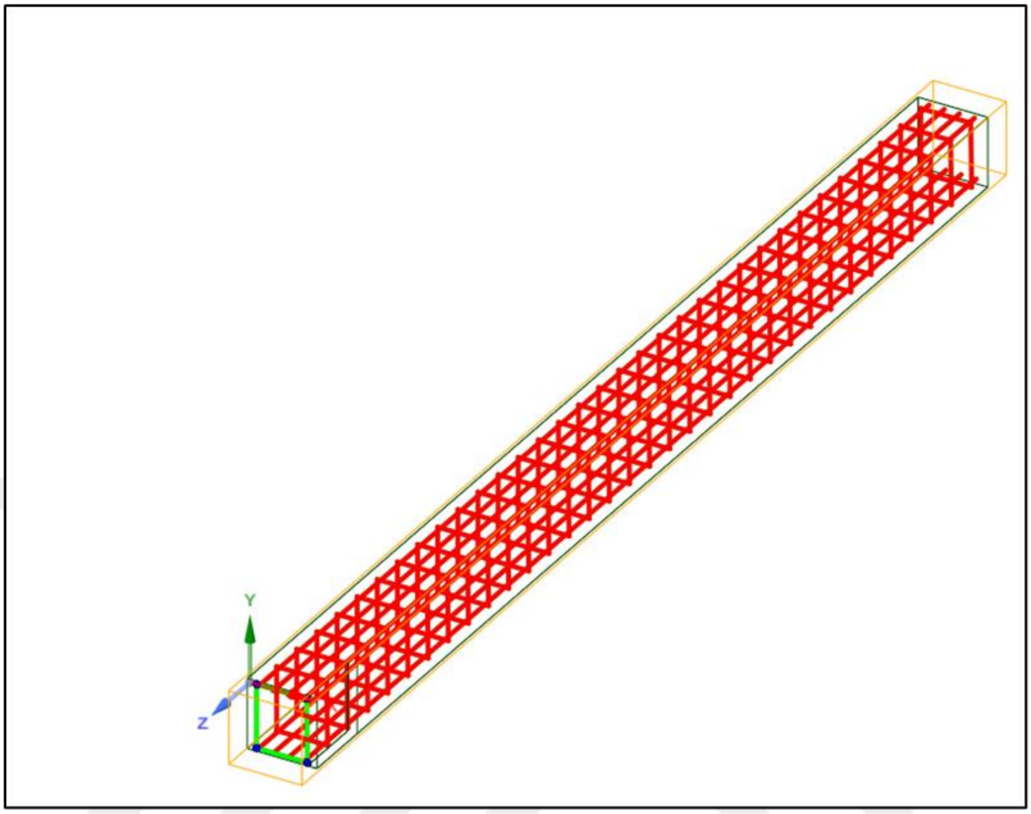

Figure 3.11: Geometrical Shape Of The Reinforcement Of The Rc Beam (ANSYS)

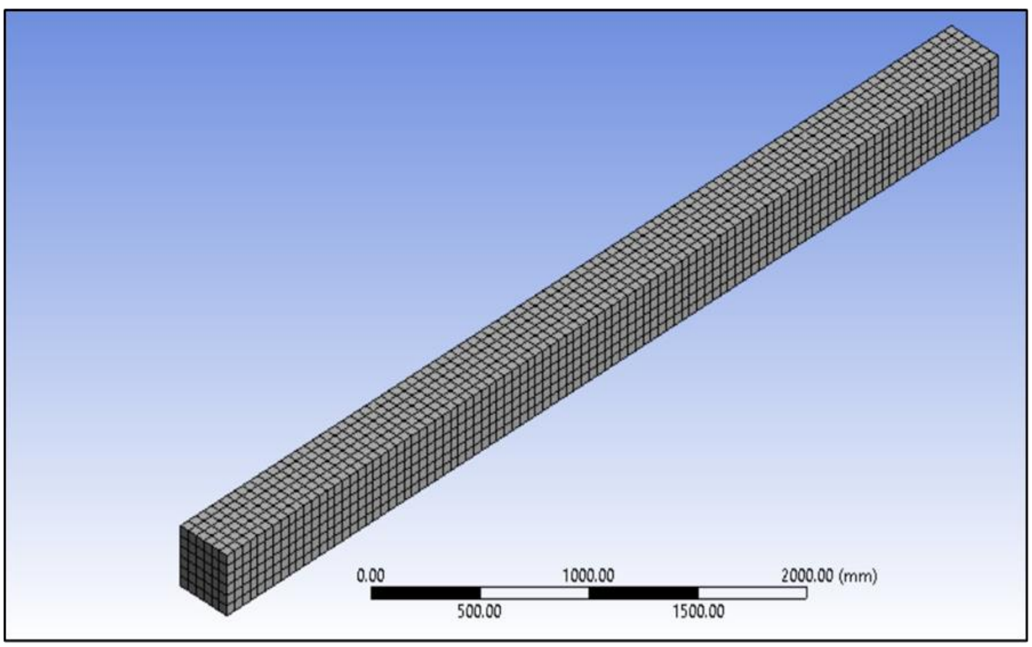

Figure 3.12: Meshing of the RC Beam (ANSYS)

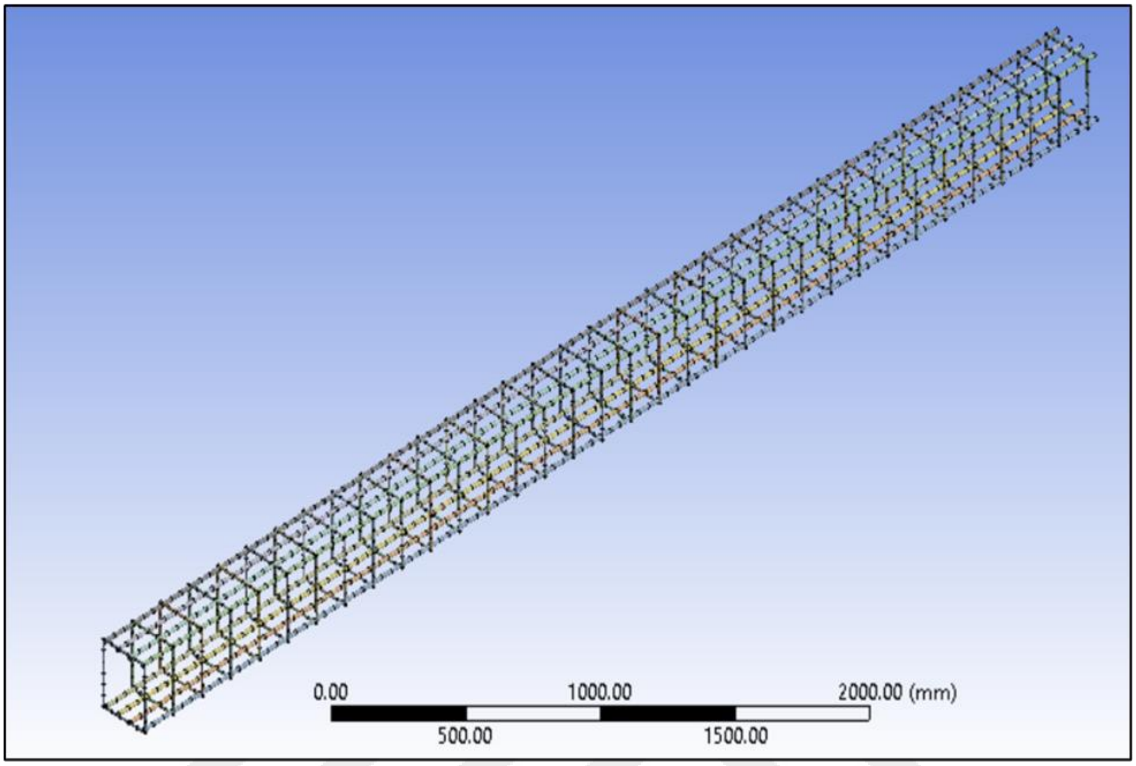

Figure 3.12: Meshing Of The Reinforcement Of The Rc Beam (ANSYS)

4. RESULT

4.1 CALCULATION AND RESULTS

According to the ACI code 318-14, the reinforcement of the beam for both bending and shear stresses are together must be limited to the desire quantities. These quantities used for the purpose of facing the bending stresses that form by the action of the external loading and in same time must not be more the limitation of the code in which over reinforcement occur which can lead to sudden failures as the compressive strength and the shear strength of the concrete must be consider also in the resistance of the external stresses. For calculating the reinforcement that required, number of relationships between the parameters that's effect the magnitude of steel in the concrete body.

4.1.1 Steel Quantities and The Effective Depth

For assigning the effect of d on the required Ast and Asv, the effective depth values were increased from 200 to 500 mm, the following data obtained were included in table 4.1 and in figure 4.1.

Table 4.1: The Impact Of The Effective Depth On The Required Steel Quantities

As (mm^2)	Mcr (kN.m)	Mu (kN.m)
804	13.8	84.7
1004	14.0	118.5
1204	14.3	142.1
1404	14.5	165.7
1604	14.8	189.3
1804	15.0	212.9
2004	15.2	236.5
2204	15.4	260.1
2404	15.6	283.7
2604	15.8	307.3

Table 4.1: The Impact Of The Effective Depth On The Required Steel Quantities "Table Continued"

As (mm^2)	Mcr (kN.m)	Mu (kN.m)
2804	16.0	330.9
3004	16.1	354.5
3204	16.3	378.1
3404	16.5	401.7
3604	16.6	425.3
3804	16.8	448.9
4004	16.9	472.5
4204	17.0	496.1
4404	17.2	519.7
4604	.3	543.3

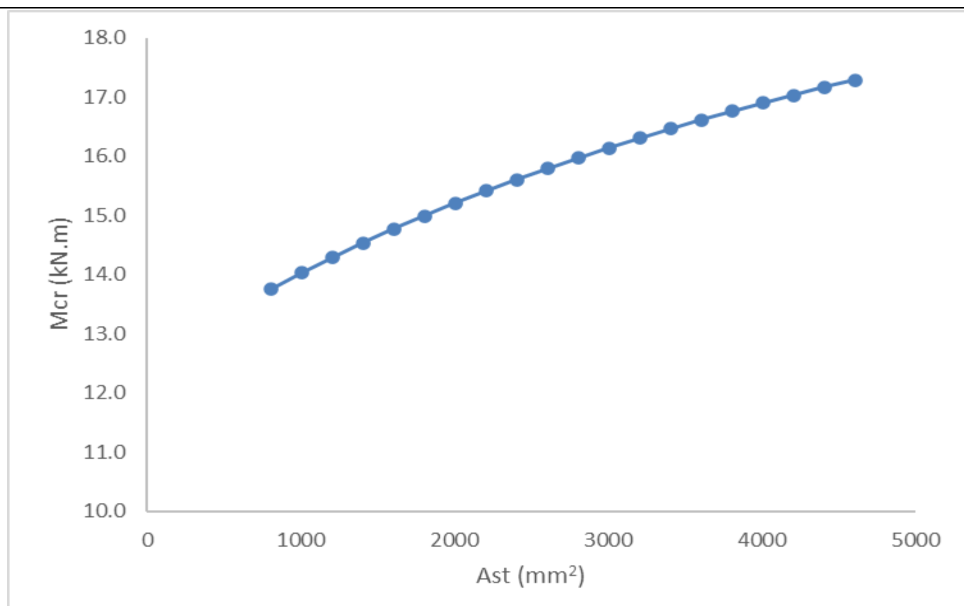

Figure 4.1: The Relationship Between Cracked Moment And Ast Under Concentrated Load

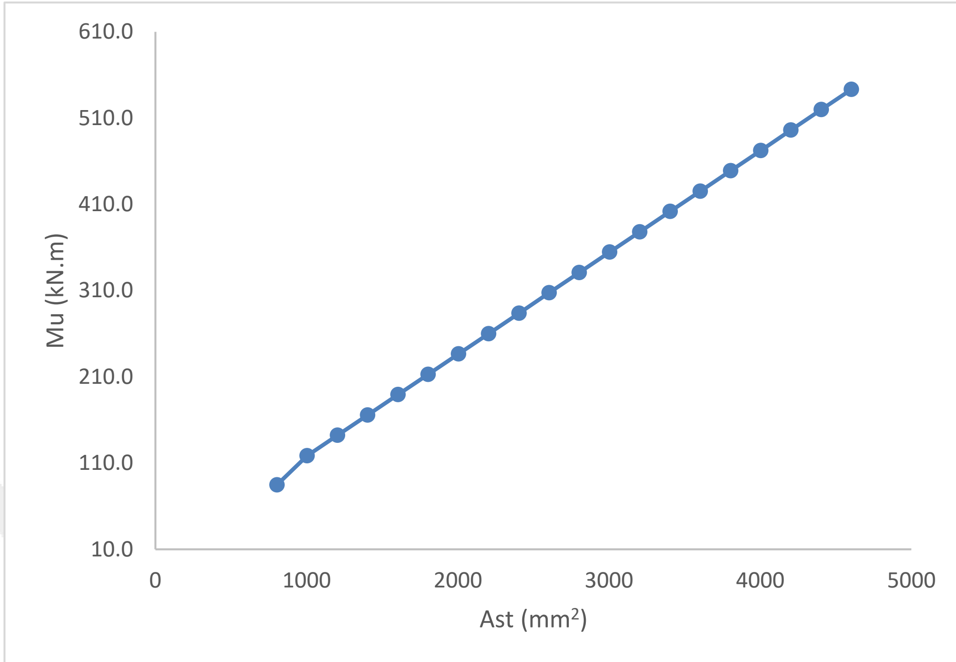

Figure 4.2: The Relationship Between Ultimate Moment And Ast Under Concentrated Load

Table 4.2: The Impact Of Steel Area Ast On Vc And Vs

As (mm^2)	Vc (kN)	Vs (kN)
804	77	243
1004	80.4	239.6
1204	83.8	236.2
1404	87.2	232.8
1604	90.6	229.4
1804	94	226
2004	97.4	222.6
2204	100.8	219.2
2404	104.2	215.8
2604	107.6	212.4

Table 4.2: The Impact Of Steel Area Ast On Vc And Vs "Table Continued"

As (mm^2)	Vc (kN)	Vs (kN)
2804	111	209
3004	114.4	205.6
3204	114.8	205.2
3404	114.8	205.2
3604	114.8	205.2
3804	114.8	205.2
4004	114.8	205.2
4204	114.8	205.2
4404	114.8	205.2

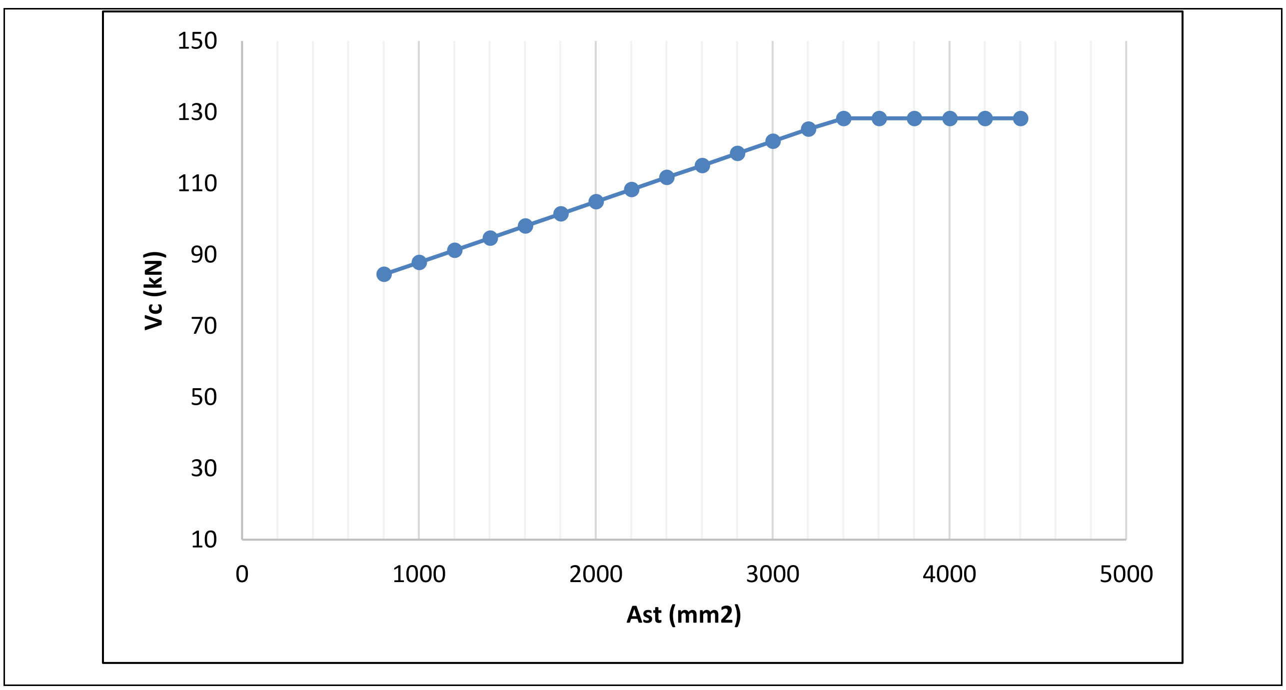

Figure 4.3: Relationship For The Vc Based On Ast Variation Under Concentrated Load (Fc=20MPa)

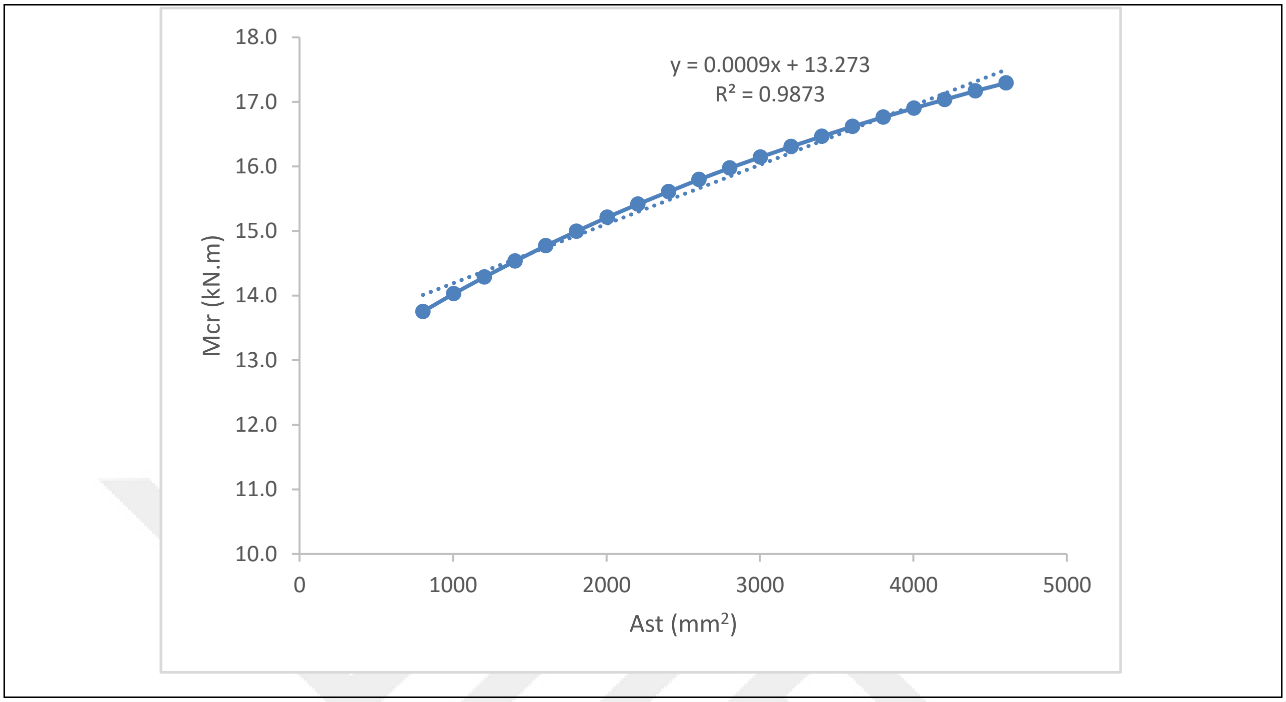

Figure 4.4: Linear Fitting For Mcr And Ast Under Concentrated Load (Fc =20 MPa)

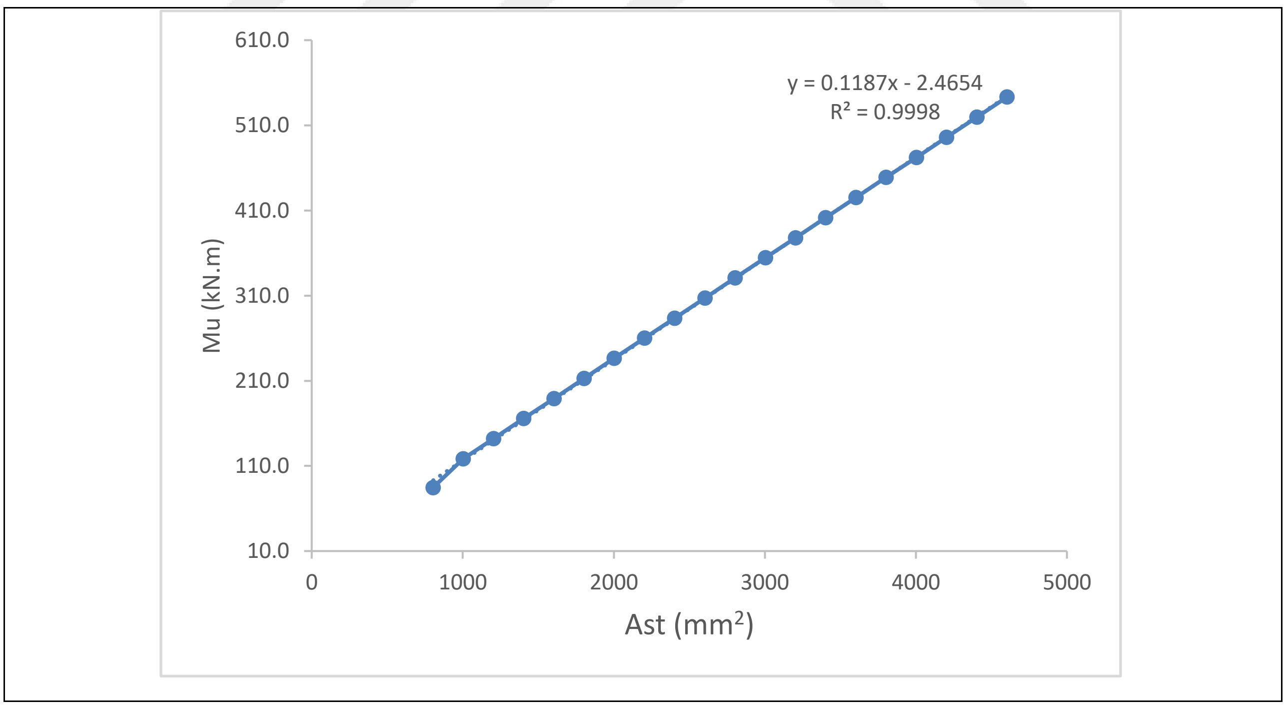

Figure 4.5: Linear Fitting For The Mu Based On Ast Variation Under Concentrated Load (Fc =20 MPa)

By increasing the compressive strength of concrete to 25 MPa, the longitudinal reinforcement still support the both the flexural strength of the member and the shear strength as explained inthe following figures.

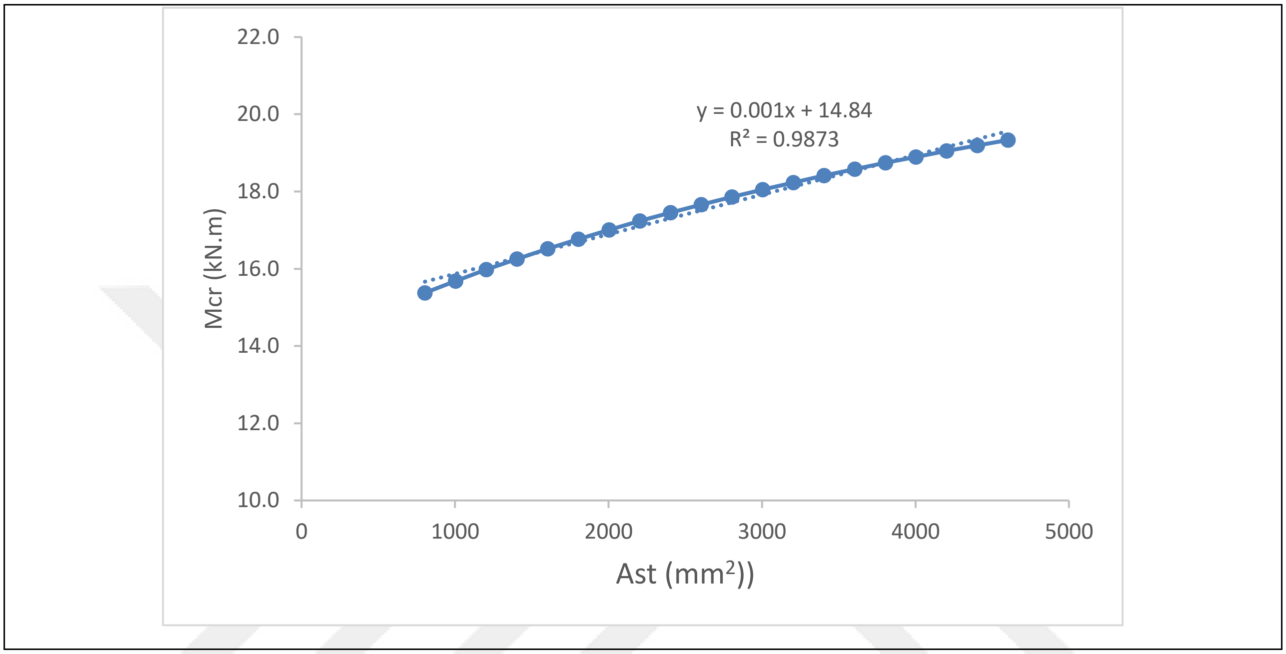

Figure 4.6: Linear Fitting For The Mcr Based On Ast Variation Under Concentrated Load (Fc =25 MPa)

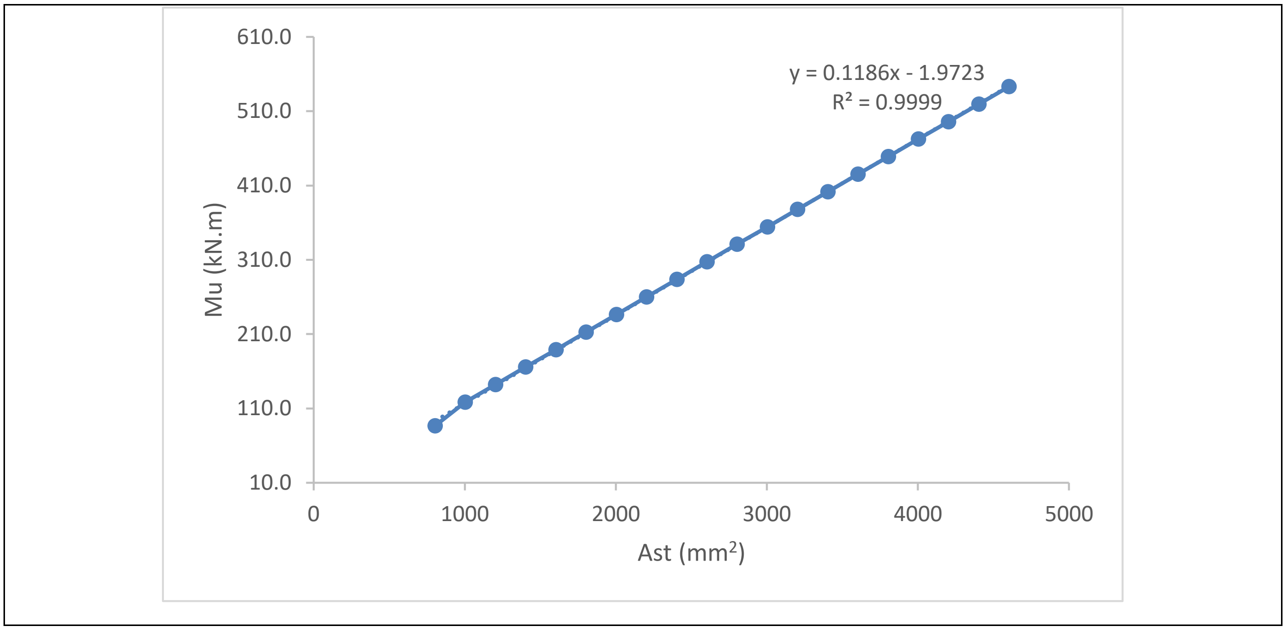

Figure 4.7: Linear Fitting For The Mu Based On Ast Variation Under Concentrated Load (Fc =25 MPa)

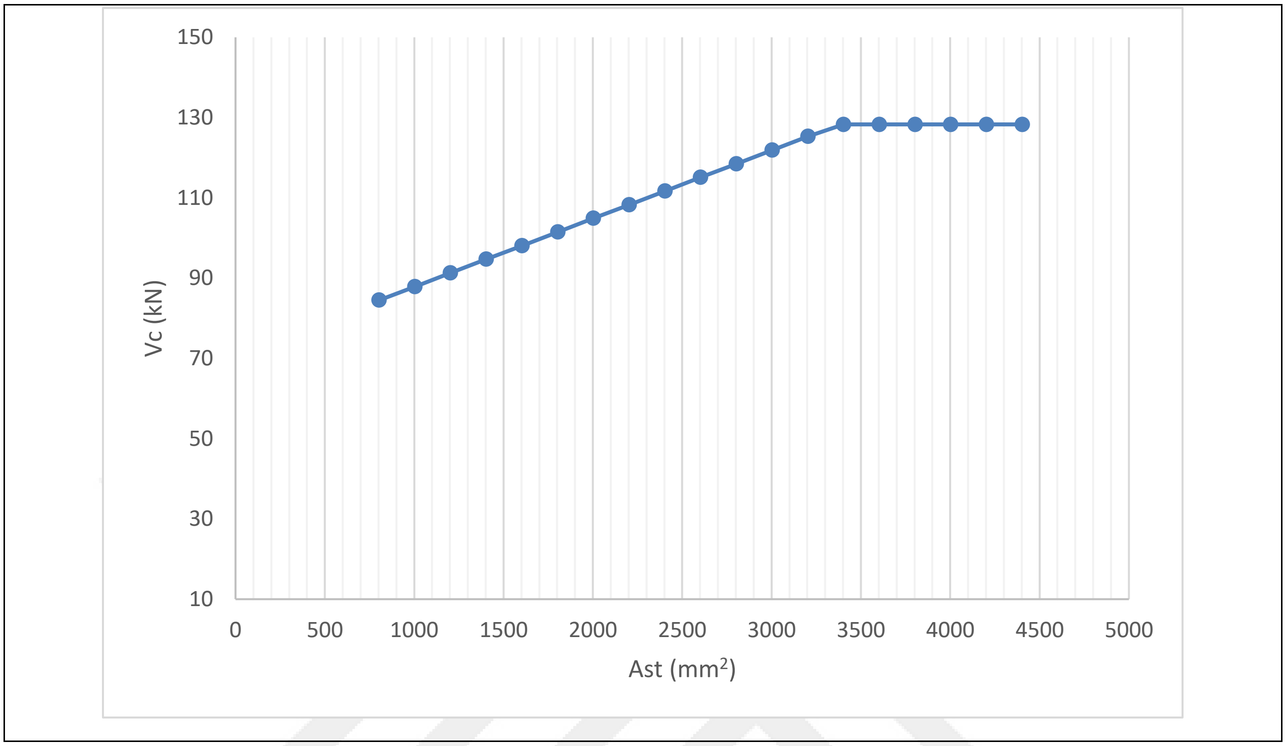

Figure 4.8: The Vc Maximum Based On Ast Variation Under Concentrated Load (Fc =25 MPa)

For the compressive strength of concrete that reach 30 MPa, the contribution of the longitudinal reinforcement in the following figures:

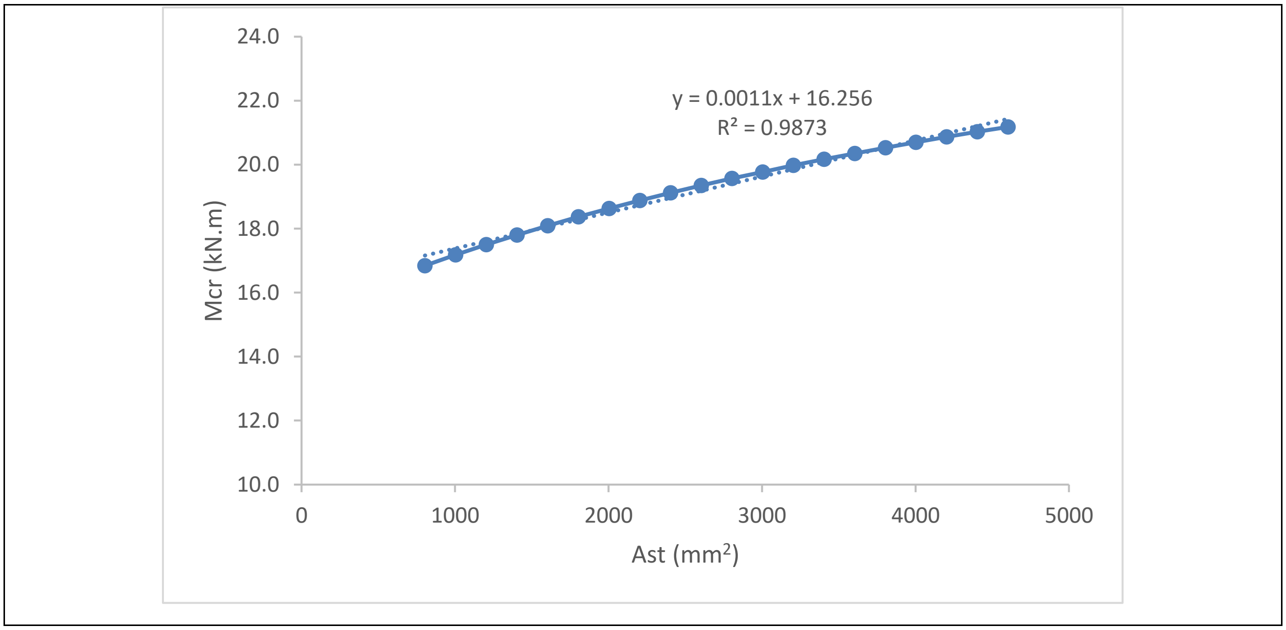

Figure 4.9: Linear Fitting For The Mcr Based On Ast Variation Under Concentrated Load (Fc =30 MPa)

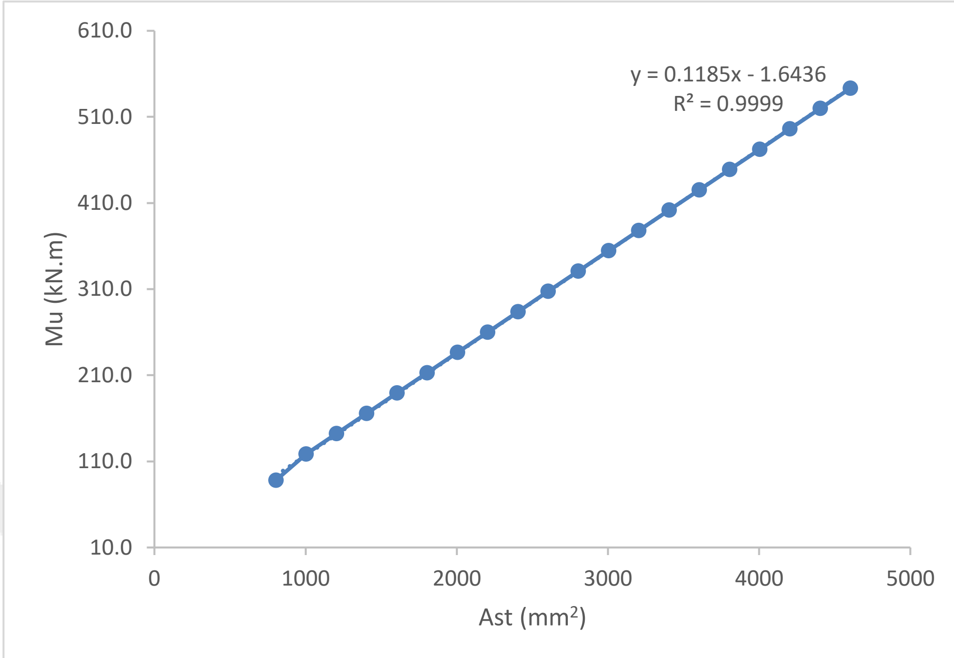

Figure 4.10: Linear Fitting For The Mu Based On Ast Variation Under Concentrated Load (Fc =30 MPa)

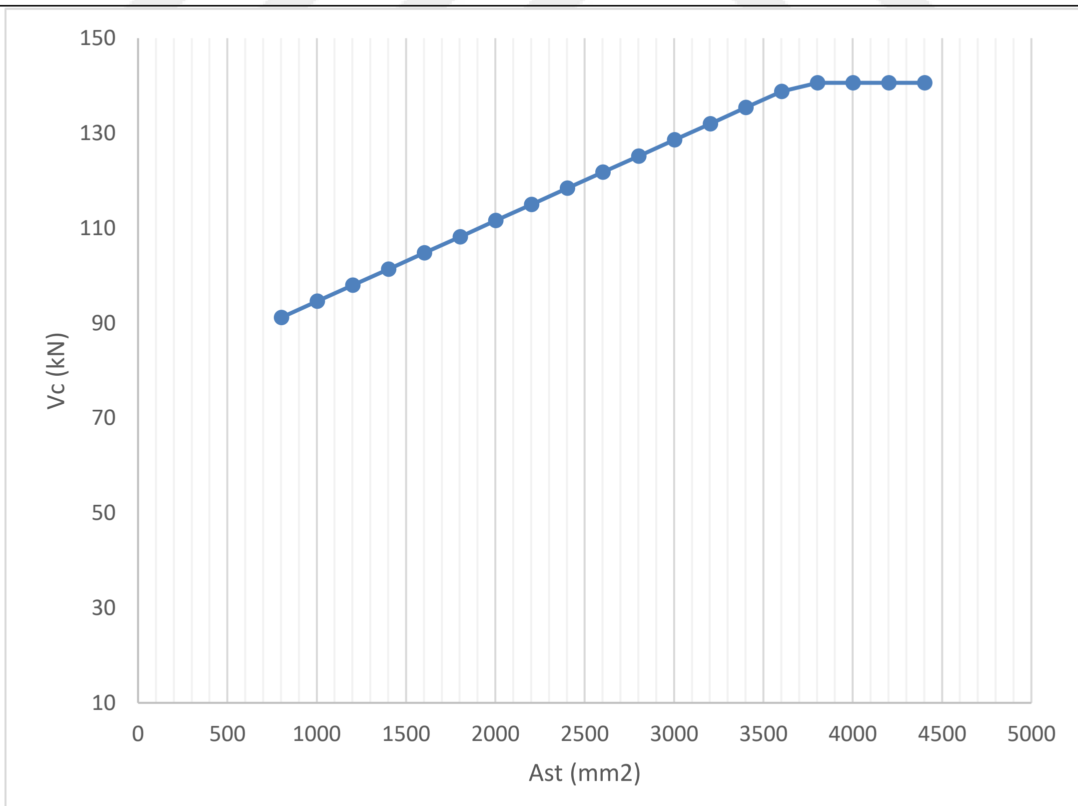

Figure 4.11: The Vc Maximum Based On Ast Variation Under Concentrated Load (Fc=30 MPa)

From the figures of Vc-Ast the longitudinal reinforcement of the member that considered as the maximum area of steel that support the shear strength and the bending stress were included in table 4.3:

Table 4.3 : The Impact Of Steel Area Ast And Compressive Strength Of Concrete Fc On The Concrete Shear Strength Vc

Ast (mm^2)	fc (Mpa)	Vc (kN)
3004	20	114.4
3404	25	128.3
3804	30	140.6

The derived equation from the variables in table 4.3, so that by assuming three factors for these equation:

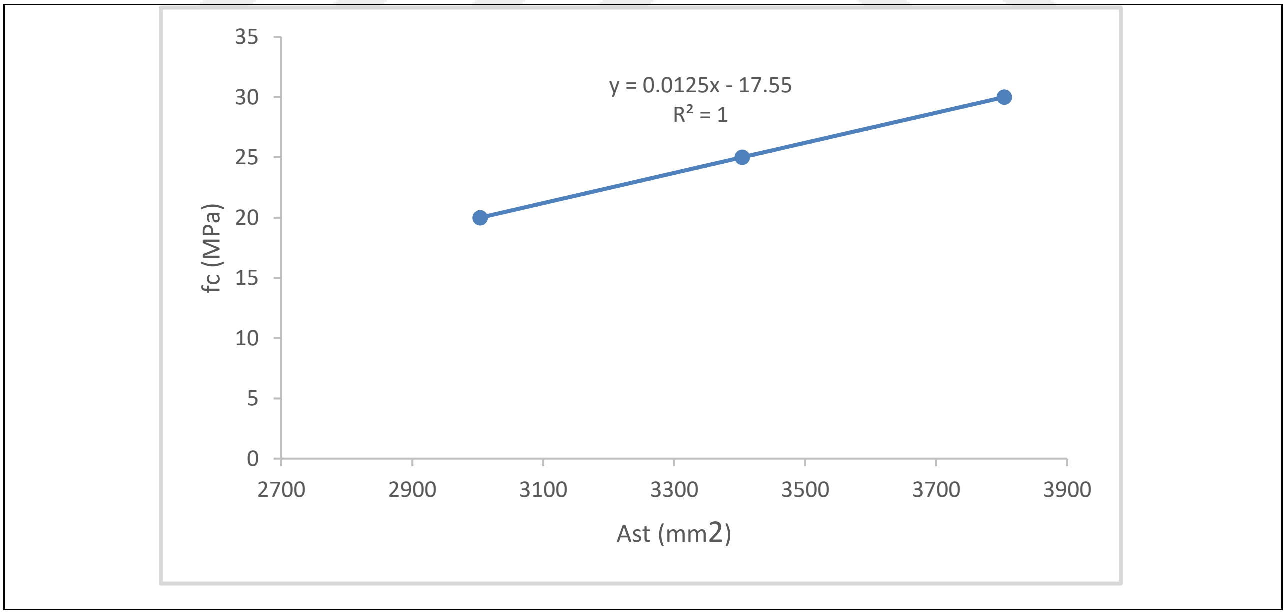

Figure 4.12: Linear Fitting For The Fc Based On Ast Variation In The Equation Of Vc Identification Under Concentrated Load

Form this equation, the magnitude of the shear strength of concrete based on the longitudinal steel area can be calculated based on the following:

$$Vc\;max = \left(0.16\,\sqrt{0.0125\,Ast - 17.55} + 17\;\frac{Ast}{b\,d}\right) b\,d \qquad (4.1)$$

As the beam taken as the case study with the following conditions:

d= 295 mm and b=300 mm

The equation became:

$$Vc\;\;max = \left(14160\,\sqrt{0.0125\,Ast - 17.55} + 17\;\;Ast\right) \qquad (4.2)$$

Table 4.4: The Maximum Values Of Vc According To The Ast Values

Ast (mm2)	Vc (kN)
1404	23.868
1604	49.65693
1804	62.33072
2004	72.84676
2204	82.24585
2404	90.93116
2604	99.10944
2804	106.9035
3004	114.3934
3204	121.6348
3404	128.668
3604	135.5237
3804	142.2255
4004	148.7924
4204	155.2397
4404	161.5799
4602	167.7617

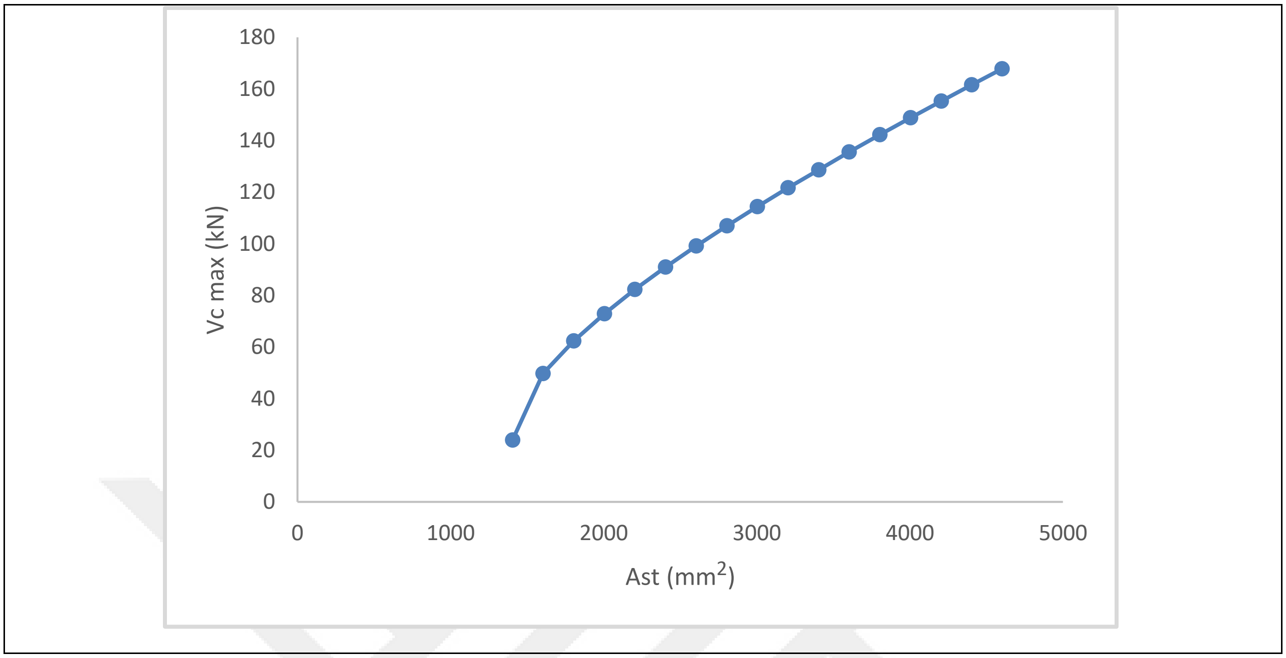

Figure 4.13: Relationship For The Vc Max Based On Ast Variation Under Concentrated Load

For various valued of bd, the relationships between the longitudinal reinforcement and the available shear strength was included in the figures:

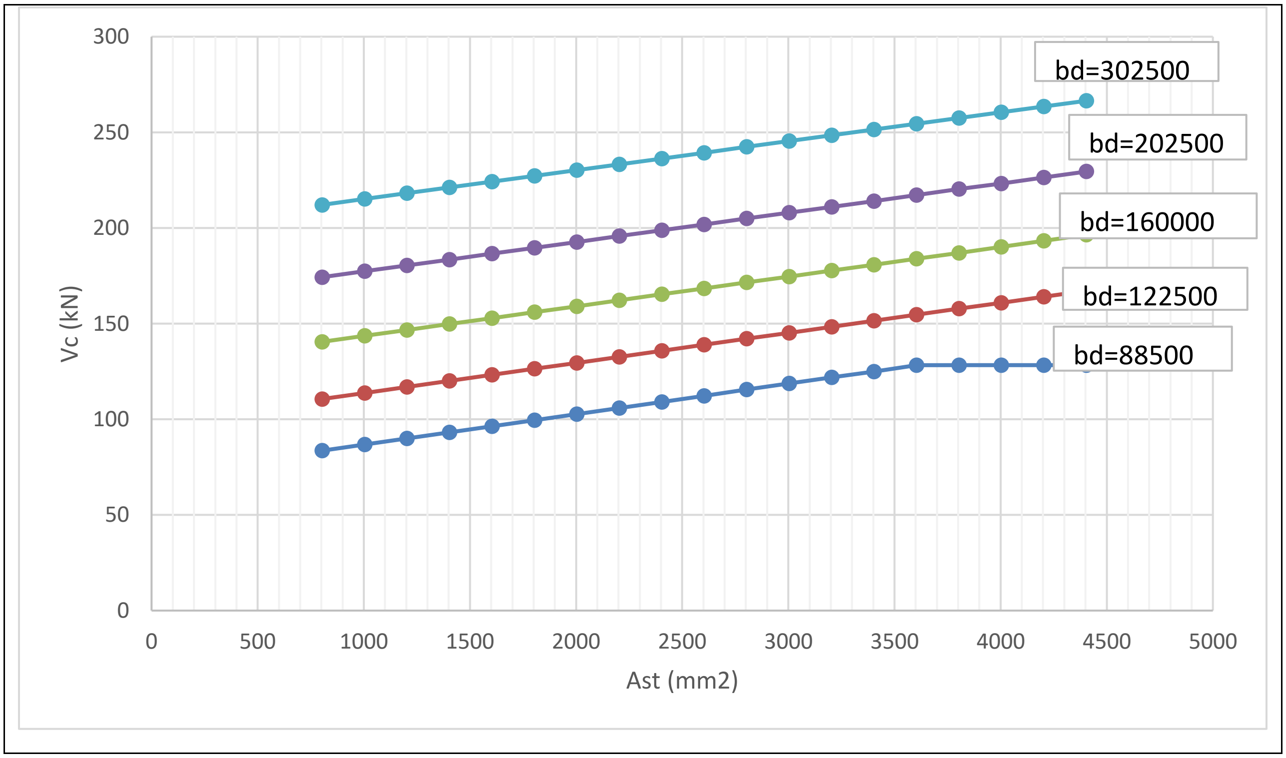

Figure 4.14: Relationship For The Vc Max Based On Ast And Bd Variation Under Concentrated Load

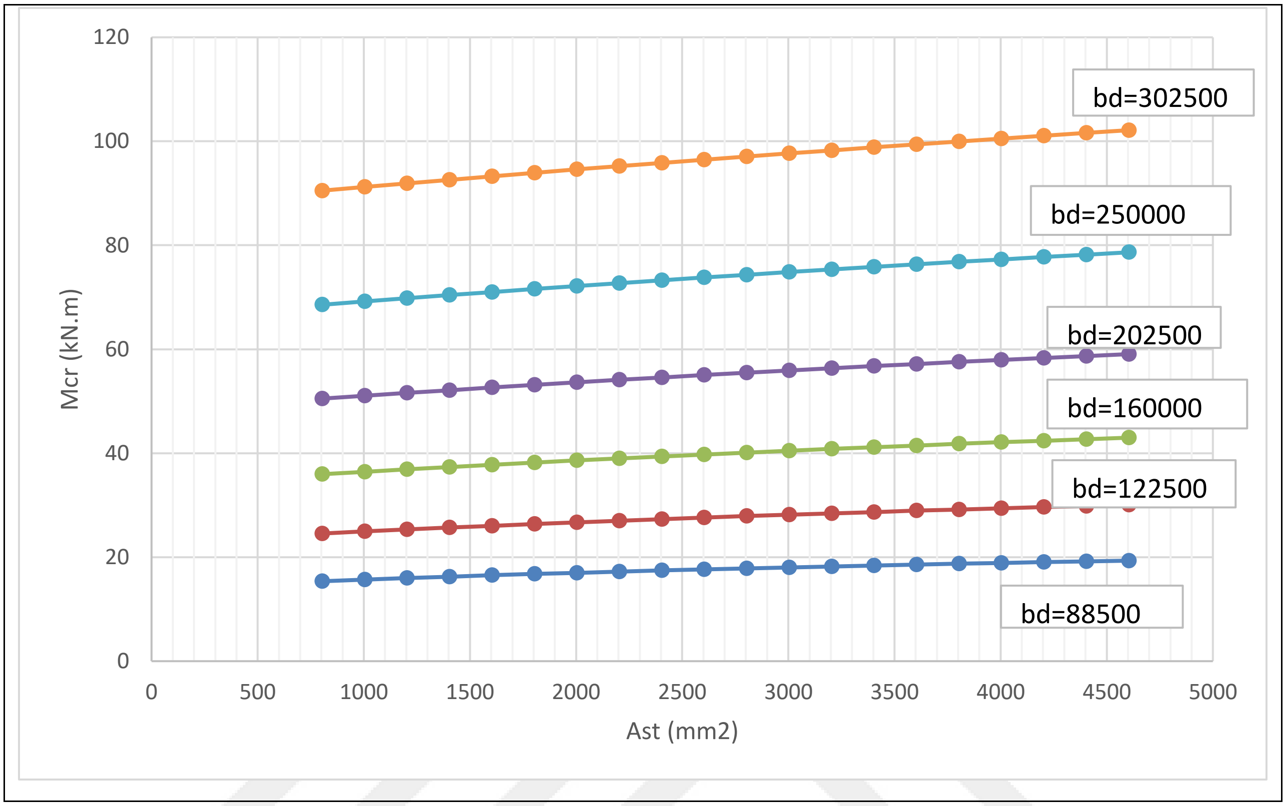

Figure 4.15: Relationship For The Mcr Based On Ast And Bd Variation Under Concentrated Load

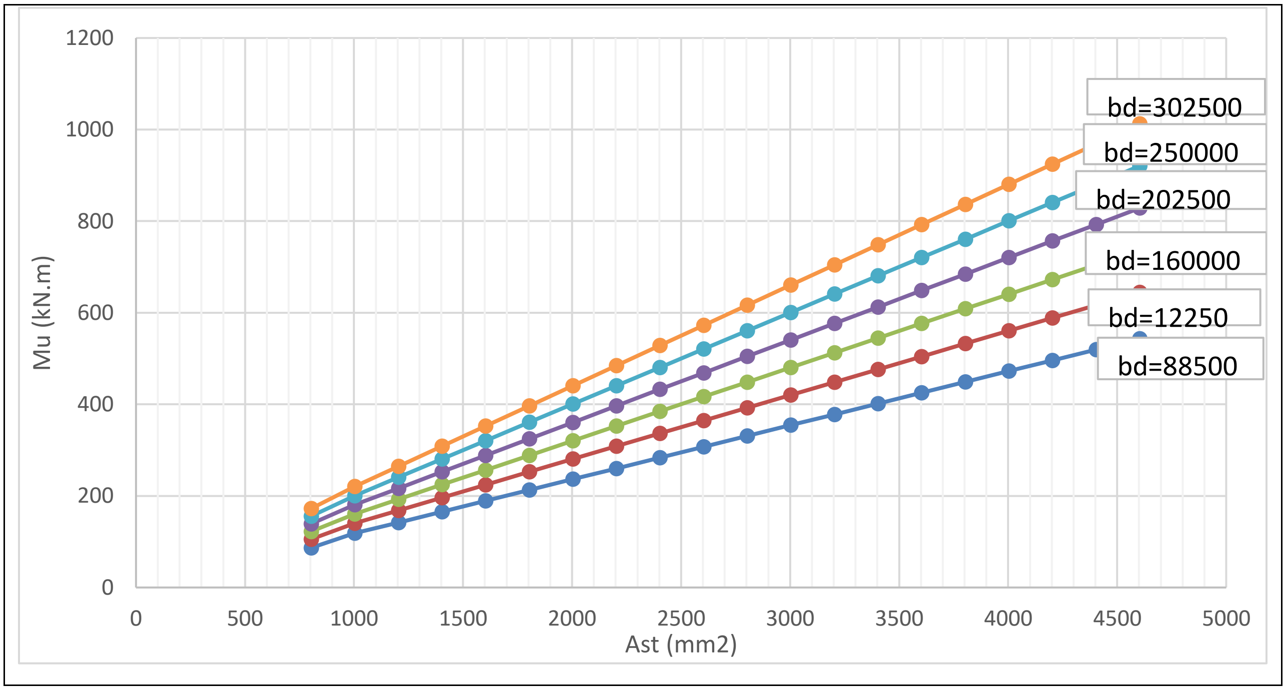

Figure 4.16: Relationship For The Mu Based On Ast And Bd Variation Under Concentrated Load

The magnitudes of Vs that can obtained by increasing the longitudinal reinforcement according to various the concentrated couple of loads values were included in figure:

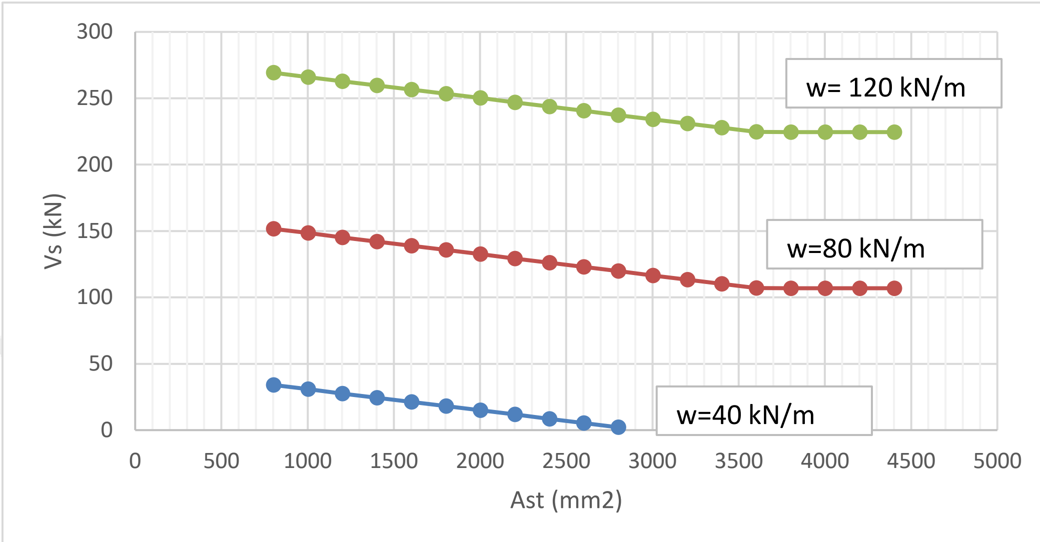

Figure 4.17: Relationship For The Vs Based On Ast And Loads Variation

From figure above, the magnitude of Vs needed for facing the external shear stress decreased to lower value as the longitudinal reinforced increased when the minimum steel vertical steel area of Ø10 mm^2 is used . The magnitude of spacing s for the forces in the range below 250 kN was 147 mm while when the forces reach 250 kN the spacing varied according to the increment of the longitudinal reinforced concrete used.

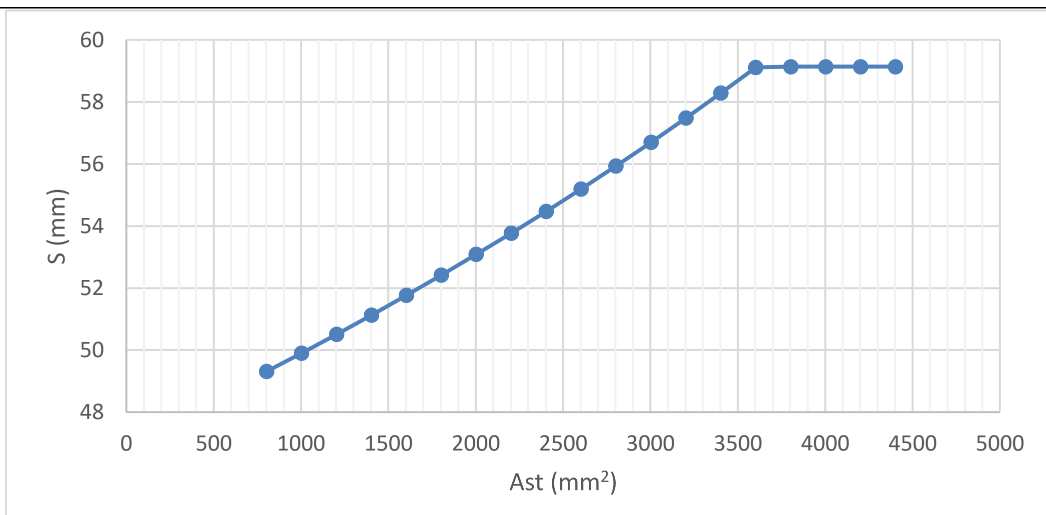

Figure 4.18: Relationship For The Spacing Between Stirrups Based On Ast Under Concentrated Loads

4.2 RC BEAM UNDER UNIFORM LOAD

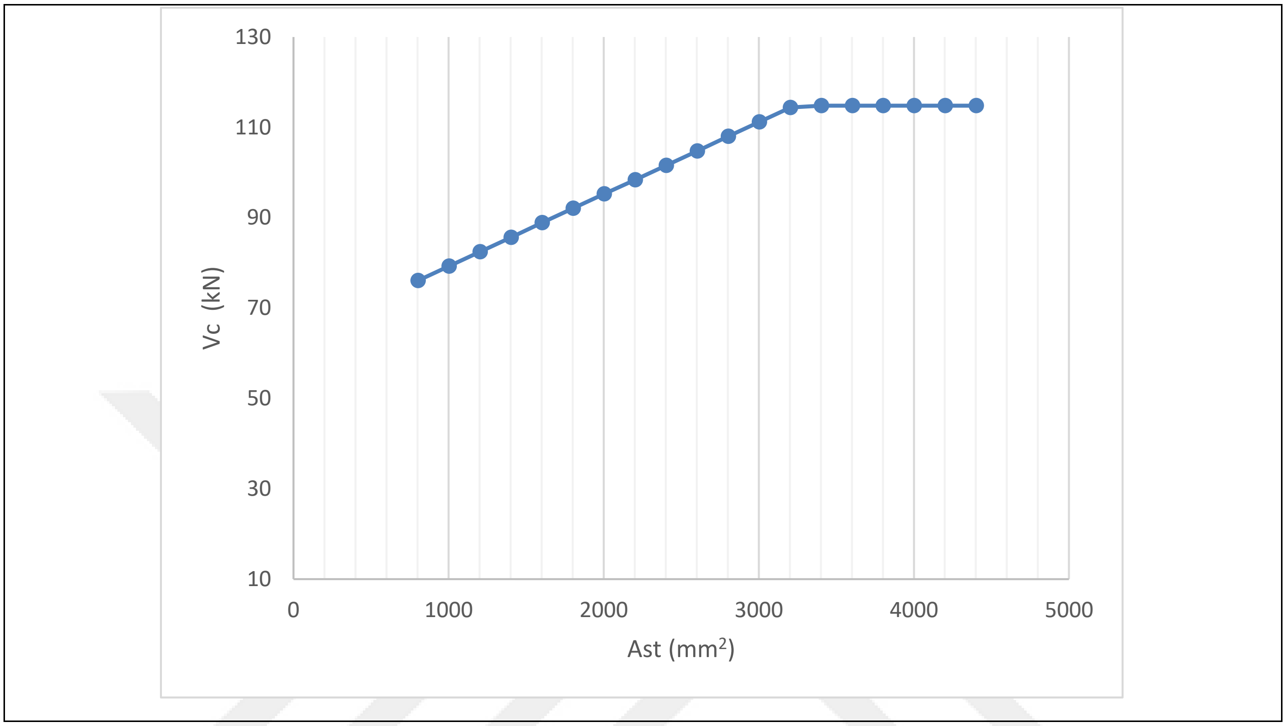

Figure 4.19: Relationship For Vc Based On Ast (Fc= 20 MPa)

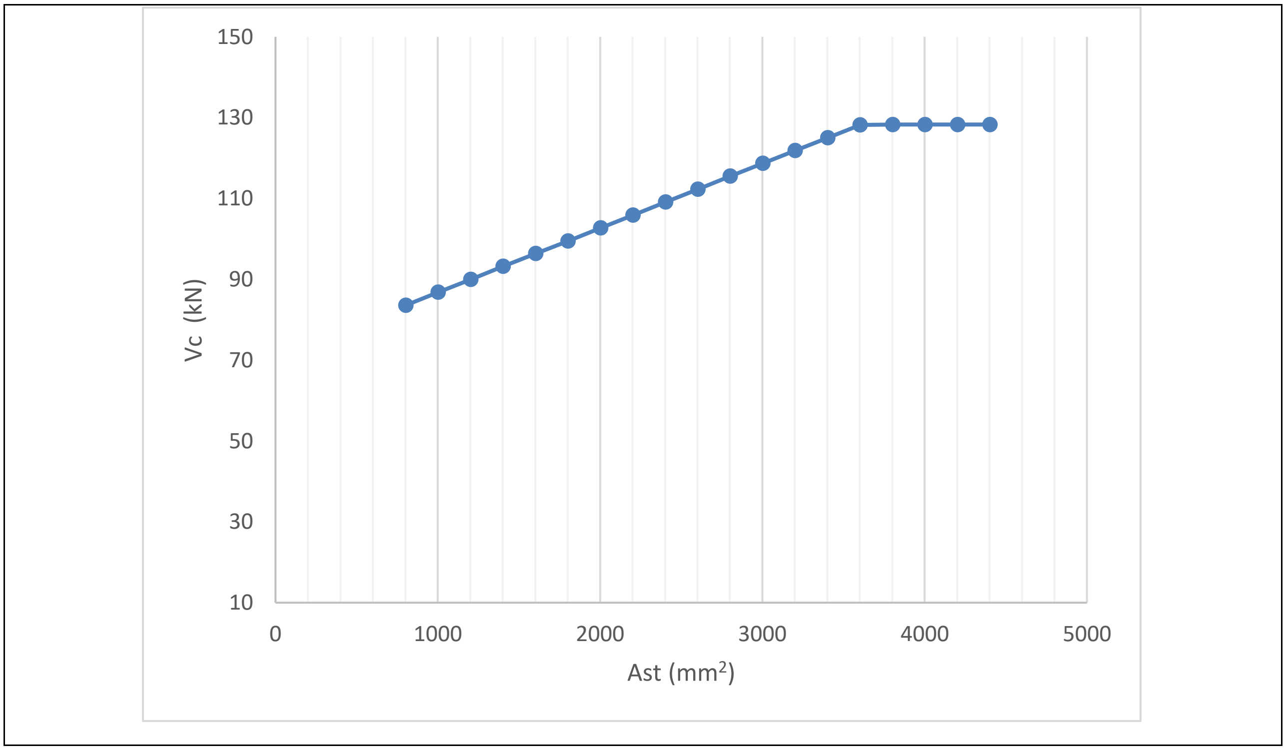

Figure 4.20: Relationship For Vc Based On Ast (Fc= 25 Mpa)

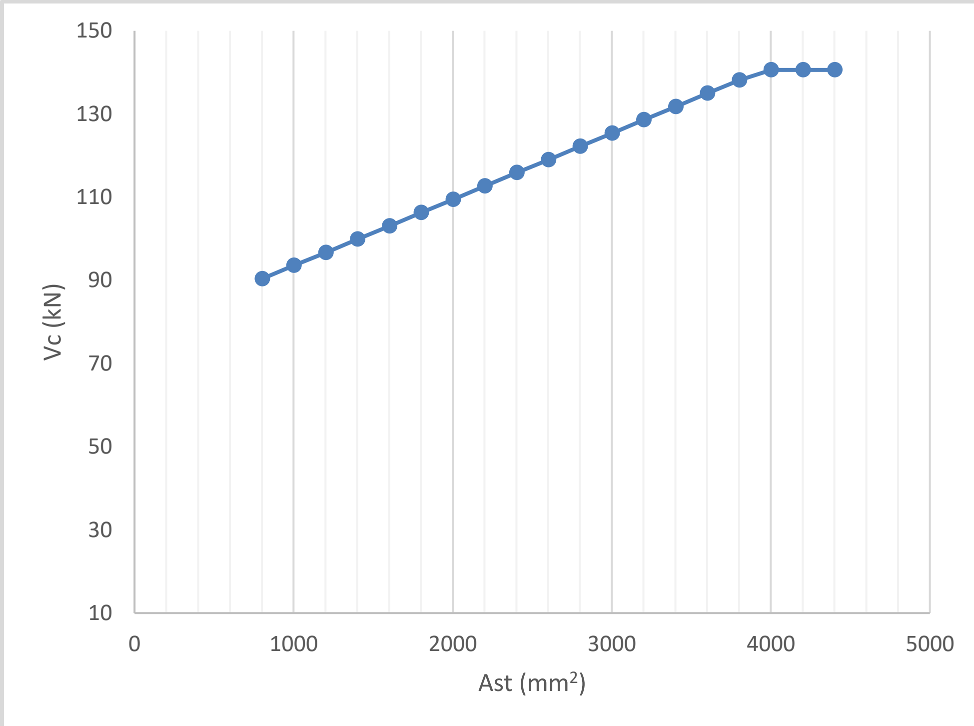

Figure 4.21: Relationship For Vc Based On Ast (Fc= 30 MPa)

Table 4.5: The Impact Of Ast And Fc On The Values Of Vc Under Uniform Loading

Ast (mm^2)	fc (Mpa)	Vc (kN)
3204	20	114.4
3604	25	128.3
4004	30	140.6

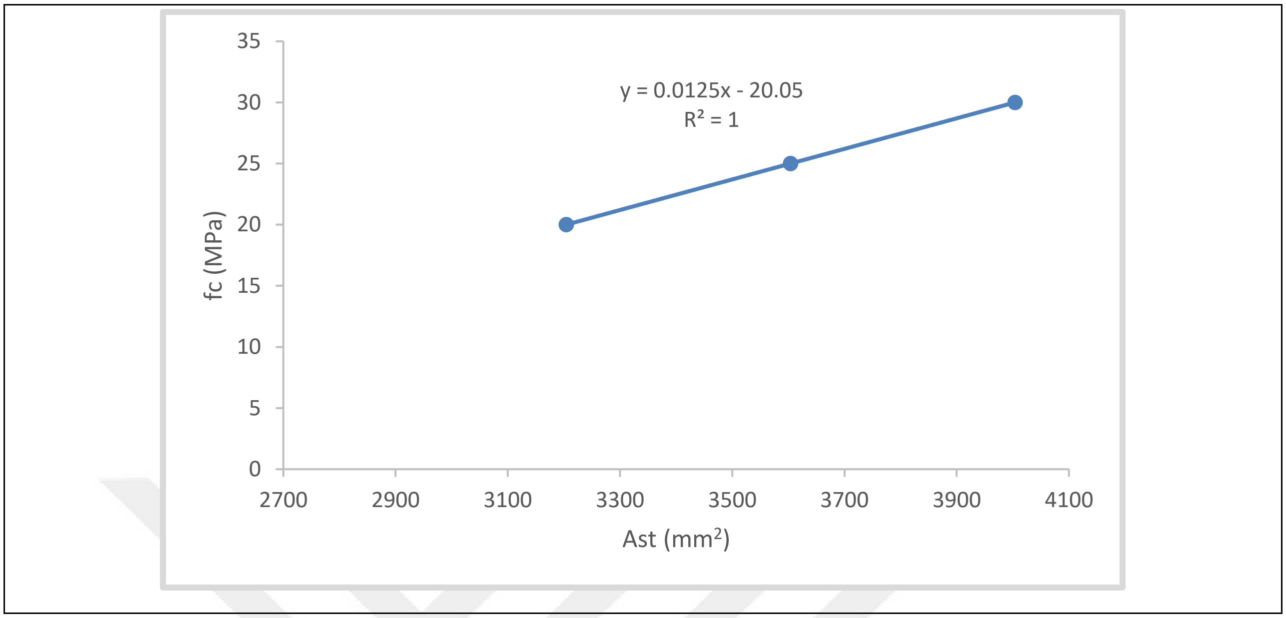

Figure 4.22: Linear Fitting For The Fc Based On Ast Variation In The Equation Of Vc Identification Under Uniform Load

Form this equation, the magnitude of the shear strength of concrete based on the longitudinal steel area can be calculated based on the following:

$$Vc\ max = \left(0.16\sqrt{0.0125\,Ast - 20.05} + 17\ \frac{Ast}{88500}\ 0.9373\right)\ 88500 \qquad (4.3)$$

Where b * d =88500 and

$$Vc\ max = \left(14160\ \sqrt{0.0125\,Ast - 20.05} + 15.93\,Ast\right)$$

Table 4.6: The Maximum Values Of Vc According To The Ast Values Under Uniform Loading

Ast (mm2)	Vc (kN)
1404	23.868
1604	49.65693
1804	62.33072
2004	72.84676
2204	82.24585
2404	90.93116
2604	99.10944
2804	106.9035
3004	114.3934
3204	121.6348
3404	128.668
3604	135.5237
3804	142.2255
4004	148.7924
4204	155.2397
4404	161.5799
4602	167.7617

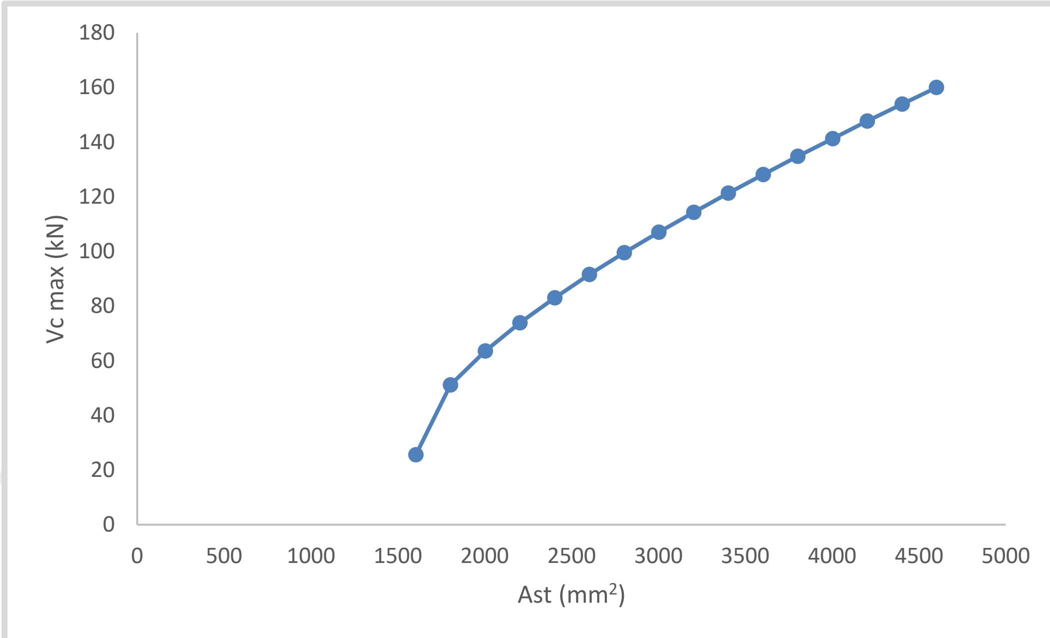

Figure 4.23: Relationship Vc Max Based On Ast Under Uniform Loading

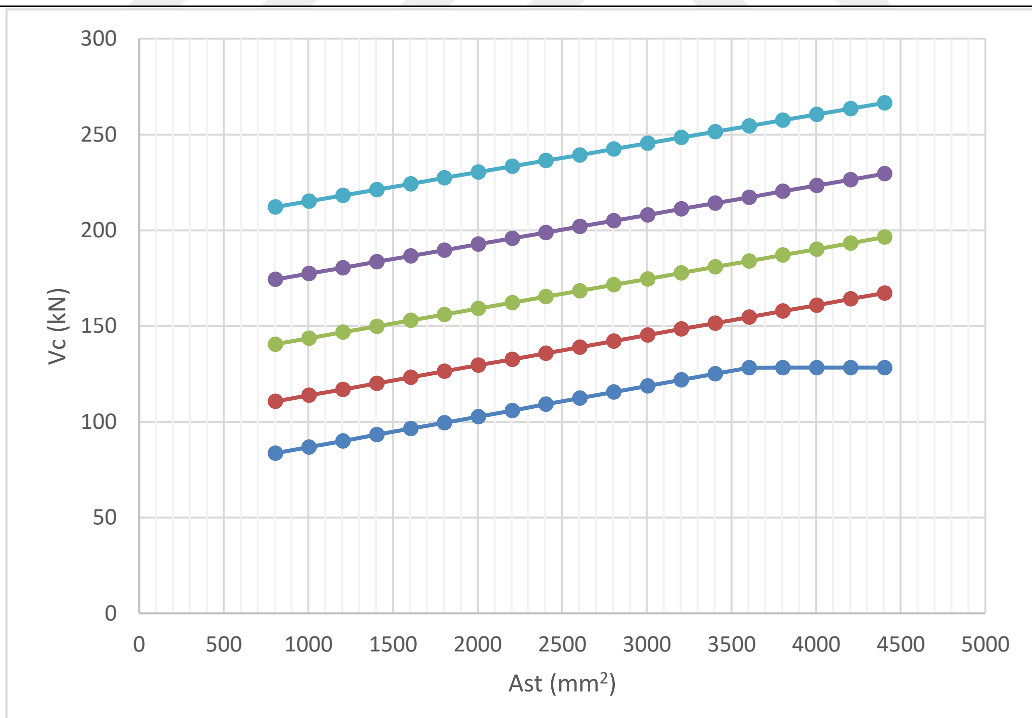

Figure 4.24: Relationship Vs Based On Ast Under Various Uniform Loadings

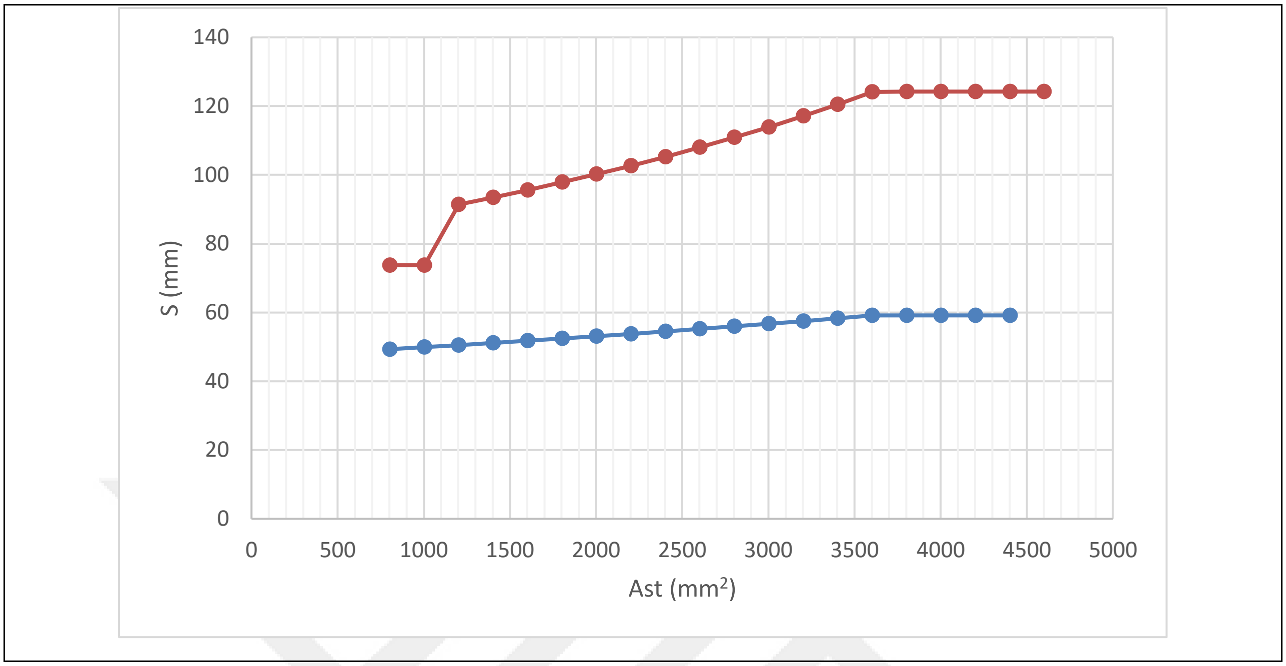

Figure 4.25: Relationship Spacing Between Stirrups Based On Ast Under Various Uniform Loadings

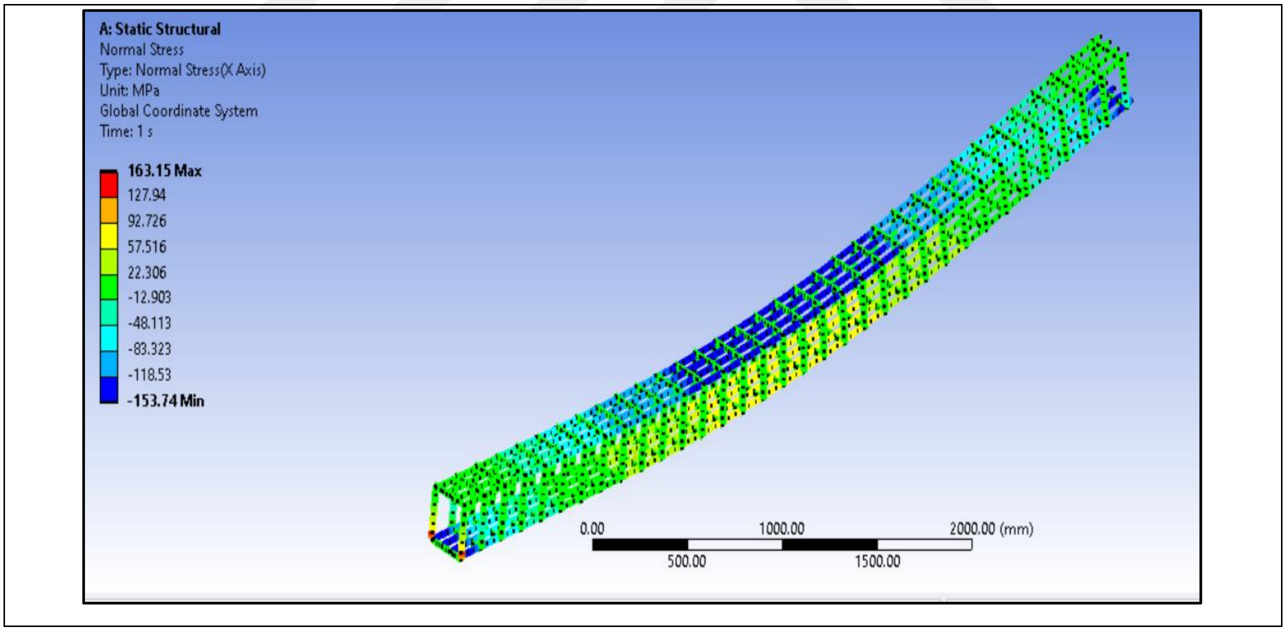

Figure 4.26: Normal Stresses Behavior On The Reinforcement (ANSYS: w=40 kN/m)

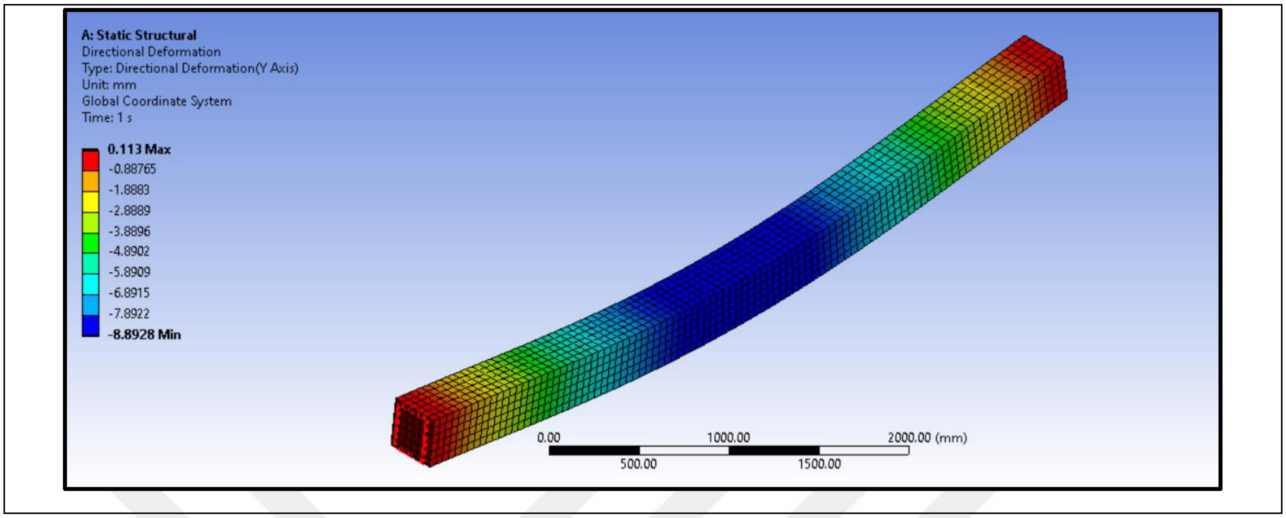

Figure 4.27: Directional Deformation Behavior On The Beam (ANSYS: w=40 kN/m)

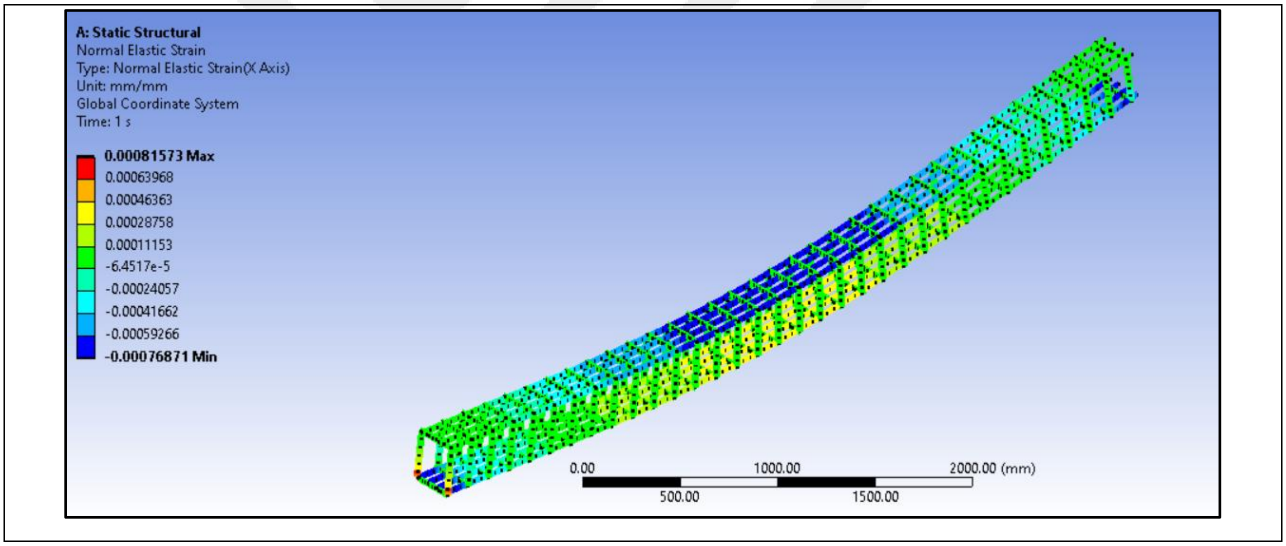

Figure 4.28: Normal Strain Behavior On The Reinforcement (ANSYS: w=40 kN/m)

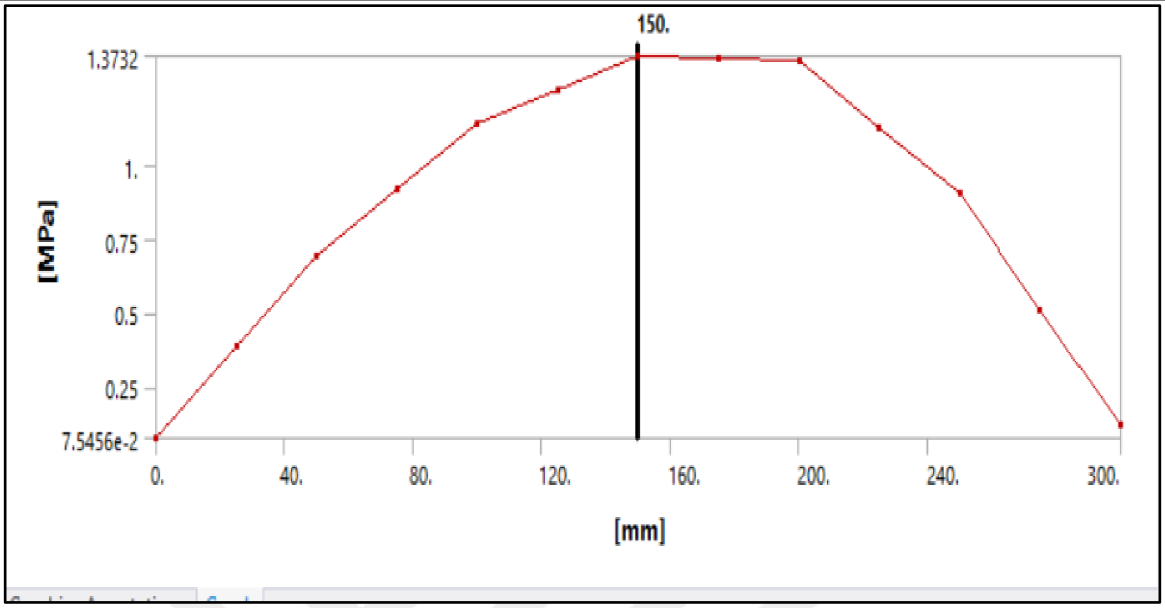

Figure 4.29: Vu Variation Along The Cross Section Of The (ANSYS: w=40 kN/m)

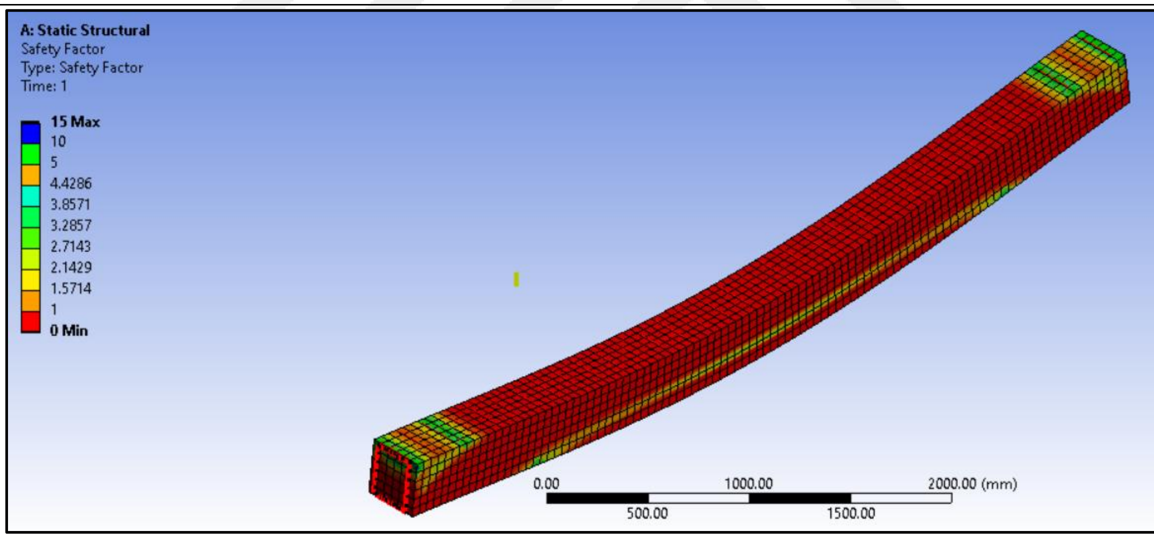

Figure 4.30: Safety Factor For On The Shear Stress (ANSYS: w=40 kN/m)

The state of figure 4.30 showed initial increment of the safety factor from the critical state of 1 to more upper values as the conditions set in ANSYS for the magnitude of the Ø(Vc+Vs) that calculated for such loading and such b and d values which was in close to Vu =88.2 kN that calculated at the d section.

5. DISCUSSION AND CONCLUSIONS

5.1 CONCLUSIONS

The contribution of the steel area of the strength of beam for facing the bending stresses and the shear stresses was analyzed by the study according to the ACI code. The steel area in longitudinal direction showed huge contribution to both the bending strength and the shear strength. The study used the theory of working stress method to evaluate the impact of the steel area Ast on the magnitudes of the cracked moment. The study then explained the effect of Ast on the ultimate strength of the member using the nonlinear analysis theory under ultimate stress method. The study then found out the contributions of the Ast on the concrete strength toward the shear stress Vc and then evaluate the required Asv which was related to the steel area in vertical direction toward the shear stress. The study made numbers of charts to find the magnitude of the maximum Vc that can obtained by increasing the Ast magnitudes in which any increment can not lead to more Vc for tye design purpose. The study made curve fitting for the Ast with various compressive strength of the concrete and programing the state of equations and the limitations under the ACI code. The study found that for RC beam with square cross section (300*300 mm) the maximum Vc reached under loading is 128 kN in which the Ast area in that magnitude 3604 mm2. The variation of the magnitude of the Vc was drawn in charts for various geometrical dimensions of the beam cross section (b d values). The study identified the required Vs for each case and the spacing needed for the Asv under various loading magnitudes I =n the case of concentrated loading and uniform loading. The simulation of the cases was made by using ANSYS program in which the directional deformation, the normal stresses, and the strain were showed in visual images explaining the behavior of the reinforcement structure under the specified structural conditions.

5.2 FUTURE WORK

a. The examinations of the RC beam with pre-stresses condition can be used for analyzed ad derived more simple equations according to the ACI code as future ideas.

b. The studies in coming time can deal with more standard codes to evaluate the effect of the parameters that found inside the RC members system on the member strength.

The future studies also can deal with improving of compressive strength of concrete by using polymers materials and programing that issue to identified the impact on the shear and bending strength of the concrete with the action of the reinforcement used.

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