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Civil Engineering

INVESTIGATION OF SHEAR STRENGTH BEHAVIOR OF TWO-WAY SLAB PANELS BASED ON DIFFERENT SFRC AND HEAT EFFECT

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Master of Science

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by

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The thesis titled "INVESTIGATION OF SHEAR STRENGTH BEHAVIOR OF TWO-WAY SLAB PANELS BASED ON DIFFERENT SFRC AND HEAT EFFECT" prepared and presented by Shakir AL-GRAISHI was accepted as a Master of Science Thesis in Civil Engineering.

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Shakir Hadi Imran

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DEDICATION

With The Most Sincere Feelings And The Kindest Words Emanating From A Loyal Heart, I Extend My Thanks And Gratitude To Those Who Were The Reason For The Continuation And Completion Of My Life's Journey (To my father who went and his spirit remained with me in every step that supports and encourages me , for my dear mother, my brothers and their families, my friends and any person he stood by my side), Those Who Stood With Me In The Most Difficult Circumstances And Who Motivated Me To Persevere, Continue And Not Despair, I Offer You The Most Beautiful Expressions Of Thanks And Gratitude From A Heart Overflowing With Respect And Appreciation.

Shakir Hadi Imran

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When you reach an important milestone in your life, you should stop and take time to thank the people who helped along the way. So, first and foremost, I thank God Almighty for giving me this opportunity and the ability to move forward successfully, enabling me to accomplish this stage of my life.

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ABSTRACT

INVESTIGATION OF SHEAR STRENGTH BEHAVIOR OF TWO-WAY SLAB PANELS BASED ON DIFFERENT SFRC AND HEAT EFFECT

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reinforced concrete slab is an essential structural element which is used to provide building surface a flat form in different structural components. the high temperature affects steel reinforced slabs punching resistance. In this study, the experimental work using a model of SFRC panels was carried out to study the two-way panels of SFRC under high temperature using ANSYS software. The experimental program marked as four groups in which each group contains one panel without steel fiber and three panels of different percentages of steel fiber panels. The specimens are 3D configuration of slab concrete with the dimensions of 500 × 500 × 60 mm using four deferent steel fiber percentage, they are *(V_f= 0, V_f= 0.75, V_f= 1, V_f= 1.25)*. the results observe that adding fiber led to lower deflection values and the best deflection value is obtained from adding 0.75% of steel fiber under the ambient condition with load (40 KN). While at high temperature the best deflection value is obtained from adding 1% of steel fiber at 100 °C.

Keywords: two-way slab, steel fiber, temperature effect, defection

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LIST OF ABBREVIATIONS

Scalars

RC:	Reinforced Concrete
FRC:	Fiber reinforced concrete
ACI:	American Concrete Institute
ASTM:	American Society for Testing and Materials
BS:	British standards code
A:	Area
d:	Effective depth
E_C:	Modulus of elasticity for concrete
a/d:	Shear span over effective depth
a/h:	Shear span ratio
l_s/d_s:	Aspect ratio of steel fiber
f_c':	compressive strength of concrete
v_u:	Ultimate Shear force
v_f:	Fiber volume fraction
V_R:	Punching shear nominal strength
W_{wet}:	Wet panel weight
W_{dry}:	Dry panel weight
f_{ct}, f_{sp}:	Tensile strength for concrete
f_{st}:	Splitting tensile strength for concrete

f_y:	Yield stress of steel
h:	Slab thickness
D_p:	Diameter of punching
d_{agg}:	Maximum aggregate size
L:	Slab length
b:	Slab width
B:	Perimeter of the slab supported on one column
b_o:	Perimeter of critical shear crack
C_{eq}:	Equivalent side dimension of the column
c:	Column dimension
δ:	Displacement
δ_1:	Displacement at the center of the panel
δ_2:	Displacement at a distance 10 cm from the center of the panel
δu:	Deflection at ultimate
δy:	Deflection at yielding
δcr:	Deflection at first crack
Py:	Yield load
P_u:	Ultimate load
P_{flex}:	Flexural capacity
ρ:	Reinforcement ratio
Σ_c:	Perimeter of column
GFRC:	Glass Fiber reinforced concrete

HSC:	High strength concrete
NSC:	Normal strength concrete
FR:	Fiber Reinforcement
NFRC:	Natural Fiber reinforced concrete
SF:	Steel fiber
SNFRC:	Synthetic fiber reinforced concrete
SFRC:	Steel fiber reinforced concrete
LWC:	Light weight concrete
LVDT:	Linear variable displacement transducers
R:	Radius of column
E_T:	The strain hardening modulus
ASTM:	American Society for Testing and Materials
C °:	Temperature in Celsius

1. INTRODUCTION

A reinforced concrete slab is a crucial structural element which is used to provide flat surfaces in building floors, roofs, bridges, and other types of structures. On the basis of reinforcement provided, slabs are generally classified into one-way slab and two-way slab. Two-way slabs resist the subjected load by bending and shear stresses about its axis. Moreover, the slabs should have sufficient depth for the control deflection. Thus, strength and deflection are the requirements of design of two-way slabs[1]. Most of the researches focus on the steel-concrete composites and concrete characteristics, due to beneficial properties of these components to enhance the structural performance. One of the main challenges in structural design aspects is the shear forces effect. Shear failure at slab-column connection could cause progressive failures of the contacts at the similar flooring[2]. It is caused by the transfer mechanism of shear forces from the slab to the slab-column connection and occurs within the discontinuity D-region, where the 3D state of stress is complex. These shear stresses are developed from gravity loads and from unbalanced moments (combination of gravity loading and lateral deflections) and movement during events; such as earthquakes and high winds. The force analysis provides load transformation to the surrounding columns resulting with a high load at the adjacent connections. Moreover, low floors might fail due to support failure due to the effect of falling panels from the top. An example of this progressive collapse is presented in Figure1.1 in Atlantic City, N.J., October 2003 for the Tropicana Casino parking garage[3]

Figure1.1: progressive collapse due to punching of flat slab [3]

With increasing load levels, flexural cracks appear in several locations of a slab subjected to a point load, leading to the initial cracking patterns. for that, the researchers try to enhance the slab resistance and specifications. Omission of shear reinforcement results in structures being susceptible to the well-established size effect, and thus prone to shear failures. For that, to avoid failure in concrete shear response, a large amount of reinforcement or large energy-absorbing ability must be considered which depends on the effects of reinforcement, different material characteristics, concrete properties, combined with the whole structural effects of in-plane actions of load mechanisms[4].

1.1 TWO-WAY SHEAR BEHAVIOR

Shear is the force that acts perpendicular to the length of a beam or a column or vertically in a slab. Shear is classified in structural concrete covering both one-way shear and two-way shear (also known as punching shear). One-way action of reinforced concrete members is the focus of shear behavior while two-way shear is a different phenomenon characterized by a punching-type failure as shown in figure 1.2.

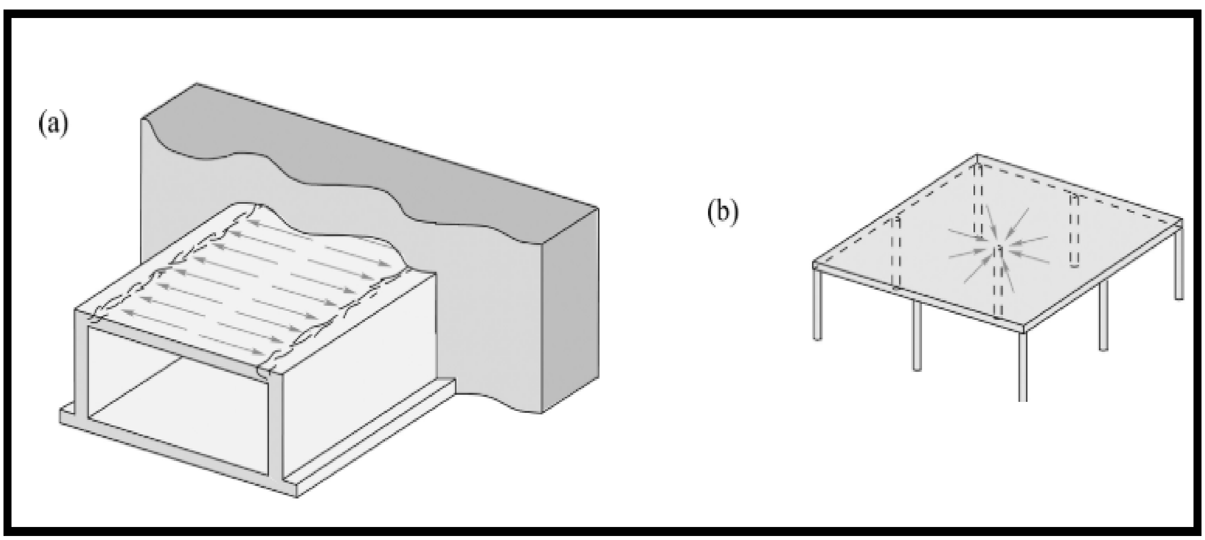


Figure 1.2: Two-way vs. one-way slab [5]

Shear reinforcements are used to enhance shear resistance of reinforced concrete and change the failure mode to a more ductile failure. Punching failure in slabs considered as one of the dangerous failures in building construction caused by the brittleness of concrete. The two-way shear failure in a flat plate positioned at column vicinity, or at specified distance from column face, that lead to total collapsing of the whole structure. Many methods have been proposed to enhance (increase) shear strength of flat slab against punching shear failure[6].

1.2 STEEL FIBER REINFORCED CONCRETE

Fiber Reinforced Concrete (FRC) is concrete combined with fibrous material. the effect of these materials is to increase the structural integrity. The fiber reinforced concrete as a composite material contains short discrete fibers which is randomly oriented and uniformly distributed. The composite material of hydraulic cements called Steel fiber reinforced concrete (SFRC). It is a fine and coarse aggregates correlated with discrete steel fibers. SFRC is widely used in concrete structure which is used to increase the tensile strength of the concrete. Also, adding of steel fiber is used to prevent the formation of micro openings caused by micro cracks. These additives provide a lower stress at the end of the cracks based on steel fiber transportation of tensile forces, that means minimize crack growth and enhance the concrete material to endure loads even after visible crack occurred. Fibers are added for long term durability of concrete[7][8]. The fibers can add a new significant features to the concrete as shown in Figure 1.3 shows the prototype of test specimen after loading

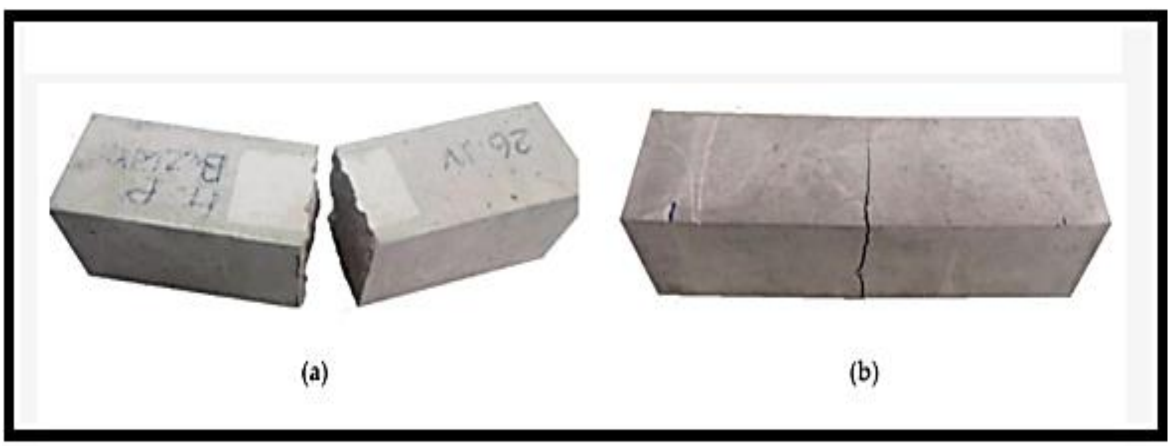


Figure 1.3: Test sample post loading (a) without fiber; (b) with fiber[9]

The concrete failure mode depends on several parameters such concrete dimensions, speed of loading which causes sliding of rebar from the concrete or break of steel when the steel reached its maximum strength. Adding fibers can enhance the concrete strength and provide an increment to the strength of the concrete[10].

Fiber reinforced concrete contains concrete mixed with distributed fibers. Combining fibers with concrete generates an increased strength and enhance crack pattern. The fiber reinforced concrete fault behavior observes a several small cracks instead of one or two larger cracks in traditional concrete. The fibers can be produced from many different materials. The ACI 544 classifies the fiber types into four rescores[11]. They used to improve the concrete properties and cementations composites. There are many types of synthetic fiber which is used to incorporate the cement matrices involve: polyvinyl acetate (PVA), polypropylene (PP), polyethylene (PE), acrylics (PAN), polyester (PES), polyamides (PA), carbon, and aramid. Some examples of different commercially available fiber can be shown in Figure 1.4. Some types of fiber are used to enhance the toughness and reduce crack widths, but other fiber types reduce shrinkage cracking[12].

Figure 1.4: Examples of commercially available fibers [13]

The both geometrical and mechanical properties of fiber vary based on their effects and provide a unique properties of concrete. Many factors affect the fiber reinforced concrete reliability such as orientation, fiber type and percentage of fibers. The mix workability is decreased if the quantity and size of particles increased greater than 5 mm. The aspect ratio (l/d) is another important factor. It has a major effect on workability of the fibers. The fibers workability decreases with increasing aspect ratio[14].

1.3 PROBLEM STATEMENTS

Concrete slab supported by columns usually subjected to two types of shear forces (one and two-way shear), in addition to the flexural forces, which act on the concrete body. These forces are interfere with each other which makes them not recognizable to measure their effects [2][15][16]. There are various punching shear models for steel fiber reinforced concrete slabs need to be studied. It needs to investigate the punching shear model of steel fiber reinforced concrete that takes into account the amount of the steel fiber. In real engineering conditions, there are differences regarding the control punching determination and the quantification of the influences of the main effective parameters [1]. The main two problems resulting from the applied loads are brittle and high deflection[7][4]. This is may be occur due to concentration of shear force and structural behavior effect which depends on the brittleness properties of concrete[17]. There are a huge number of researches addressed this subject, many mechanical model had been proposed, and any code equations were introduced, but still many problems to be resolved, such as, how to increase the concrete strength and ductility in the same time. Many methods had been suggested to increase the ductility, and resisting the two-way shear action of partially loaded panels. Using shear reinforcements and steel stud are widely used nowadays, but using fibrous concrete (mostly using SFRC) shows good improvement[18].

1.4 OBJECTIVES AND SCOPES

The effect of steel fiber on the residual strength of the flat plate is experimented. In order to achieve this objective, SFRC flat plate is exposed to different reinforcements are studied through the:

a. Comparison between the residual punching shear behavior of SFRC slab due to different steel-fiber conditions and punching shear behavior of SFRC slab at normal condition.

b. Investigation of the effect of steel fiber volume fraction on punching shear capacity.

c. Characterizing the post cracking and cracks pattern at failure stage.

1.5 THESIS ORGANIZATION

This thesis has five chapters. Chapter one includes an introduction to flat plate behavior under punching shear strength and the effect of steel fiber on the behavior.

Chapter two presents a general view of steel fibers effects on concrete behavior in different studies collected from vary researches.

The experimental program, including the studied parameters, the work methodology, and testing of SFRC flat plates specimens, are presented in Chapter three.

Chapter four discusses the result and the calculation of the work. Chapter five is the conclusion.

2. RELATED WORKS

Concrete is one of the most important construction materials due to its functionality and stability in structure construction. Concrete slab panels represent a structural element of modern building. The wide diversity of materials that used in slabs panels varied the behavior of slabs. For that, studying the factors and characteristics that can improve concrete slab panels considered a major issue in engineering industry where it gradually becoming a new horizon in composite material in construction project [9]. Many independent methods have been used to achieve this target such as adding different steel-fiber. These methods are called Steel fiber reinforced concrete SFRC[8][19]. SFRC described as a mixed concrete with fibrous materials. When steel fibers added to concrete, it improves the structural properties such as flexural strength and tensile. The mechanical properties achieved by using SFRC depend on several factors, such as size, shape, percentage, volume and distribution of fibers [7][20]. It improves the concrete brittleness and weak endurance to shear and tensile forces. Plain concrete does not easily resist the vibrations, wind, earthquakes, and other forces. Adding fibers enhance the concrete quality against the failures[21]. The theoretical models developed the researchers apply an applicable structural solution to modify the concrete forces resistance by using SFRC as in Figure 2.1.

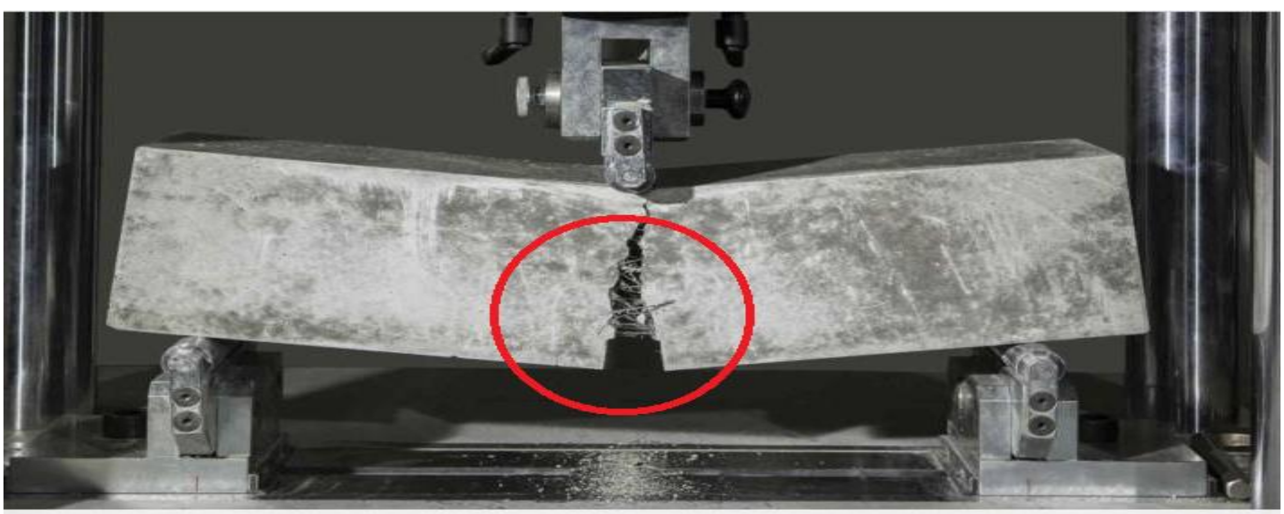


Figure 2.1: Fiber Reinforced Concrete (sikaconcrete.co.uk)

the present chapter will overview the previous related works of fiber concrete reinforcement and present the effective factors and properties of concrete to employ this information in simulation testes to investigate the response of different reinforcement effect based on fibers structure.

2.1 TYPES OF STEEL FIBER REINFORCED CONCRETE

2.1.1 Steel Fiber Reinforced Concrete

Steel fiber reinforced concrete (SFRC) could expressed as a composite material which have fibers as the additional ingredients. The fiber reinforcement effects as rigid inclusions in the concrete matrix. The presence of fibers with the concrete can improve the resistance of conventionally reinforced structural members to deflection, cracking and other serviceability conditions due to the inherent material properties of fiber. The fiber reinforcement can be used in three forms in concrete body; the first is one-dimensional random distribution which added advantages to the fiber shear resistance and crack control. The range of normal weight SFRC proportions presents in table 2.1.

Table 2.1: SFRC proportions [20]

Property	Mortar	9.5mm Maximum aggregate size	19 mm Maximum aggregate size
Cement (kg/m^3)	415-710	355-590	300-535
w/c ratio	0.3-0.45	0.35-0.45	0.4-0.5
Fine/coarse aggregate(%)	100	45-60	45-55
Entrained air (%)	7-10	4-7	4-6
Fibre content (%) by volume			
smooth steel	1-2	0.9-1.8	0.8-1.6
deformed steel	0.5-1.0	0.4-0.9	0.3-0.8

Aylie et al in 2015 studied five steel-fiber beams, having a difference in restricting reinforcement configurations. The testing approach under increasing monotonic loading was deformation controlled.

The second form of fiber reinforcement is two – dimensional orientation of the fibers which is used for tensile skin to cover the steel reinforcement. And finally the three-dimensional for steel fiber reinforced shotcrete based on different considerations with most mix empirical designs [9,10]. Typical mix designs for steel fiber shotcrete are given in table 2.2.

Table 2.2: steel fiber mixer [20]

Property	Fine aggregate mixture (Kg/m³)	9.5mm Aggregate mixture (Kg/m³)
Cement	446-559	445
Blended sand (<6.35mm)[a]	1438-1679	697-880
9.5mm aggregate		700-875
Steel fibres[b, c]	35-157	39-150
Accelerator	Varies	Varies
w/c ratio	0.40-0.45	0.40-0.45

SFRC mechanism behaves differently during loads increasing. When concrete start to crack, steel fiber will carry out the load, then the mechanism depends on the steel fibers shape and properties only. Sometimes the steel is obtained from chopping wires milled from ingots or cutting steel sheets, or it be produced from hot melt extract [22][23]. There are two main categories of steel fibers, smooth and deformed. It comes in various shapes like circular, rectangular, hook shaped etc, as shown in Figure 2.2. The deformed steel fibers are more efficient due to the surface area effect which increases the cement-matrix bond this results an improvement in pull out resistance [24].

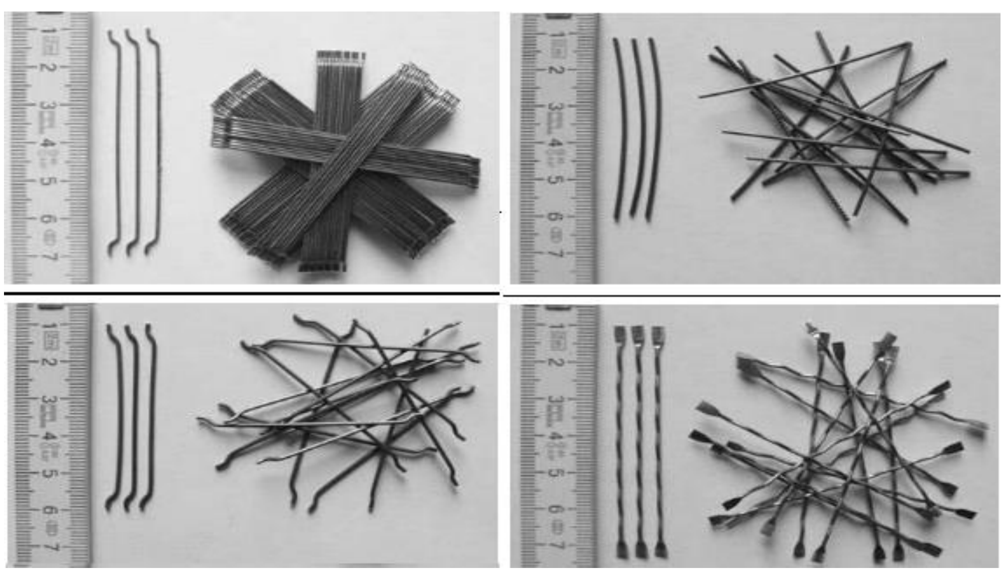


Figure 2.2 Different shapes of steel fibers [24]

Fibers may split out or fracture, that depend on length of steel fiber and concrete strength [21]. The steel fibers can be found in different shapes, sizes and properties which include high tensile steel fibers, stainless steel fibers and normal steel. The steel characteristics depend on types of manufacturing process. It may produce by hot or cold working methods which are affecting the steel properties. The straight fibers which are not deformed can only bond with the concrete by friction and chemical adhesion. Steel fiber lengths are in range from 10 to 65 mm with diameters ranges between 0.5 and 1.2 mm[24].

2.1.2 Glass Fiber Reinforced Concrete

Glass fiber has used in construction elements over 30 years such as pipes for sewage and water lines. Glass fiber concrete (GFC) involves a matrix of cement, water, sand, and admixtures, in which short length glass fibers are dispersed. The effect of the fibers leads to an increase in the impact strength and tension of the material. Fiberglass is material manufactured from fine fibrous glass materials. Fiberglass is considering as an extremely strong, and lightweight material. Also, it's very favorable when compared to metals, due to easily formed using molding processes. Glass is the most familiar and oldest performance fiber [25].

Pshtiwan et al, in 2011 tests a concrete without glass fiber and with glass fiber to find out the differences in flexural strength and compressive strength. Various applications of GFRC shown in the study, the experimental test results, techno-economic comparison with other types, as well as the financial calculations presented, indicate the tremendous potential of GFRC as an alternative construction material[26].

Chaitanya kuma et al, in 2016 proposed that the Increasing of the properties of concretes such as compressive, tensile and split tensile strength. This research examined the concrete with glass fiber of 0.5%, 1%, 2% and 3% of cement by adding as an admixture [16].

Arunakanthi et al, in 2016 compare between glass fiber and steel fiber. They studied the strength of the FRC which was added at percentages of 0.5, 1, 2 and 3%. They found that the flexural strength, compressive and split tensile strength is increasing linearly by adding SF, on the other hand adding glass fiber up to 1% the strength is increasing but it starts decrease at 2%.

Alex Tharun et al, in 2018 studied the strength characteristic of glass fiber reinforced concrete. They found that workability of glass fiber reinforced concrete decreases with increase of fiber and compression factor is less than conventional mix. Also, Flexural strength, compressive strength, and split tensile strength increased because of the addition of glass fiber.

2.1.3 Natural Fiber Reinforced Concrete

Natural fibers are used to improve the durability and strength of brittle materials. Natural fibers that are suitable for reinforcing concrete classified as shown in Figure 2.3. Fibers derived from palm trees observed stronger results than coconut fibers. The addition of coconut and jute fibers increases only slightly the tensile strength of the concrete composites and decreases the compressive strength[11]. Paramasivam et al., in 1984 recommended the use of such slabs in housing using asbestos cement sheets [27].

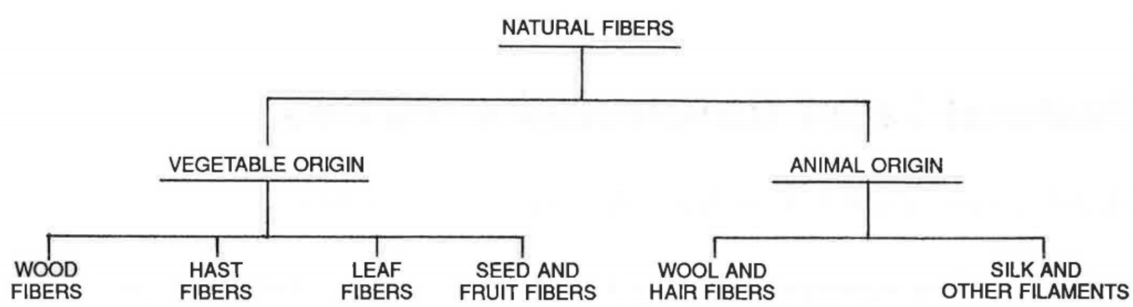


Figure 2.3: natural fibers classification [27]

Seneviratne et al, in 2017 added Coir fiber extracted from coconut husk to high strength concrete. The test results show that a reduction in flexural strength in most cases except for 2% coir fiber reinforced concrete. Kavitha et al, also in 2017 investigate the factors that affect the performance of mechanical characteristics and durability of NFCs.

2.1.4 Synthetic Fiber Reinforced Concrete

Synthetic fibers have been used to improve the concrete structure performance by enhancing the modulus of elasticity, flexural strength, and other mechanical properties of concrete. Synthetic fibers engineered to utilize in the aramid, polyethylene (PE), polypropylene (PP), acrylics (PAN), polyamides (PA), poly (vinyl alcohol) (PVA), polyester (PES) and carbon reinforcements. These fibers are manufactured polymer-based such as nylon, or polyethylene, polypropylene[13][23]. Camille et al, in 2019 proposed mechanical Properties of synthetic fiber reinforced concrete under static loading for railway transoms application. They found that the Synthetic fiber enhanced the workability, durability and flexibility of the concrete sleeper.

2.2 RELATED STUDIES

The first to experimental study in this field was by Talbot in 1913 which presented a footing model for punching behavior of reinforced concrete[28]. The study was interested with deflection in the footing's concrete and marking the cracking patterns. Also, the study computed the failure loads for each footing. Talbot led to the first recommendations for independent punching shear which is published in 1925 in ACI-American Code. After that, the studies developed by many researchers to enhance the slab shear such as, [28][29][30]

More than a few parameters like the shear reinforcement system, slab thickness and the column size were involved to reveal their effects. The results spotted that the influence of shear reinforcement amount reduced to 40% leading to non-agreeing values[31]. khandokar in 2015 proposed an improvement of punching shear capacity of existing flat plates by using shear reinforcements. Eight half scale frame specimens were tested based on lateral cyclic loading. The specimens were subjected to incremental cyclic loading by hydraulic jacks under gravity and constant axial load. The results showed that the joints without shear reinforcement in all specimens underwent brittle failure when used cyclic loading, but their ductility increased respectively with increased concrete strength(tusar khandokar', 2015)

Bonic et al in 2017 proposed the punching capacity characteristics. They found the optimal concrete compressive strength and reinforcement ratio. Also, they investigated the strains in concrete and in reinforcement steel [21].

Mahmoud in 2015 described the features of flat slab simulations for the finite element model. The research presents single equally loaded panels which considered not exposed to membrane forces. The arrangement of punching shear reinforcement systems shown in Figure 2.4 (a and b)[31].

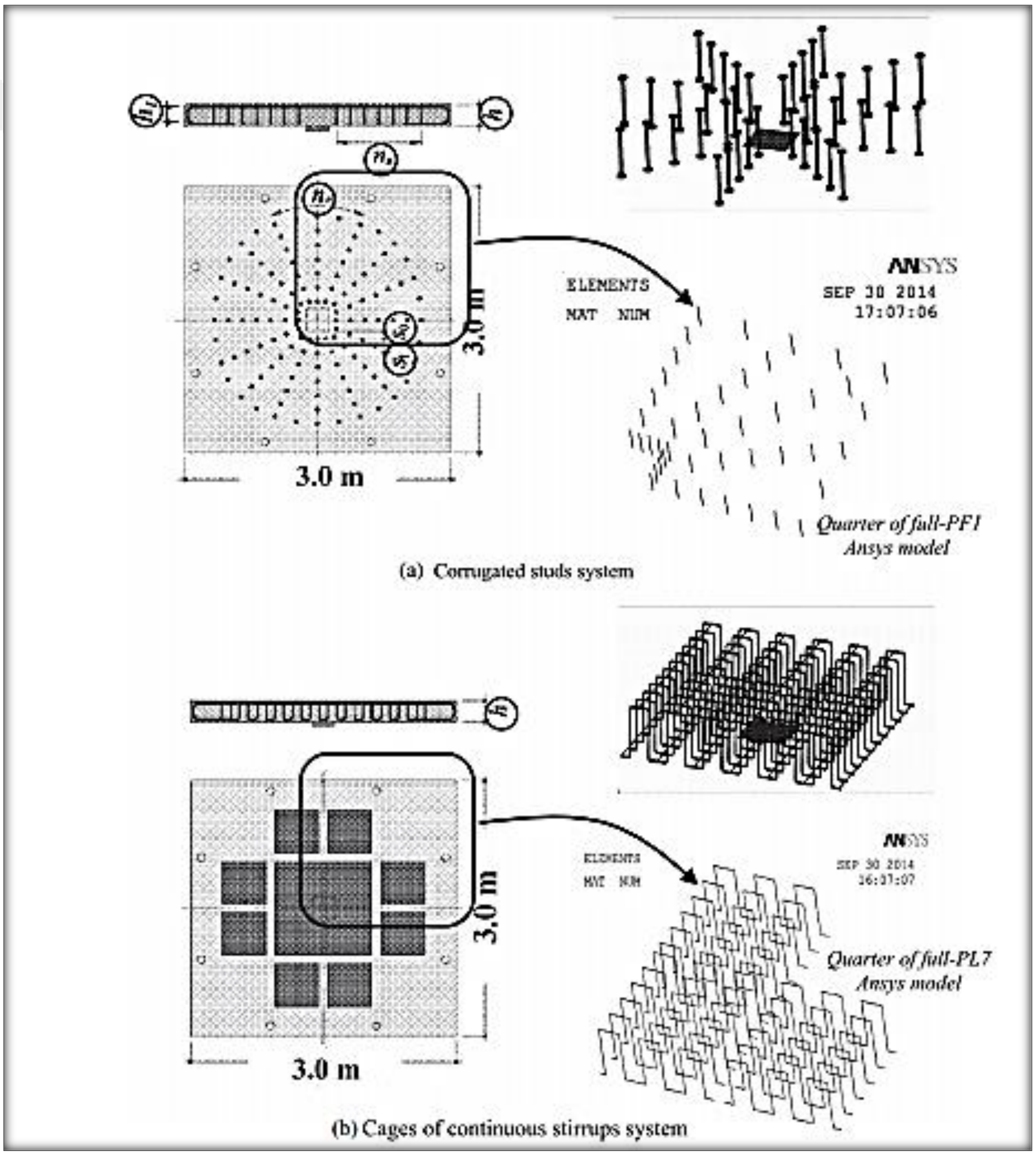


Figure 2.4: The organization of reinforcement systems for punching shear [31]

2.3 MECHANICAL PROPERTIES

The mechanical characteristic of a material is those features that include a response to an subjected load. The mechanical characteristic of metallic material defines it's advantages of a material and determine the expected service life. Mechanical characteristic assist to classify and recognize material. The most important known features are strength, ductility, hardness, impact resistance and fracture toughness [23]. The mechanical properties of SFRC deflect either in elastic or plastic, on account of the applied stress. The mechanical properties contain compressive strength, tensile strength, flexural strength, shear strength ,punching shear resistance, ductility, and crack pattern. The mentioned mechanical properties appear to be affected by parameter of V_f (%), l_s/d_s as aspect ratio, shear span ratio, thickness (h), and also concrete strength (fcu)[33][5].

2.3.1 Compressive Strength

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate. The Compressive strength of control concrete (plain concrete) was found to be 49.1 MPa [30]. Fibers enhanced the compressive strength of concrete, with increasing in strength ranging from basically 0% to almost 25%, adding steel fibers increases the post-cracking ductility, or energy absorption of the concrete as shown in figure 2.5. It can conclude from the figure that the increasing of V_f led to the increasing of compressive strength of concrete[34].

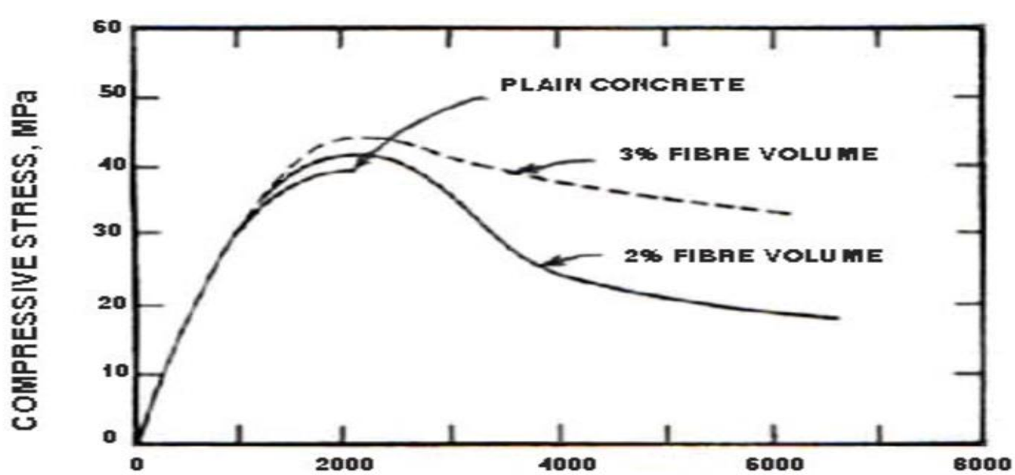


Figure 2.5: Stress – strain curves in compression for SFRC [34]

The thickness of concrete must be increased to obtain the same value of axle load. For example, for concrete strength ranged 20 MPa–25MPa (C20/25), in order to reserve 100kN, the plain concrete, reinforced concrete, and SFRC needs slab must be at thickness of 253mm, 218mm, and 209mm respectively. The concrete strength roles are very important roles in affecting compressive strength. For example, for plain concrete at 150 kN, from C20/25 to C40/50, the slab thickness is decreases by 65mm (20.3%); for reinforced concrete, the slab thickness is decreases by 45mm (18%); and for SFRC, the slab thickness is decreases by 45mm (19.1%).

As shown in Figure 2.6 curves, the highest effect on the capacity of load is shown at a span shear ratio a/h equal to one. This refers to that the principal stresses were very affected by the shear stresses. Then after the fiber volume increasing from 1% to 2% when a/h is equal to one, the capacity of load expands from initially 1.62 up to 1.89 times at end. At a higher values of a/h ratio, the capacity of load increase is not so considerable. For instance ,at a/h = 0.5 and a/h =1, as shown in the figure below the increase [35].

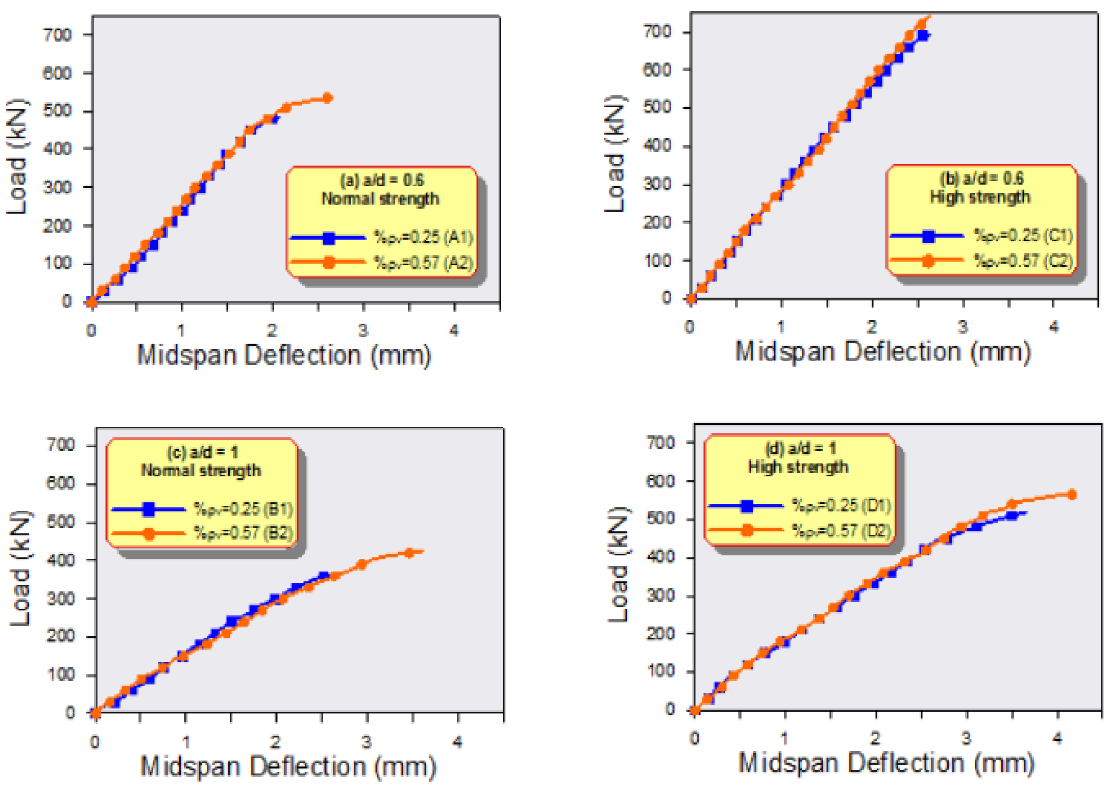


Figure 2.6 Effect of (ρv) ratio on load-mid span deflection plot [35]

2.3.2 Tensile strength

Tensile strength is a measure of the strength essential for pulling an object for example cable, rope, or a structural element to the point that it breakdowns. A material tensile strength is the maximum amount of tensile stress that it can be obtain earlier to fail, for instance fracturing. The tensile strength of SFRC increased when l/d ratio increased; especially with the employment of 1.5% fiber volumes more efficient on the tensile strength .In a similar way, tensile strengths were also raised with the raising of V_f [16].Fibers located aligned in the same orientation of the tensile stress might be result higher raise in direct tensile strength. On the other hand, the random distribution of steel fiber, may not increase the strength a bit, or increase it in some examples nearly 60%, as many surveys showing intermediate values, as presented in the figure 2.7 . The experimental investigations used by researchers to find out compressive behavior observed that the coated samples with a high proportion of steel tolerate larger loads irrespective of fiber directions. Moreover compressive strength change is very marginal from 30-45% of steel content due to poor interconnection resulting in large delamination and laminates failure[36].

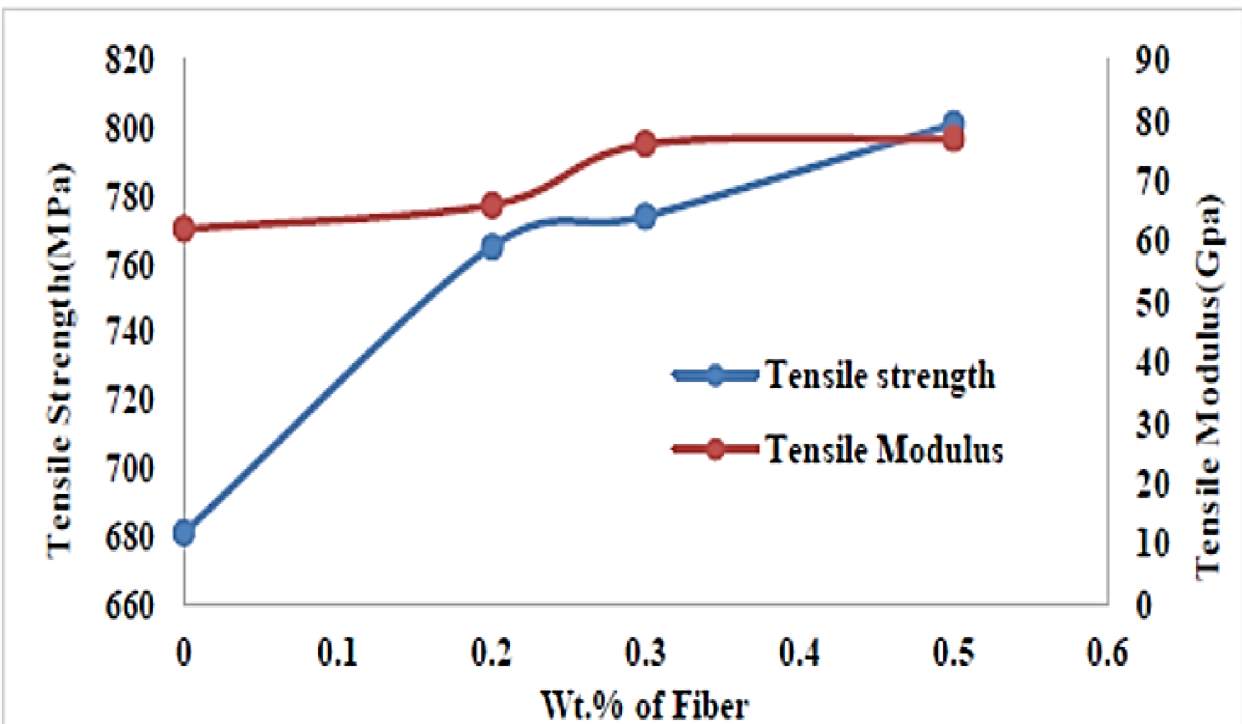


Figure 2.7: Influence of Fiber Content on Tensile Strength [36]

The increase in shear stress does not depend entirely on the steel, because the shear stress depends not only on the strength of the fibers, but also on the bond between the fiber and the matrix material. Splitting-tension test of SFRC also shows comparable result .Thus, the addition of the fibers is simply to increase the direct tensile strength is probably worthless. However, as a compression, steel fibers are grated for the increases in the post-cracking behavior or composites toughness [7].

2.3.3 Flexural strength

Flexural strength is the measurement of concrete tensile strength. It is a measure of the maximum stress applied on the tension of concrete face which is unreinforced. the slab at the point of failure in bending. studied the flexural strength of SFRC, they carried out series of tests and reported the results, Figure 2.8 shows that by increasing steel fiber dosage from 20 kg/m3 to 40kg/m3, the flexural concrete strength will increase nearly 12% in the concrete class. At the meantime, in the concrete class, the flexural strength varies from 9.5% to 11%. Sometimes, steel fiber dosage also may refer in term of V_f [37][38].

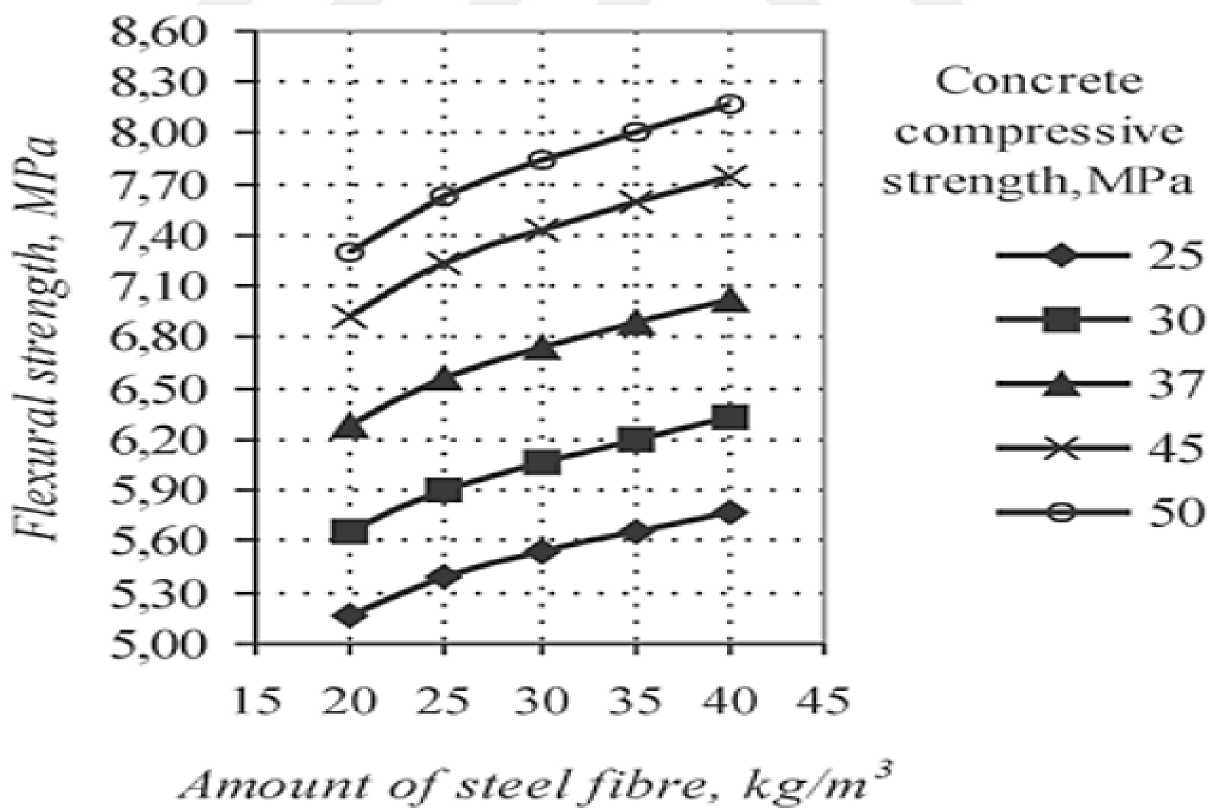


Figure 2.8 Flexural strength dependence on the amount of steel fiber [38]

The maximum flexural strength registered was 7.75 MPa ,9.33 MPa, and 10.76 MPa in sequence. It can also be seen from the results that, the flexural strengths of SFRCs were higher nearly about 3% - 81% than control mixture which is a plain concrete.

Clearly, steel fibers significantly improved the flexural strength of concrete as compared to compressive and split tensile strength. Also, flexural strength of SFRC is significantly improved with the increasing of l_s/d_s ratio and V_f.

2.3.4 Shear resistance

Shear strength is the Substance or component strength versus the kind of yield or structural failure once the Substance or component fails in shear. A shear load is a force that aims to make a sliding failure on a Substance alongside a plane that is parallel to force direction. Shear resistance behavior of SFRC. Figure 2.9 shows the correlations between shear stress with the increasing of span ratio [39].

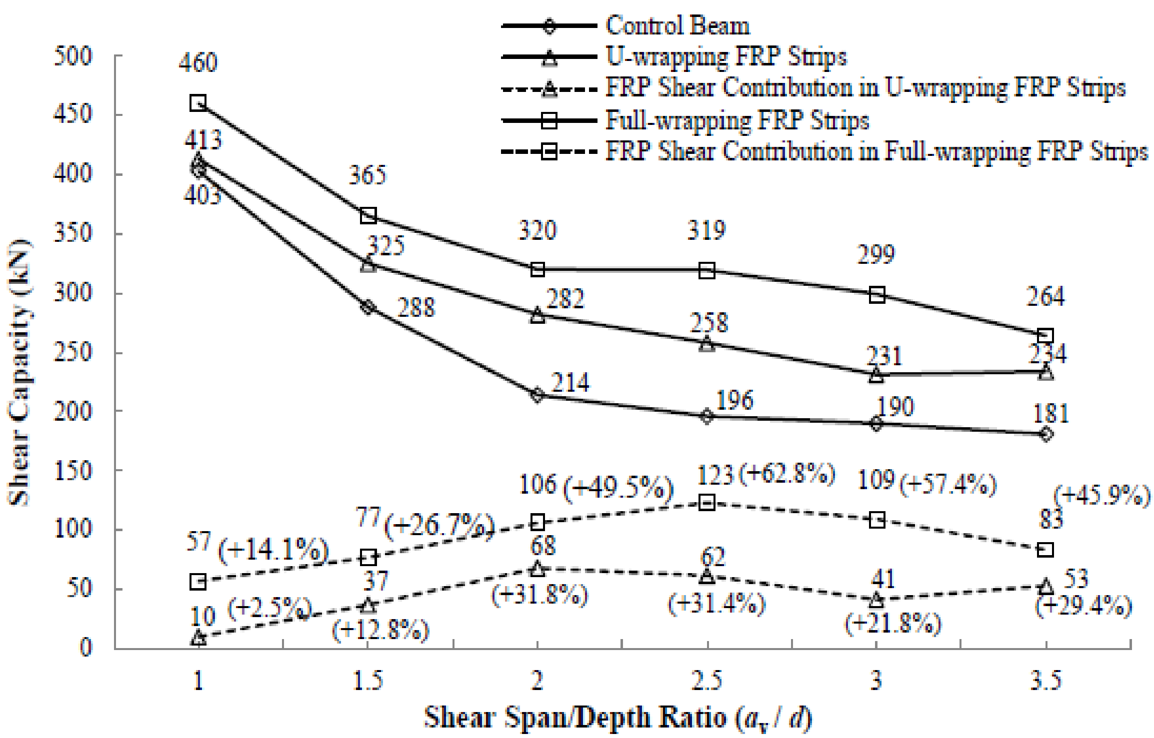


Figure 2.9: Influence of shear span ratio on shear resistance [39]

If the capacity of flexural beam can be control the maximum shear, the used ultimate shear would be proportional to Ia. for that, the effects of Vf on shear strength of SFRC are explained in Figure 2.10[40].

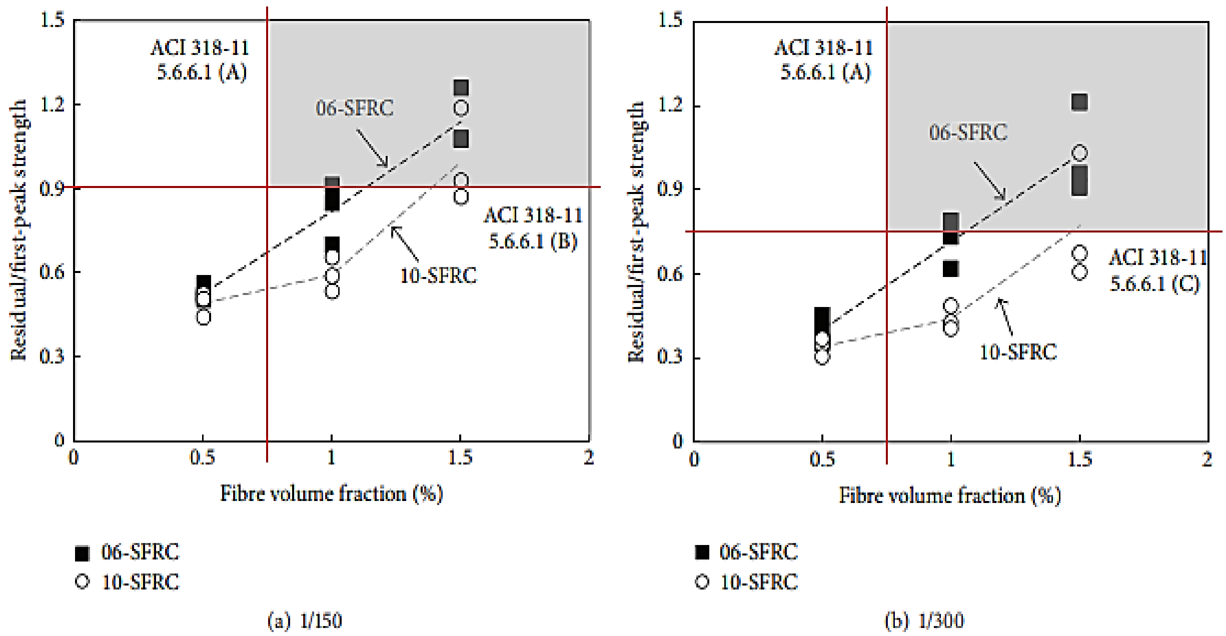


Figure 2.10: Influence of volume friction on Shear Strength [40]

The strength of SFRC beams ranged from 122% to 180% of the plain concrete beams stress. The increase of strength was particularly large with the range of 69% to 80% for the beams with low a ratio, which is gri = 2 as shown in figure that will probably fail in collection of flexure and shear. For larger a ratio, which is a well-known thing in engineering, the strength increasing is ranging from 22 to 38%. This beams will definitely a flexure failure; thus, the load applied upon failure is not equal to the shear resistance. In fact, this load will just provide a lower confined on the shear strength. On the other hand, concrete strength also plays a role in affecting the shear strength. As the concrete strength was approximately doubled from 31Mpa to 65MPa, the shear strength increased by 21% to 26% for a given Sand ratio [10]

2.3.5 Punching shear resistance

The weight of the plate supported on a column causes the shear stress in the plate. These stresses, if satisfactory and where additional reinforcement is not provided, will cause the column to be 'punching' across the slab. The researchers studied the punching shear resistance. Figure 2.11 indicates that by increasing the slab thickness (h), it will result a higher cracking load, yield load, and ultimate load .On the other hand, the ductility defined by $\delta u/\delta y$ where δu is the deflection at ultimate and δy is the deflection at yielding, also tends to increase with the increase of slab thickness (h) [41]

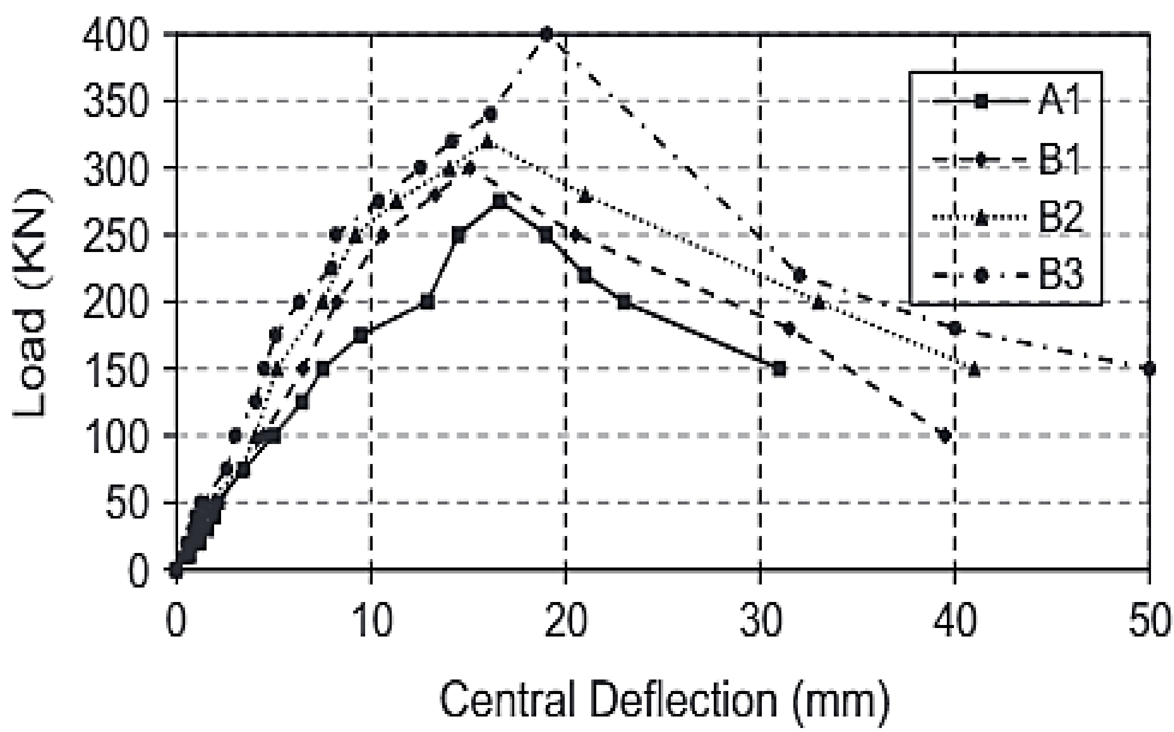


Figure 2.11: Load-central deflection for specimens of different groups Under Punching Shear [42]

2.3.6 Ductility

Ductility is a mechanical property usually described as the ability of a material to draw (for example in wires). In materials science, ductility is determined by the degree to which a Substance can withstand plastic distortion in tensile stress earlier to failure. Ductility is a significant regard in manufacturing and engineering, defining a material's convenience for particular engineering works (for example cold working) and its ability to mechanical overload absorption. Figure 2.12 shows an example of the first yield displacement, y, relates to the intersection of the tangents to the load displacement curve at the origin and maximum displacement. So, the displacement–ductility ratio use provides a new criterion furthermore to the criterion strength for expecting the lap-spliced reinforced concrete beams behavior [43]. Studied the ductility, according to, the region in load-deflection curve that define the deflection at first crack (δcr), deflection at yielding (δy), and also deflection at ultimate (δu) corresponding to the cracking load (P_{cr}), yield load (Py) ,and ultimate load (P_u) for slabs tested[33][25].

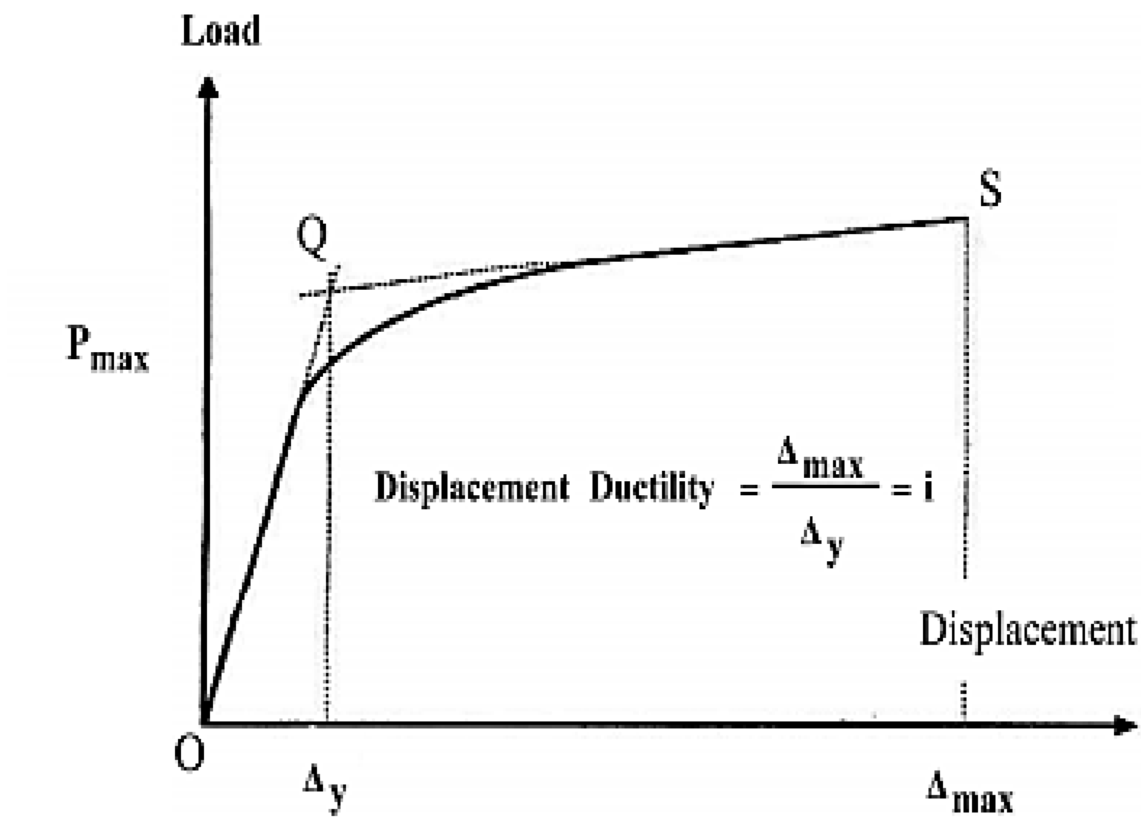


Figure 2.12: Definition of displacement–ductility ratio

Load crack was determined from the load-deflection curve and confirmed by steel-strain reading. The yield load (Py) was obtained from the intersection of linear portions of regions. The same procedure is applied when getting the ultimate load (P_u) which was obtained from the intersection of regions [44]. The ductility also increased as compare to other parameter such as the concrete strengthf_{cu} , loaded area (r), and volume fraction (V_f) that give a low ductility result.

2.4 TYPICAL CRACK PATTERN

Concrete cracking is a result of the combined effects of mechanical loading and environmental conditions. Stress mechanisms that cause can cause concrete cracking can be divides into those that happen in the plastic condition and those that take place in the hardened state, then it might also be tell apart by whether they arise from internal factors or from external factors. For example, overloading, thermal expansion, restraint, and chemical reactions. The cracks itself can variety from a minute internal micro cracks to a very large cracks produced by external factors of nature [41]. Every neglect throughout the construction process can cause distress in concrete slab pavement. Cracks could appear form these distress in concrete slabs resulting from a number of variables such as water inclusion, seasonal temperature changes that causes expansion and contraction and the exposure to sun. Understanding the type of crack formed and its effects is significant to structural stability. The structural capacity for a designed live load and a super imposed dead load conducted to determine the actual floor capacity. Loreto et al, in 2013 proposed cracks behavior based on different variables. They tested FRCM samples in tensile coupon hydraulically. These samples are gripped to the testing machine anchors; the results are stress-stain behavior which is shown in figure 2.13. the stress is calculated as the applied load on the spacemen and divided by the net area of the fiber threads in the load direction.[43]. The figure observed the correlations in strain are below the matrix cracking and the stiffness compound is managed by the stiffness matrix. Also, the first crack is occurring based on the load in every crack position and transported to the matrix using the fabric with creating multiple cracking patterns.

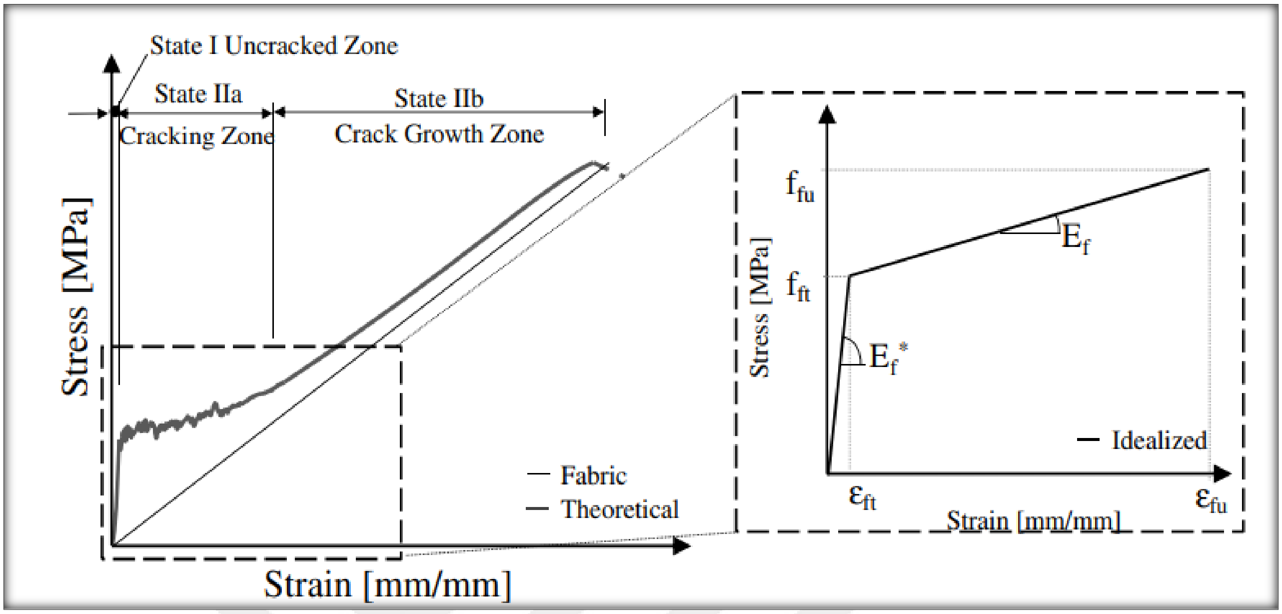


Figure 2.13: Stress-strain for fully-clamped FRCM in tension [43]

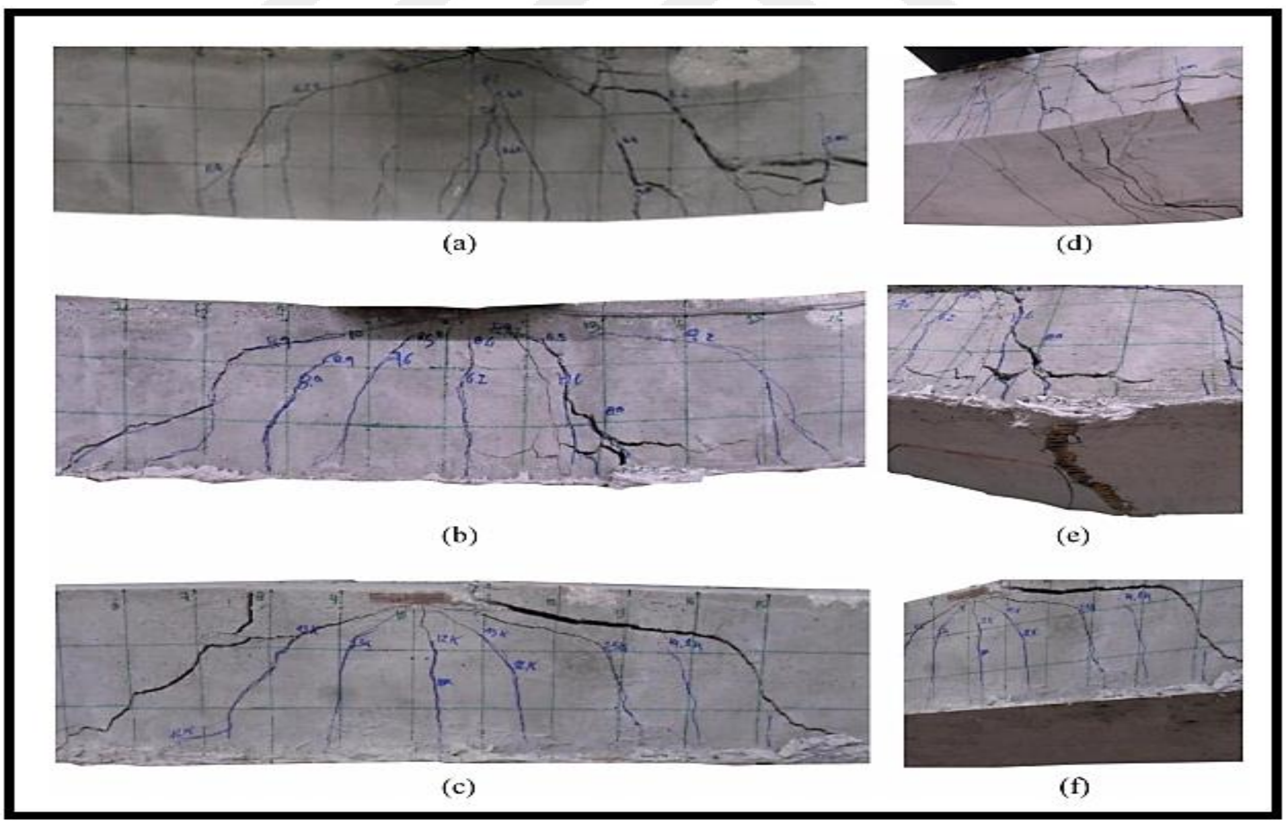


Figure 2.14: crack pattern [43]

the load effect is completely carried via the fabric elements to reach the tensile strength. It is clear from the figure that can compare the crack outlines on the lowest position of the tested slab. by increasing the subjected load, the steel yielding, depth, and width of the cracks dynamically increase. [43]. the interaction might make the failure. The shear and the flexural cracks stayed distanced nearly such as V_f increased. As an example, in concrete beams that has no fibers, the crack spacing was typically 90mm to 170mm ,while this spacing decreased to 70mm to 90mm in the addition of steel fibers [47].

2.5 ULTIMATE LOAD PROPOSED EQUATIONS

Punching shear is introduced decades ago, therefore; it was taken in consider by lots of cods that gives designs and calculation provisions for punching shear capacity, such as:

A. British standard BS8110:1985: The standards proposed by the British standard BS8110:1985 are comparable to what Regan proposed.

$$V_c = const \times (p \times f'c)^{1/3} \times (\frac{400}{d)^{1/4}}) \qquad 2.1$$

(SI units) Where: d is the effective depth of slab in mm

But it can be seen in British standard BS8110:1985 that the critical shear perimeters are rectangular located 1.5d form the face of the column, regardless of the column shape if it was circular or rectangular.

B. ACI 318-83 and CSA A23.3 84M: Punching perimeter in ACI 318-83 and CSA A23.3 84M is located at a distance d/2 from the column face, both calculate the shear strength from the root of concrete strength (ACI318-14, 2014), (CSA, 1984).

$$V_u = 0.33 \times b_o\, d\, (f'c)^{1/2} \qquad 2.2$$

Where b_o is the perimeter $d/2$ from the column face, d effective depth.

C. Regan in a contract with the Construction Industries Research and Information Association, Regan developed an equation for punching shear capacity calculation. Regan suggested that the shear perimeter is rounded rectangular located 1.25d form the face of rectangular columns and a circular shear perimeter located 1.25 from the face of circular columns.

$$V_u = K_a K_{SC} K_S \, (p \times f'c)^{1/3} \times d(\Sigma_c + 7.85d) \qquad 2.3$$

Where:

V_u ultimate Shear force.

K_a 0.13 for concrete of normal density.

K_{SC} $1.15 \times (4\pi x\ column\ area\ /\ (column\ perimeter)^2)^{1/2}$

K_S size effect term $(300/d)^{1/4}$ (SI units).

p steel ratio.

$f'c$ compressive strength.

d effective depth of slab in mm.

Σ_c the perimeter of column.

D. Bazant and Cao focused on the size effects; also a formula was suggested for calculating the punching shear.

$$v_u = \frac{V_u}{D_p h} \qquad 2.4$$

$$v_c = const \times f'c \, \frac{(1 + 0.6\ {}^{D_p}/_{h})}{(1 + {}^{h}/_{25d_{agg}})^{1/2}} \qquad 2.5$$

Where: D_p diameter of punching, h slab thickness, d_{agg} maximum aggregate size.

3. RESEARCH METHODOLOGY

This chapter presents all the procedures utilized throughout the project in order to investigate the behaviour of SFRC panels. The present work used a model of SFRC panels to investigate the residual strength of two-way panels of SFRC and the degradation of concrete mechanical properties. The different numerical methods and a number of computerized algorithms applied in order to solve and analyse problems that involve the structural and materials. Several important parameters are incorporated in the analysis, specifically reinforcement design and thickness of the slab for studying its effects on the behavior of the flat slab. A parametric investigation was conducted to investigate the variables for example the transformation of loading types that can mostly affect the mechanical behaviors of the sample. This work aims to produce a numerical model capable to predict the two-way panels of SFRC characteristics such as strength values related to the add percentage of the fibre volume to the concrete in order to investigate the punching shear behavior of SFRC slab due to different steel-fiber conditions and punching shear behavior of SFRC slab at normal condition. The calculations required simulating the interaction of structural with different steel-fiber conditions, and initial conditions are done by the ANSYS software program. The methodology procedure in this work will test the model by discretized the partial differential equations into a finite set of the control volumes, which are termed meshes and cells. The main issues in this process is how to specify the concrete data specification. The researcher used a previous experimental work to solve this problem. The concrete component taken from experimental data and the same data used to validate the developed model. Also, the heat effect exposed into the concrete slab model to investigate the concrete change in properties and the shape effect of the heat in the model response. After that the solver will prepare the general conservation equations. All the dimensions and unites taken as a metric unites in the simulation process. The partial differential equations are solved numerically to render the solution field based on structural analysis. The procedures utilized throughout this project as shown in the flow chart in Figure 3.1.

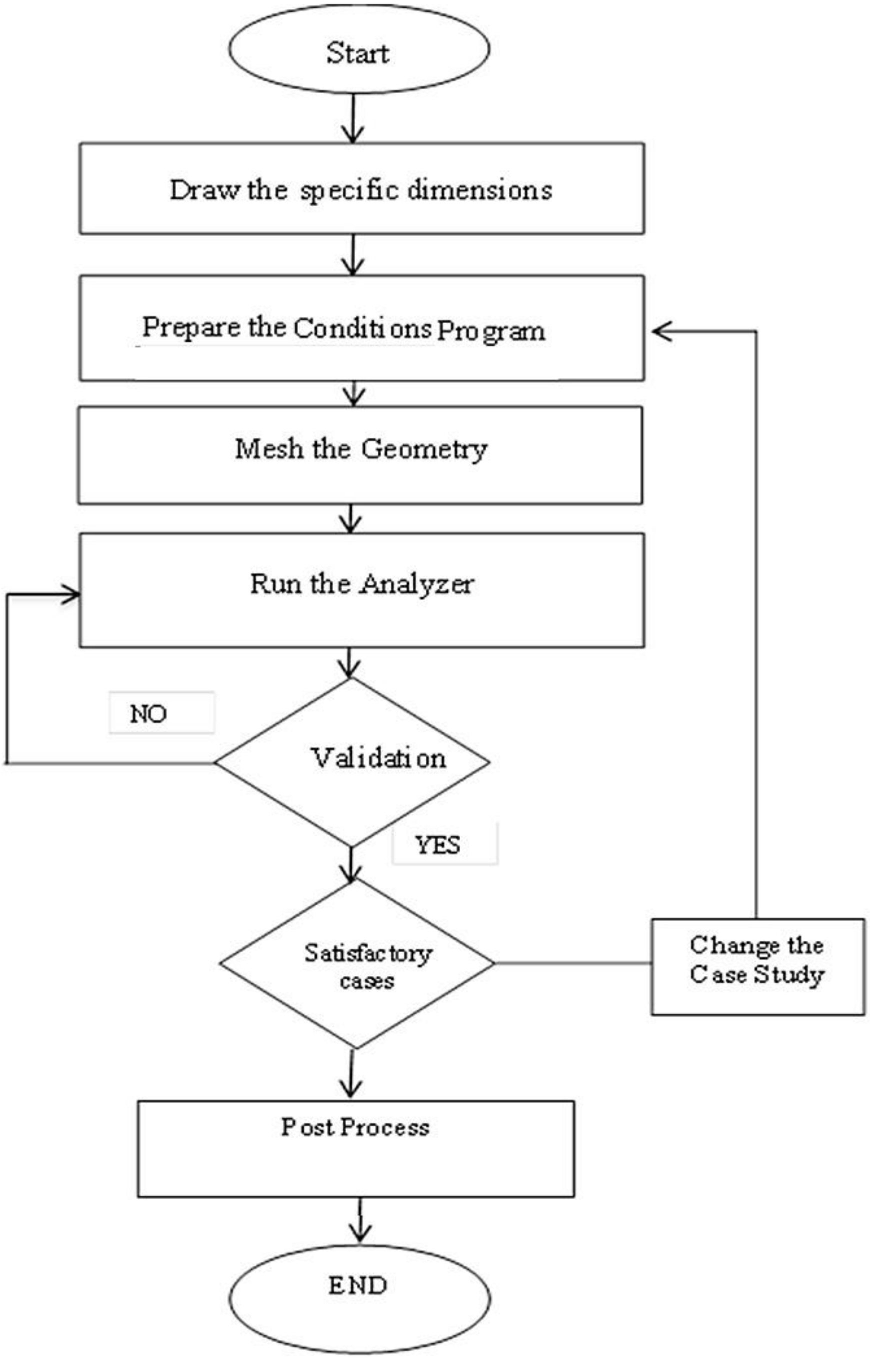


Figure 3.1: Flowchart of the Project

3.1 MODELLING IMPLEMENTATION

Modelling is a sample of the building construction and also presenting some system of concern. A model is comparable to the system it signifies but simpler than it. The most important aim of a modelling is to allow the analyst the prediction of the effects on the system by making changes. Model must be a near approximation to the actual system and combine maximum of its notable features, also the model must not be very complicated the way that it makes it difficult to understand and but it under experiment. The general modeling solution processes shown in Figure 3.2. The ANSYS modelling sequence could be classified into few major steps:

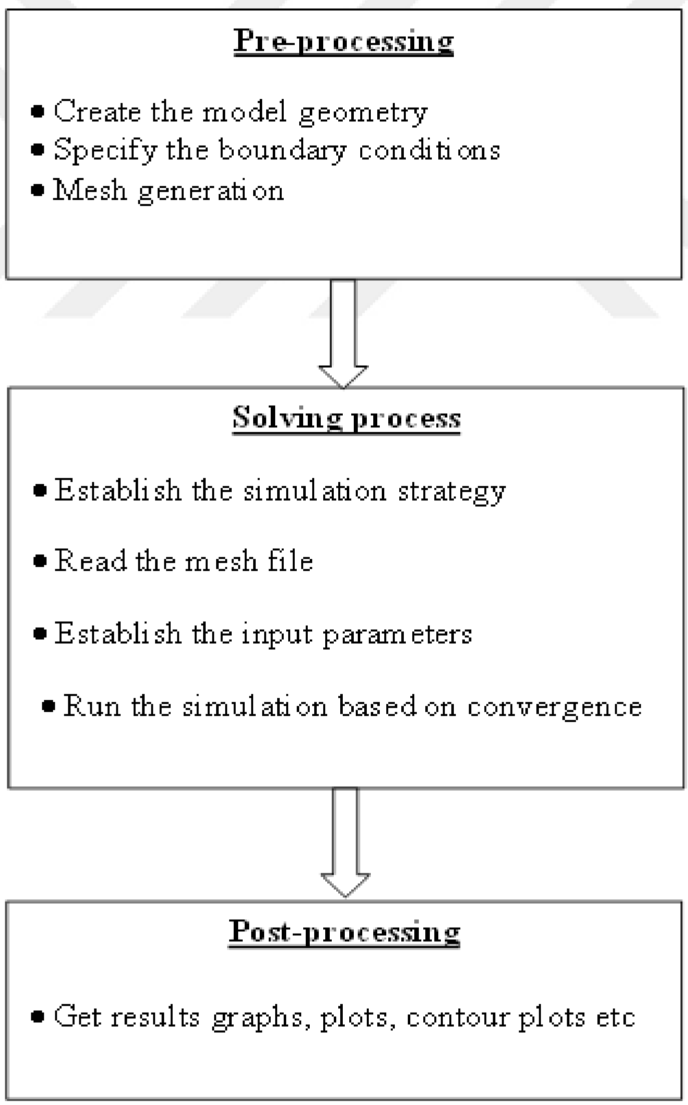


Figure 3.2: The ANSYS Modelling Sequence

A good model is a wise balance between practicality and ease. The the commercial software which is used to solve structural problems can be expressed by ANSYS. Based on the present procedure, the present work will be implemented as in the next sections.

3.2 PRE-PROCESS IN THE ANSYS ENVIRONMENT

The procedure of parameters identification of the selected material model from ANSYS file was carried out in the ANSYS setting via numerical calculation of the database of the model. Initial data of materials parameters represents the basis for the optimization or the evaluation process. The required for initial studies depend on the constraints and goals of study. The first role in initial study is all studies referenced in defining constraints and goals must belong to the same configuration. The phases considered below:

3.2.1 Specify Geometric Data Specification

The first stage to investigate the slab model involves specifying the concrete and other components characteristics. It's an important part of simulation procedure to gain accurate results of the model behavior. The following steps present the ANSYS procedure:

Step 1: Define element types

In this step, there are many options that contribute to build the model, where the three-dimensional model is considered, which may consist of one or more materials (in this study the sample was considered to consist of three different materials, which will be tested on the basis of changing the specifications of one of the three materials), be Evaluate the inputs on the basis that the concrete mixture consists of specific proportions of sand, gravel and cement. And the added glass fibers are of specific properties and according to variable proportions and quantities for the purpose of studying the effect of the change in those quantities on the behavior of the material. The selected model is made of three vectors, and the change in the effect of forces on the model used in these three vectors as a directional base.

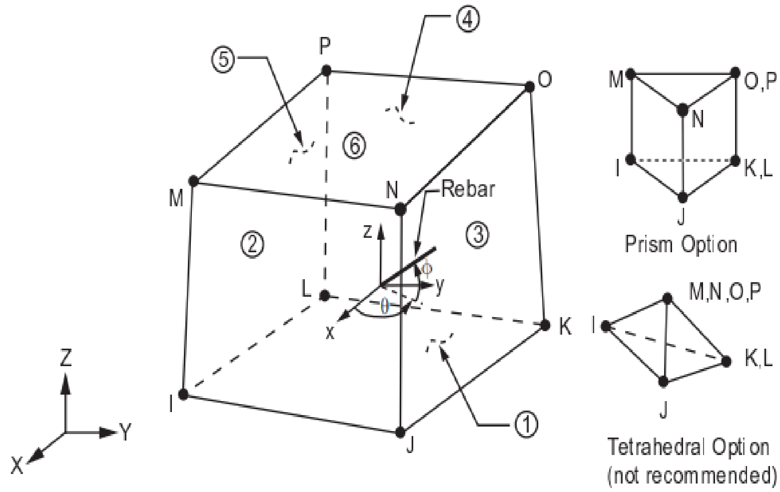


Figure 3.3: solid input representation in ANSYS

The additional concrete data and technical specifications such as shear transmission coefficients, tensile stress, and compressive values are entered as indicated in the table 3.1 for solid concrete materials.

Table 3.1: SOLID Concrete Material options

Constant	Meaning
1	Shear transfer coefficients for an open crack.
2	Shear transfer coefficients for a closed crack.
3	Uniaxial tensile cracking stress.
4	Uniaxial crushing stress (positive).
5	Biaxial crushing stress (positive).
6	Ambient hydrostatic stress state for use with constants 7 and 8.
7	Biaxial crushing stress (positive) under the ambient hydrostatic stress state (constant 6).
8	Uniaxial crushing stress (positive) under the ambient hydrostatic stress state (constant 6).
9	Stiffness multiplier for cracked tensile condition, used if KEYOPT(7) = 1 (defaults to 0.6).

The ANSYS configuration of practical model implementation is shown in Figure 3.4.

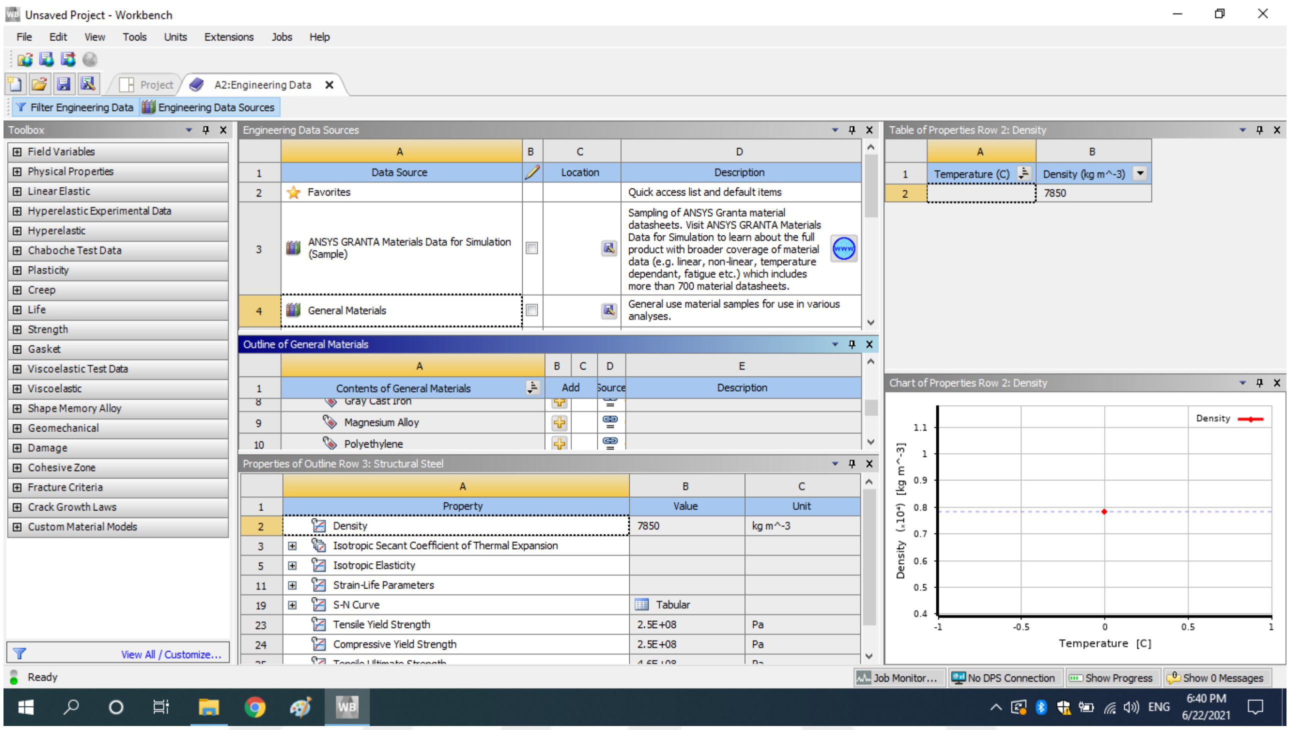


Figure 3.4: Configuration of elements type definition

Step 2: specify the material characteristics

The used material characteristics in the model is inserted through a sequence of operations in ANSYS program. The inserted data can be specified from the model geometry that connect with the system, then insert the data specification of material as shown in figure 3.5. To enhance the analysis of the structure, the ANSYS program can be enhanced with all the information about the specifications of concrete, rebar and other added materials by insert process to the model as shown in the figure. This method is suitable to insert the value of the added fiber and its properties, and thus studying its response under the influence of different loads and different temperatures. Three types of material have been used in this model, the first material is the concrete, the second is the steel bars which is used to reinforce the concrete, and finally the steel fiber which is used in different percentages with the concrete mixture.

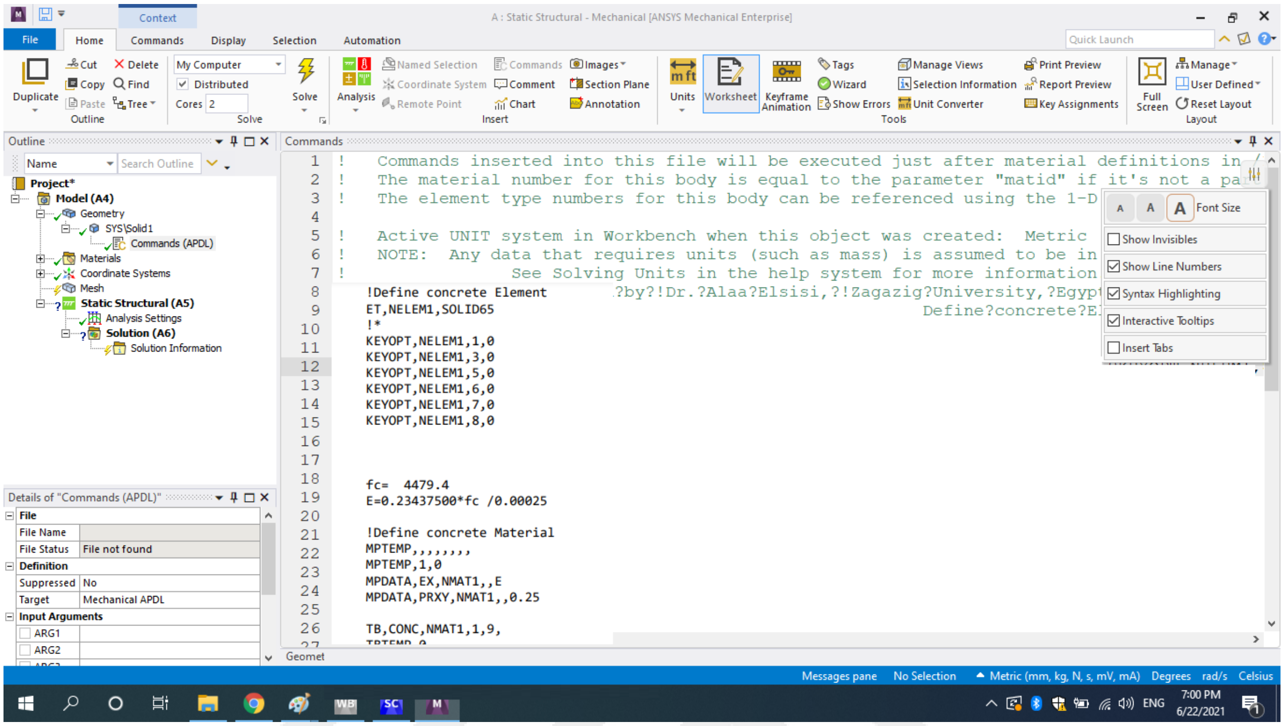


Figure 3.5: Initiate data specification

Step 3: Independent material properties

Building material model and specifying the material properties is a major step in studying the model. The independent properties of the used material presented in tables 3.2 to 3.4. the tables show the typical properties of normal strength steel fiber materials and they present the typical properties of normal strength Portland cement concrete:

Table 3.2: Steel fiber properties [41]

Type	Geometry	Density kg/m^3	l_f mm	D_f mm	l_f/D_f	Tensile strength MPa
KMX 55/30 BG	Hooked-ends	7850	30	0.55	55	1500

Table 3.3: Cement Properties [44]

	Property	Cement	Perlite
Physical properties	Initial setting time (minutes)	170	--
	Final setting time (minutes)	225	--
	Specific gravity	3.10	2.38
	Blaine specific surface area (m^2/kg)	340	500
	28-day compressive strength (MPa)	42.5	--
Chemical properties, basic oxides (%)	CaO	63.40	1.42
	S_iO_2	21.60	71.73
	Al_2O_3	4.45	13.43
	SO_3	1.92	0.01
	Fe_2O_3	5.35	1.4
	MgO	1.65	0.42
	Na_2O	0.11	3.12
	K_2O	0.22	4.33
	LOI	0.78	3.66

A. Steel bars of steel reinforcement with 5.3 mm in diameter. the typical properties of normal steel bar materials.

Table 3.4: Steel bars of steel reinforcement properties

parameters	Bar samples		
	EC	ASTM A706	BS4449
Yield strength S, (N/mm^2)	460.14	415	460
Ultimate tensile strength, (N/mm^2)	597.21	580	600
Elongation, (%)	9.02	10	12
Reduction in area, (%)	22.15	---	----

According to earlier researches and studies fibers are more active with a mixture with total mix percentage as shown in the Table 3.5.

Table 3.5: Mix design

Mix code	V_f %	Cement (kg)	Sand (kg)	Gravel (kg)	Steel fiber (kg)
1	0	10.5	26.5	17	0.0
2	0.75	10.5	26.5	17	1.3
3	1	10.5	26.5	17	1.75
4	1.25	10.5	26.5	17	2.2

Step 4: Specify material models

The regulation of the material model was done through an automatic batch; it was likely to do the entire calculation using this way. A benefit of this process was the ease of calling an external script for the assessment of the resemblance between the original data and the calculated results.

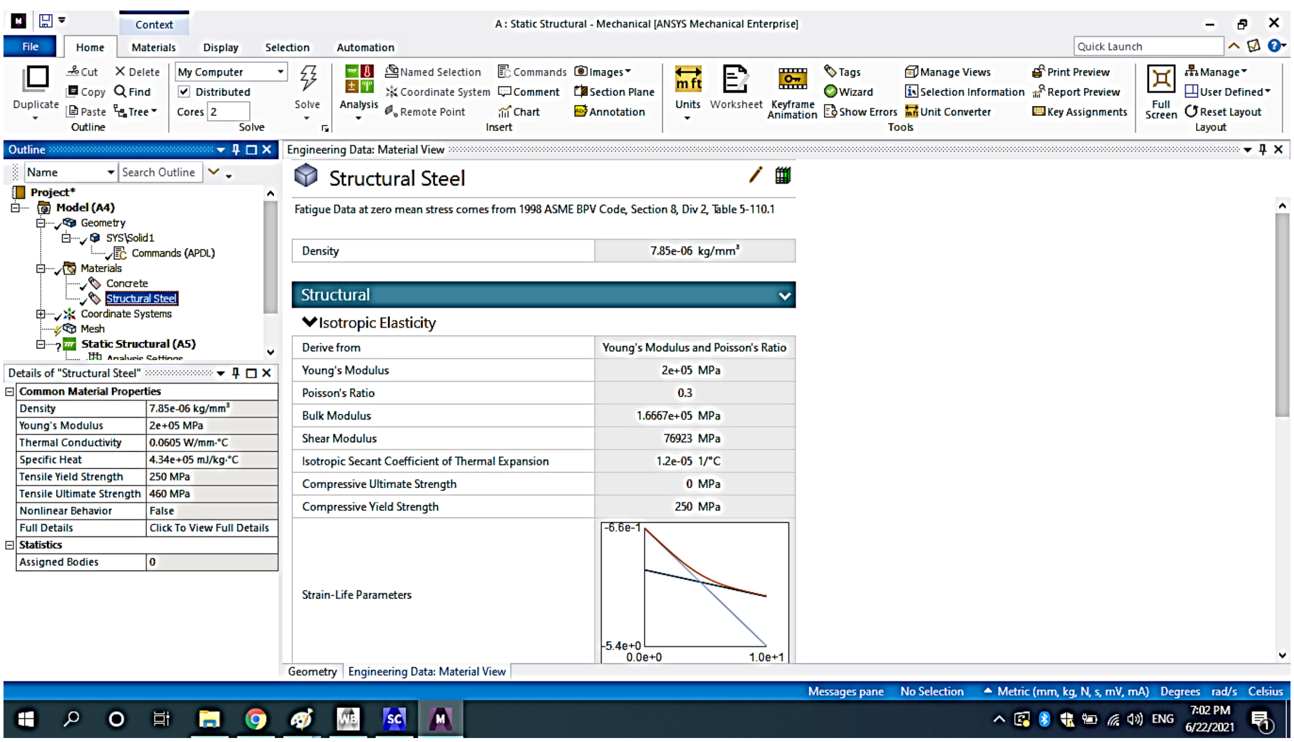


Figure 3.6: material constitutive options

A wide range of material constitutive possibilities (like anisotropic hyper elasticity, shape memory alloy, re-dependent plasticity. Hyper elasticity, plasticity and viscoelasticity) etc. The programmed set therefore completed the gathering of the geometry of the computational model, the meaning of the material model, the launch of the nonlinear calculations, and the calling of the external script which allowed the calculation of the objective function value. Steel bars of steel reinforcement modeling approach were introduced for linear isotropic model with 2x105 MPa and poison ratio of 0.3 and nonlinear inelastic with yield stress preliminary values 1581. The models have an integral form based on classical linear viscoelastic cases and nonlinearity was incorporated by linear interpolation of the material parameters with respect to stress. The viscoelastic model generated corresponds to the traditional rheological linear viscoelastic modeling approach. Figures 3.6 and 3.7 show the modeling processes.

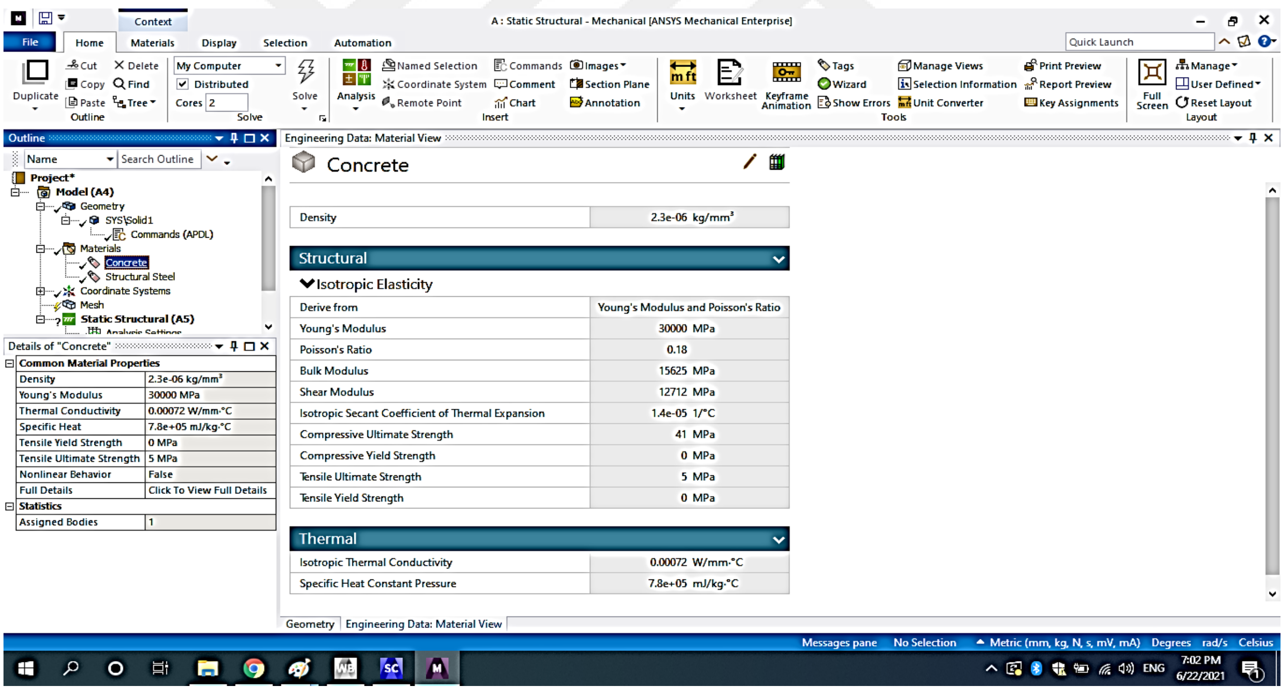
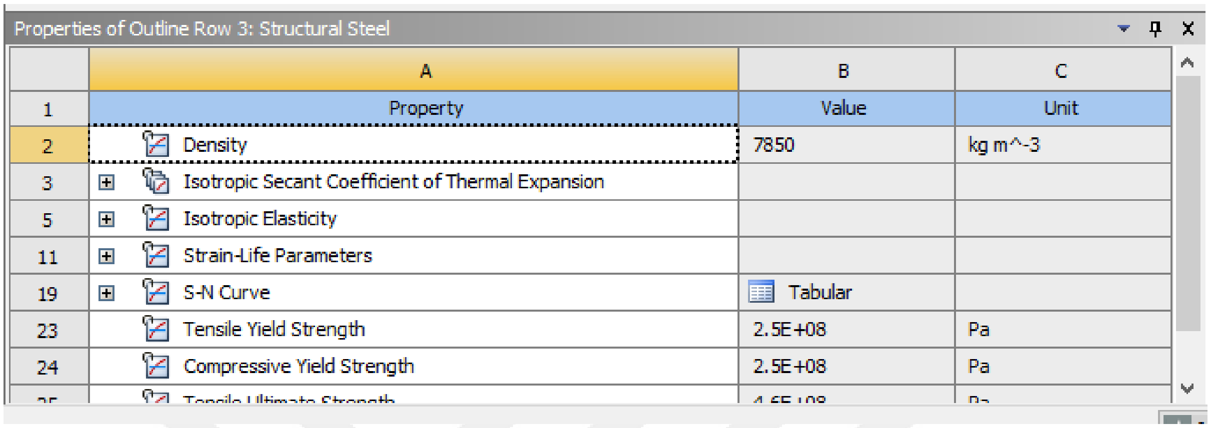


Figure 3.7: Initialize concrete material parameters

For concrete material, a modeling approach was introduced for elastic isotropic model with elastic isotropic preliminary values of 29700 MPa and poison ratio of 0.2 and multi-linear strain preliminary values from 0.0001 to 0.003 and stress values from 38.8 to 50 as shown in Figure 3.8. Then the density of concrete will be transferred throw the model with the preliminary values of 2400 kg/m3 as shown in Figure 3.8.


Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Density	7850	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
5	Isotropic Elasticity		
11	Strain-Life Parameters		
19	S-N Curve	Tabular	
23	Tensile Yield Strength	2.5E+08	Pa
24	Compressive Yield Strength	2.5E+08	Pa

Figure 3.8: Density initialization

The other concrete features will be fixed in the integrated with non-metal plasticity and the preliminary values presented in Table 3.6

Table 3.6: Non-metal plasticity initialization

a.	Parameter	b.	value
c.	Open shear transfer coefficient	d.	0.2
e.	Close shear transfer coefficient	f.	0.8
g.	Uniaxial cracking stress MPa	h.	4
i.	Uniaxial crushing stress MPa	j.	50

Based on the inserted data, the geometrical shape must be developed using the dimensions mentioned in previous studies.

Step 5: Developing slab geometry:

Model generation will present the process of defining the geometric configuration of the model's nodes and elements. ANSYS has two essential features to build geometry; they are; Nodes, which can be defined as a coordinate location in a field where the Degrees of Freedom (DOF) are described. The

DOFs for the point shows the possible movement of this point due to the loading of the structure. The DOFs also represent which forces and moments are moved from one element to the next. The second feature is the elements which can be defined as the primitive building block of finite element analysis. It is a mathematical relation that defines how the degree of freedom of node is related to the next node. There are several basic types of elements. These elements can be lines (trusses or beams), areas (2-D or 3-D plates) or solids (bricks or tetrahedral). Different element types are chosen based on the type of analysis which is going to be performed. The ANSYS program involves the following approaches to model generation:

A. Start with planning the slab dimensions and reinforcement type and steel bars position.

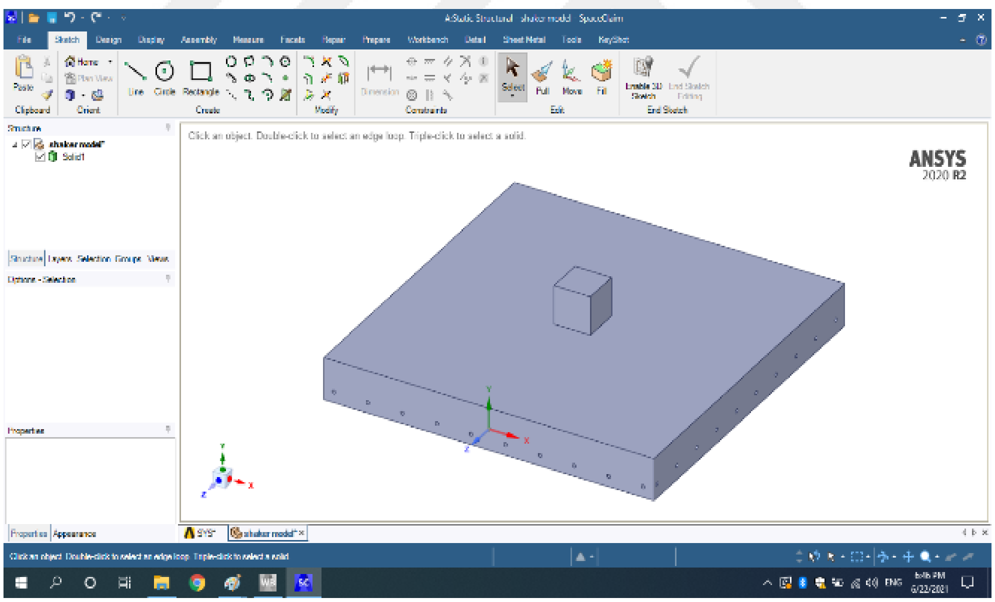


Figure 3.9: Drawing Geometry Shape

B. Enter the file to initiate the model-building session based on solid modeling procedures.
C. Generate solid model from the modeling code, than create the slab block by dimensions as shown in Figure 3.10.

By using the basic tools of drawing which plane is used to sketch the profile, the proper views are easily generated on the detail drawing. Every geometry cell has a list of imported favorites. These favorites must give an impression in the properties pane when enabling the property viewing in the project schematic. When a geometry cell is created, it must inherit its early settings from the favorites correlated with the geometry segment. The imported preferences listed for that cell in the belongings opinion will be used once importing the geometry into an editor. Display in working plane operators the offsets to create reinforces steel bars. The result of drawing step is the geometric shape of slab plane as shown in Figures 3.10 and 3.11.

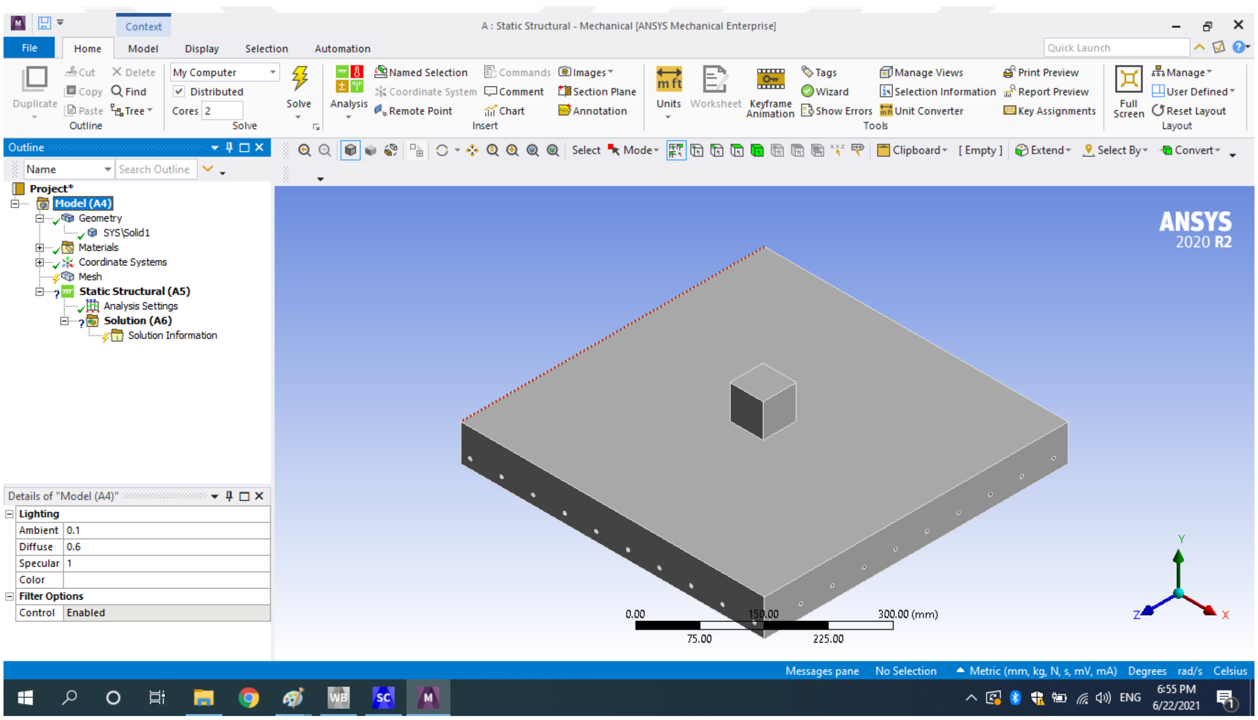


Figure 3.10: Slab plane drawing result

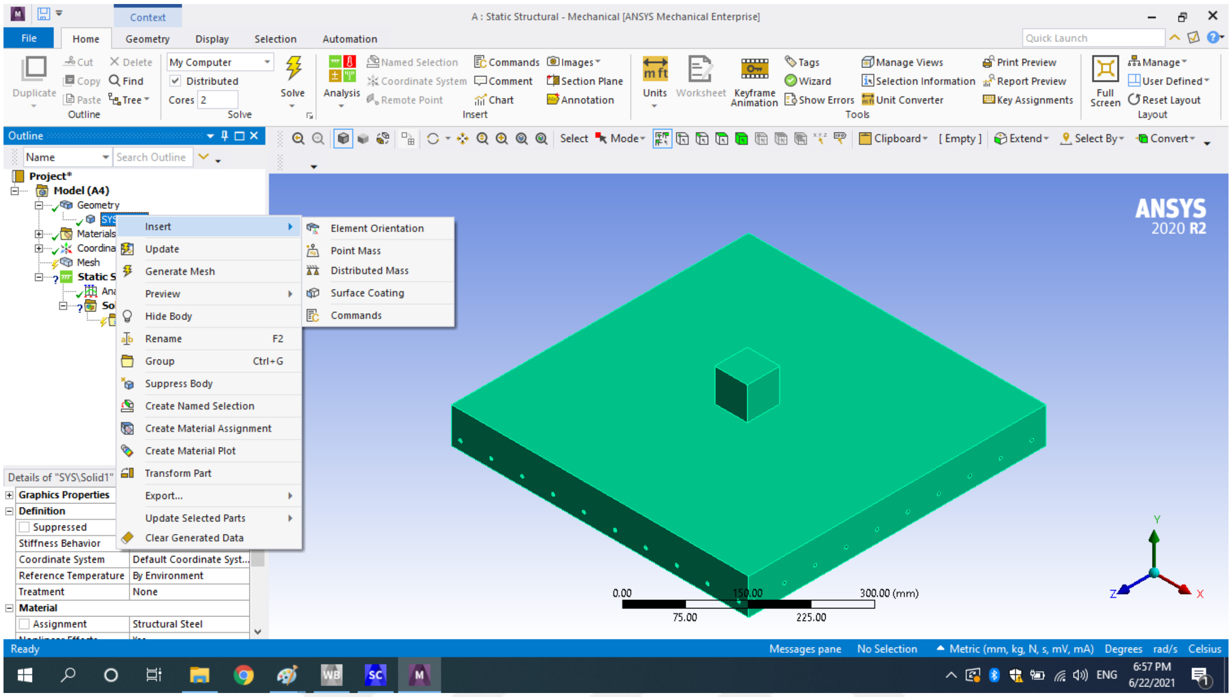


Figure 3.11: Slab plane reinforcement result

After that, the process of mashing the geometry will apply to create the nodes and elements inside the slab plane in order to discrete the geometry and find the force effects.

Step 6: Meshing process

The next step is to mesh the geometry. In order to generate a computational mesh throughout the slab volume, it must be use the ANSYS Meshing application to create a mesh for the structural analysis. The procedure for generating a mesh of nodes and elements should process of setting the element qualities and setting Mesh controls. ANSYS presents a lot of mesh controls. The ANSYS Mesh Tool (Main Menu> Preprocessor> Meshing> Mesh Tool) provides a convenient path to many of the most common mesh controls, as well as to the most frequently performed meshing operations. The Mesh Tool is an interactive "tool box," due to opening the operation until, either close it or exit PREP7. While all of the functions available through the Mesh Tool are also existing through the traditional

ANSYS orders and menus, via the Mesh Tool is a beneficial shortcut. The numerous functions offered through the Mesh Tool contain:

D. Control the Mesh size
E. Specify mesh type
F. Specify element shape
G. Reining the mesh

The 3-D mesh elements can be of two types namely Triangular and Quadrilateral. Use of triangular element creates an unstructured mesh whereas; the use of a quadrilateral element creates a structured mesh. To create a mesh, either the element count (number of elements) or the element size can be specified. The size functions allow us to control the size of mesh-element edges for the geometric edges and for faces or volumes that are meshed. Meshing results propose a discretization of the case study. It is the most important part of an analysis and can determined the efficiency and effectiveness of an analysis because it gives the finite elements analysis. Therefore, a lot of time is given to meshing of complex models. In our case study, the mesh result can be shown in Figure 3.14.

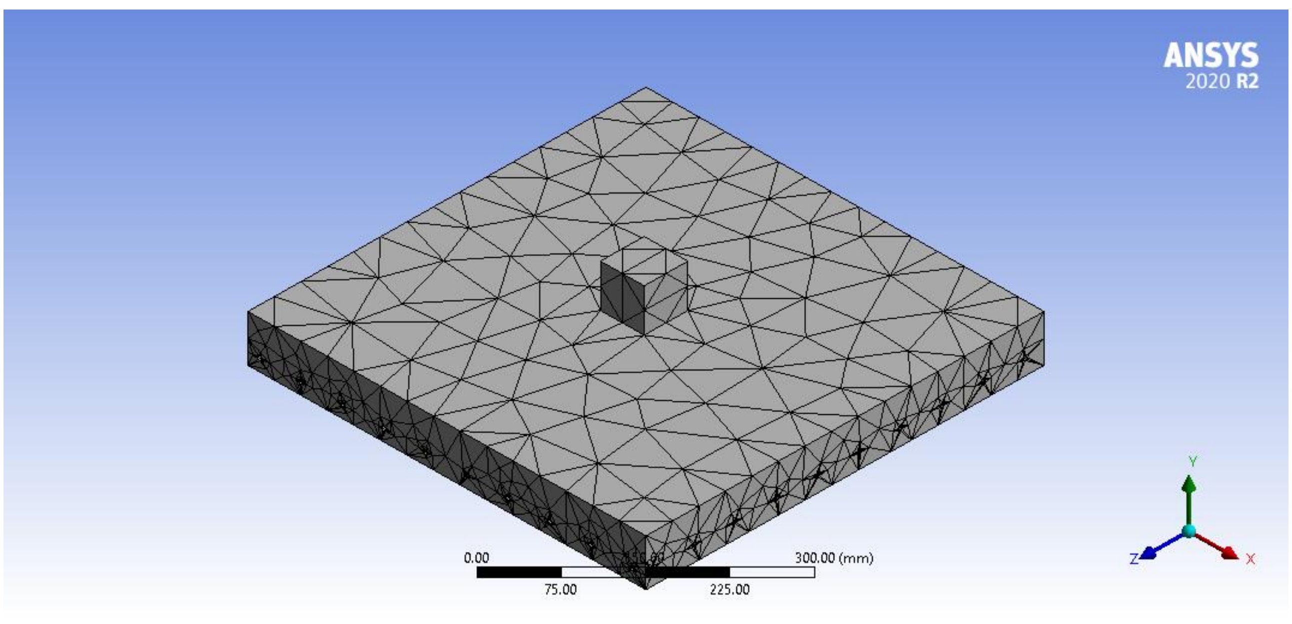


Figure 3.12: Mesh File configuration

Its observe that the boundary layer contain a multi types of discretization which is enable us to analyses the boundary layer in more specific detail to get a higher accuracy results. The meshing complexity measures the degree of difficulty Faced in meshing the geometry. Numerous aspects are recognized to make mesh generation challenging including near-tangencies, topology arrangement, etc. Meshing complexity includes the translation of these complications into a metric that quantifies them. For instance, there is much geometry that has highly geometrically complex curves and surfaces on the other hand is meshed trivially. It can be enhance the Mesh size as shown in figure 3.13

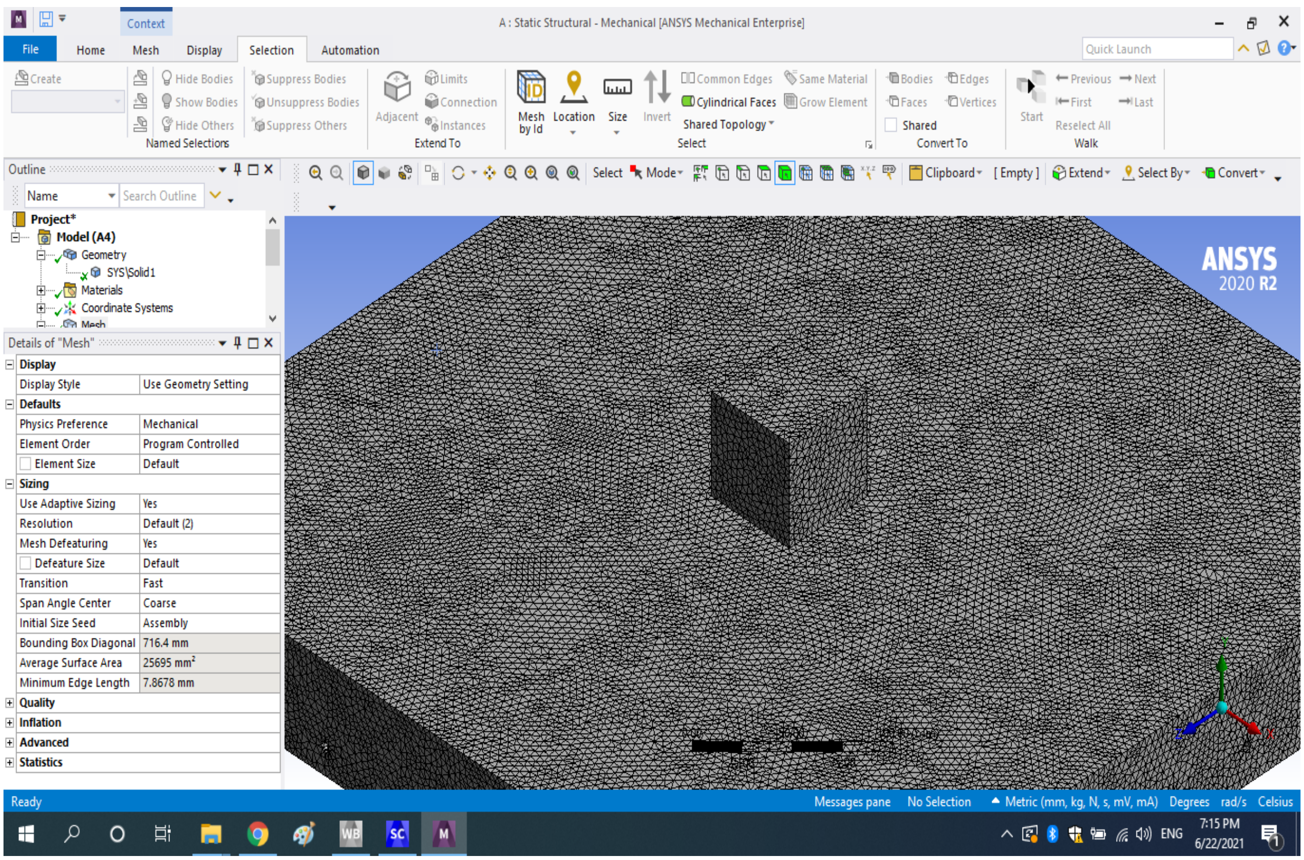


Figure 3.13: Enhance Mesh size

Similarly, it can be easily build a model by employing linear curves and planar surfaces that is almost impossible to mesh. For that the metric can be used to identify invalid as well as potential poor quality elements, which may cause larger solution. The standard ANSYS mesh quality presents that (0.5 to

0.8) can be considered as a good result based on skewness statues, and the researcher achieve (0.79) mesh quality.

Step 7: Define the applied loads

The process of applying the loads on the model is one of the most important process in building the simulation, as the value, type, location and direction of the load are essential in studying the behavior of the model response. It is possible in the ANSYS program to determine the type, quantity and locations of loads before or after the Mesh process. Because the loading process is filled with objects that have physical properties, such as specific densities. In the model for this study, the place of loading was determined in the middle of the model and according to the actual model that was adopted. the forces will be distributed on the elements and nodes of the Mesh in the body and thus transfer the effect of the forces to those elements by a series of calculations based on the infinite elements of the body to find the effect of the load on both sides of the sample. On the other hand, the effect of temperature is included in the calculations, which causes changes in the model's response based on the load. It is possible to change the load value and the temperature value in each test to obtain the results. The results values can be stored in form of Excel tables to use them by studying the behavior of the examined model. It is also possible to obtain images of each test to see the method of change and its values on the model visually. Figure 3.14. shows the instructions for this stage. It is seen that the static structural options can be provide an inset choices based on thermal conditions and static load conditions. Also, it is seen that the options contain the type of support are fixed correlated with the type of used materials. The variations in this work represent a different type of loads and different temperature subjected to the concrete body.

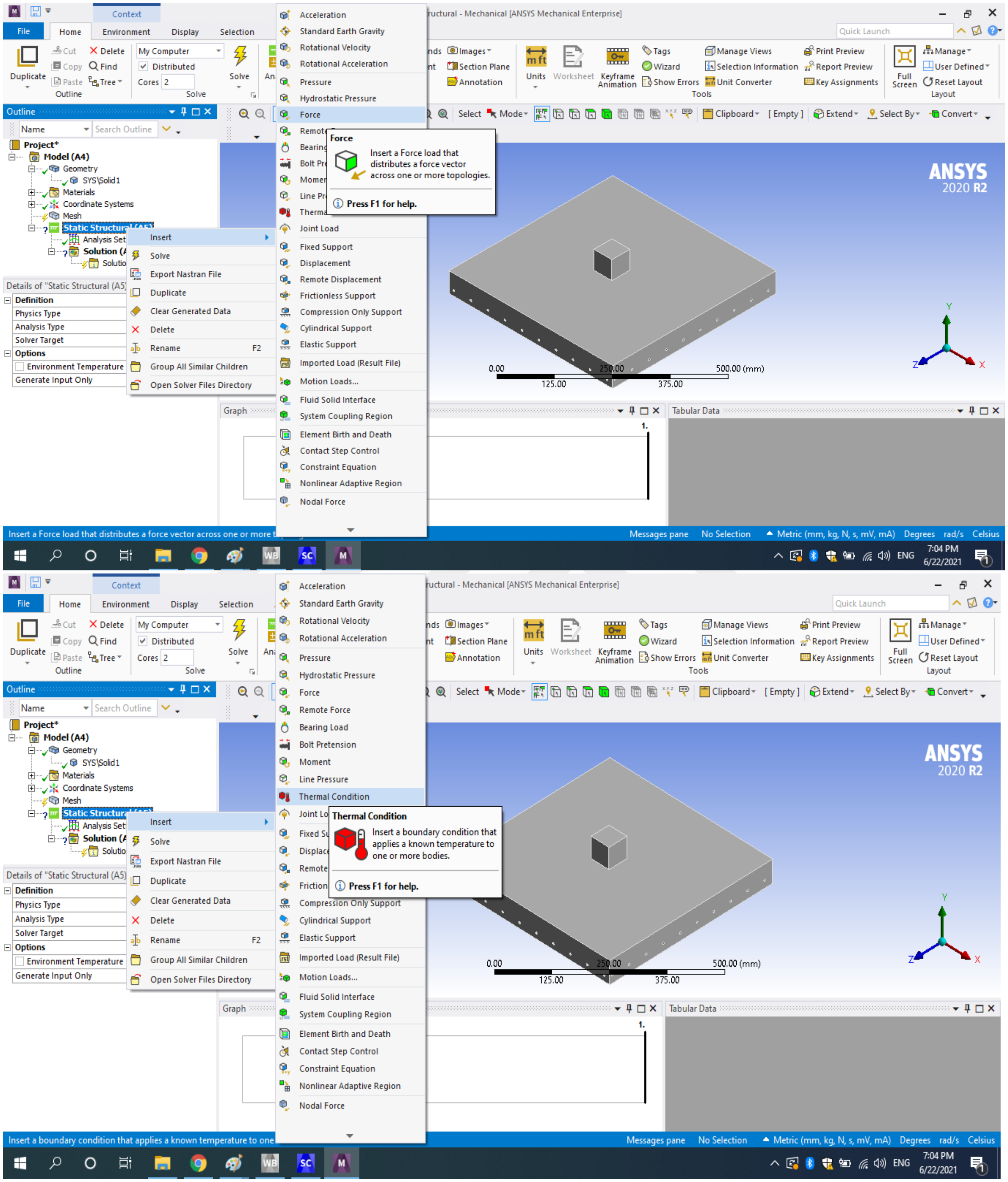


Figure 3.14: applied load and temperature on slab elements

3.3 SOLVING PROCESS

Solid model loads would be transported to the finite element model automatically when applying the resolution calculations. SOLVE orders involves (Main Menu> Solution> Solve> Current LS)) as shown in Figure 3.15. After preprocessing, the model generation, including meshing is complete. The ANSYS presents the solution phase. ANSYS allows selecting certain options during the solution phase. They are specified through either Analysis Options or Solution Controls. Users can use orders to map stresses from ANSYS model to examine the mapped stress values in the receiving model. It can make all degrees of freedom in the receiving model, remove any other loads, and solve. If the material properties are linear, the mapped stress values must be existing to list and plot as results over the model.

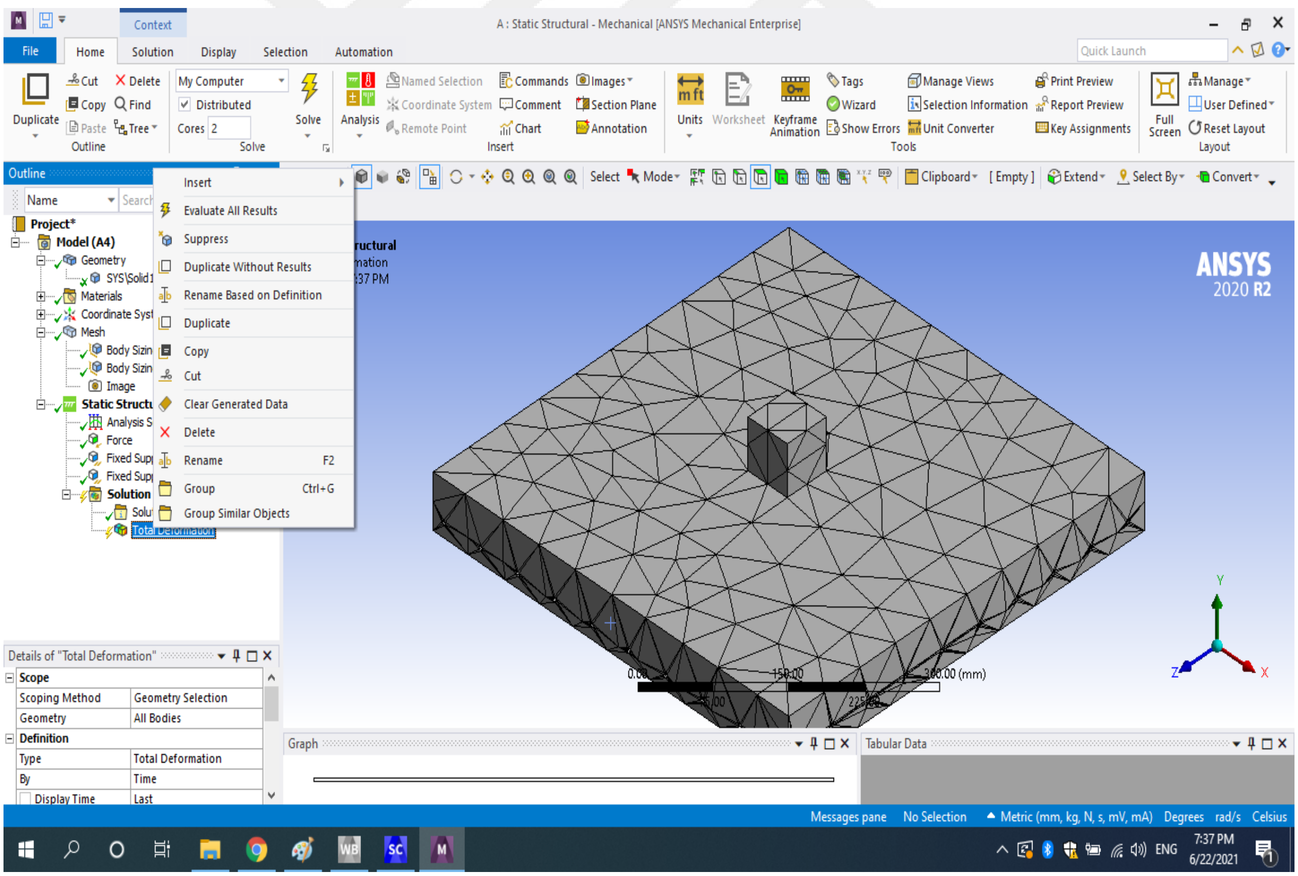


Figure 3.15: Deformation command in ANSYS SOLVER

4. RESULTS AND DISCUSSION

This chapter is intended to present the collected experimental load and displacement based on different types of steel fiber correlated with heating exposure effect. In this study, the experimental work using a model of SFRC panels was carried out to study the two-way panels of SFRC under high temperature using ANSYS software. The experimental program can be described as follows: the main parameters are the volume fraction of steel fibers effect and the high temperature. Total of forty-eight simulation test are suggested for investigation; they were marked as groups: (G1, G2, G3, G4 and G5) in which each group contains one panel without steel fiber and three panels of different percentages of steel fiber panels, Group G1 was at ambient conditions and the other groups were subjected to heat exposure at a temperature (100, 200, and 300 °C), like follow in Table 4.1. The specimens are selected as a model with dimensions of 500 × 500 × 60 mm based on previous study presented by abu altemen et al, in 2017. The specimen design was supported with column steel plate of dimension 55 ×55 mm, this steel

Table 4.1: Study Groups.

Specimen	Steel fiber V_f (%)	Exposed Temperature °C
G1-1	0	Ambient condition
G1-2	0.75	
G1-3	1	
G1-4	1.25	
G2-1	0	100
G2-2	0.75	
G2-3	1	
G2-4	1.25	
G3-1	0	200
G3-2	0.75	
G3-3	1	
G3-4	1.25	
G4-1	0	300
G4-2	0.75	
G4-3	1	
G4-4	1.25	

plate was used as loading through, where the slabs are supported by special made support. The support mimic the actual slab and fixed in both sides reinforced orthogonally using ten bars of 5.3 mm diameter in each direction with an ultimate and yield strength of 400 MPa. These reinforcements were placed orthogonally at tension face as a single reinforcement layer with clear cover of 15 mm and equally spaced in each horizontal directions Sx = Sy = 46.6 mm center-to-center. The model drawn using Solid Work program and transferred to the ANSYS software program as shown in Figure 4.1 and Figure 4.2

Figure 4.1: Actual Casting mold (Altemen et al, 2017)

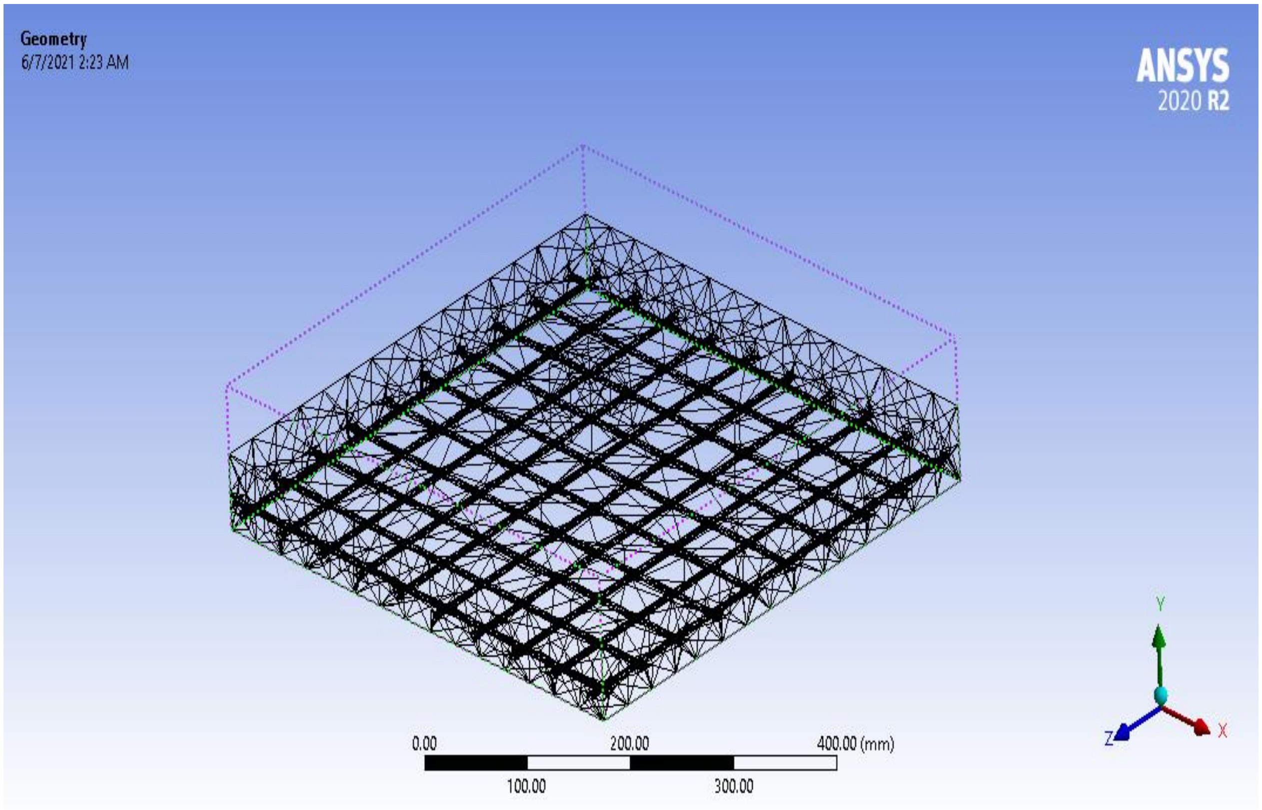


Figure 4.2: Simulation model

4.1 VERIFICATION AND VALIDATION

This section presents the validation and verification of the study. The two-way slab is simulated based on the test conditions of previous study. The obtained experimental data are used to validate the models in this study, also it is used to choose appropriate turbulence model with a correct model configuration and a suitable mesh strategy which can be generated and utilized on the boundary condition which we are interested in. By carrying out all those studies, the results observe the way to generate a correct model and also understand the concrete behavior based on selects slab model.

4.1.1 Model Validation

In order to ensure that the structural simulation model built in right conditions and will be solved in a good representation of reality, the validation technique used by comparing the results based on specific selected model.

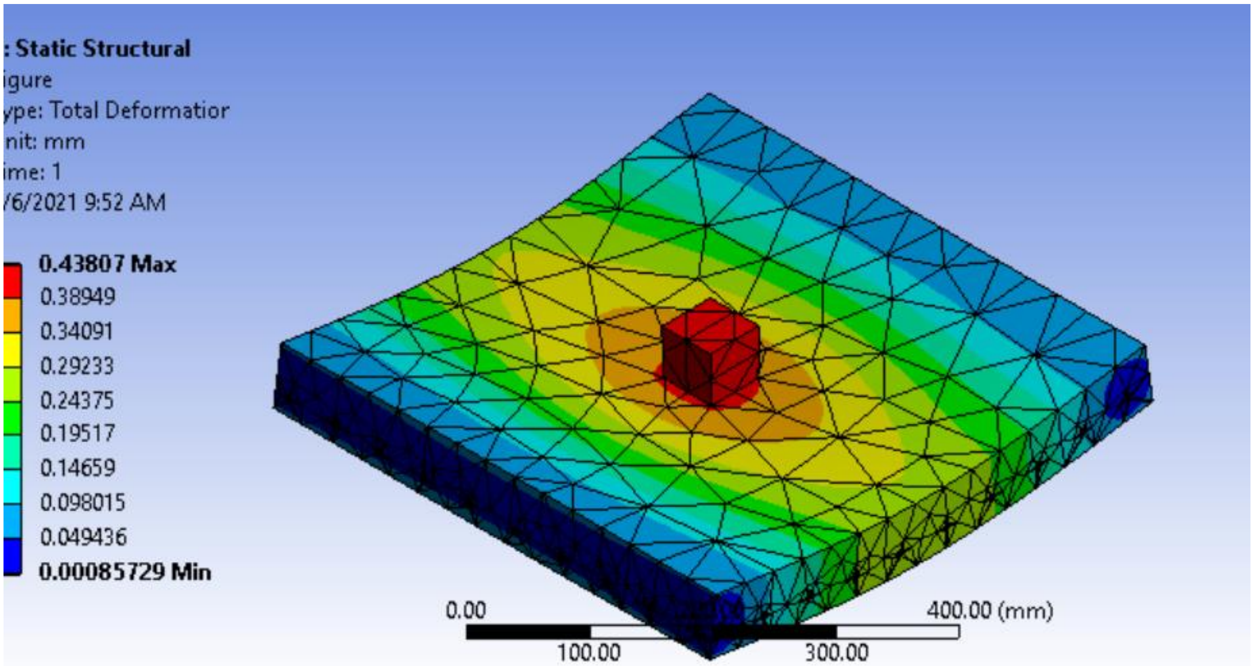


Figure 4.3: Static structure result for G1 group

The researcher uses the results of laboratory experiments which is developed by aAltemen et al, in 2017 as a validation model and the experimental results have been performed by applying the multi loads on the center of two-way slab in order to measure the deflection in the center of slab.

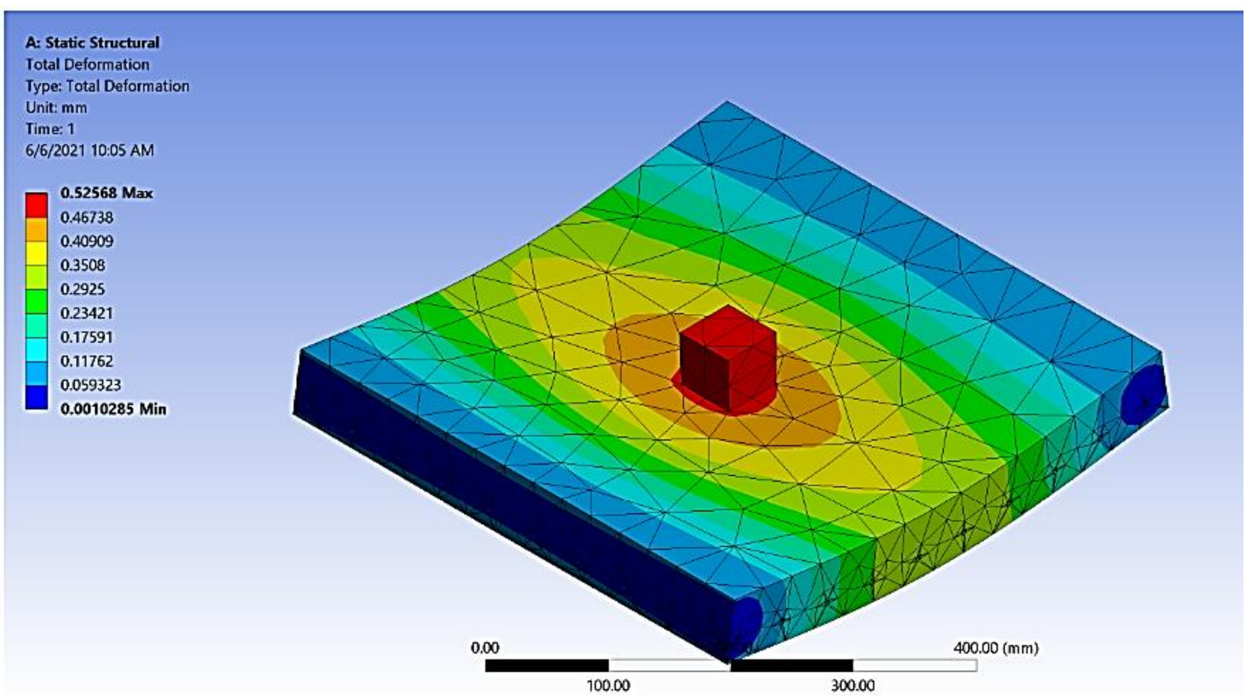


Figure 4.4: Static structure result for G1 group based on ambient temperature

The numerical results of are compared with Altemen et al, results based on room temperature condition.

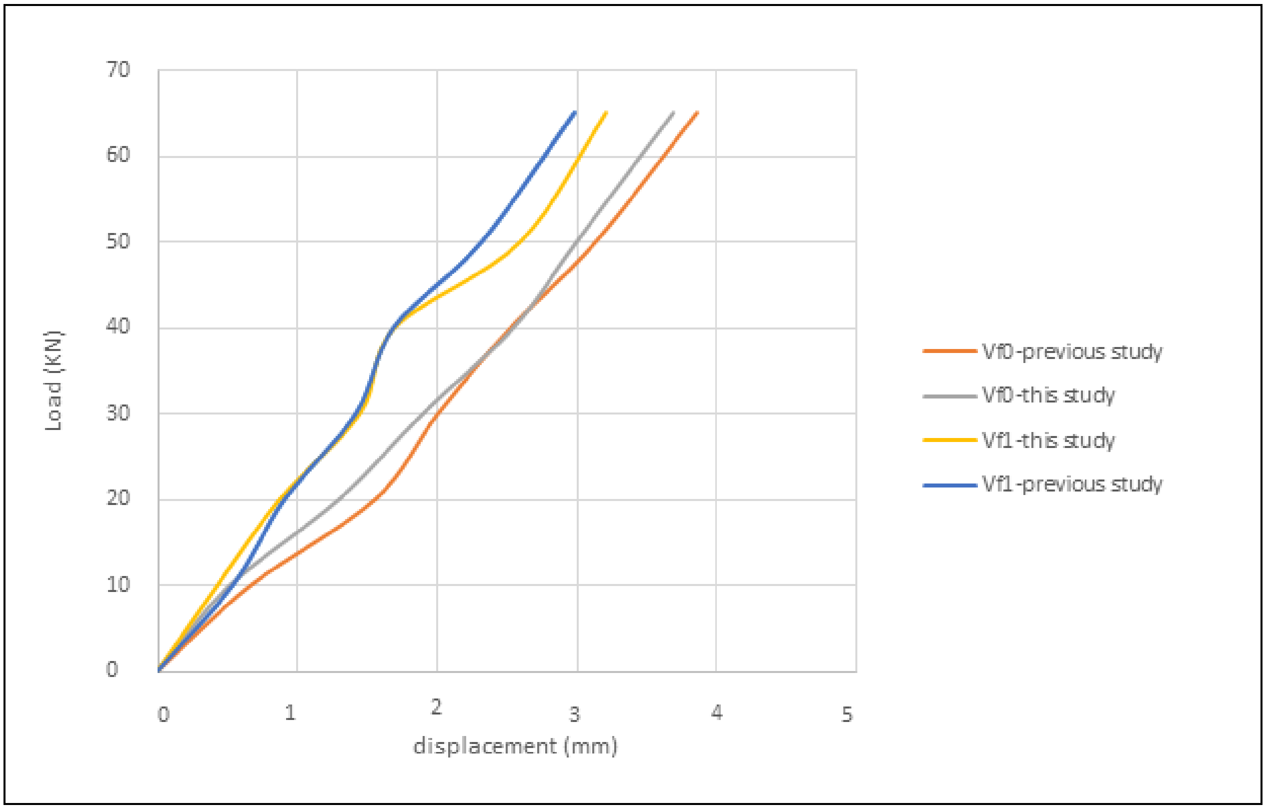


Figure 4.5: Plot the test results for both of Altemen et al, 2017with the present results.

The simulation results observe a comparison between independent data of laboratory numerical results and ANSYS tests based on the same conditions. The results show the variation in values in different force magnitude and different Steel fiber V_f percentages. It observes an increase in displacement values in all cases results which indicate that the model is valid. Investigation of Effect of steel fibre percentage is used as a one of the aims of present study. It is crucial step because it will provide a standard to measure the differences in behaviour between the different types of steel fibre percentage. The independent scenario to achieve this goal was by run the ANSYS solver based on 3D configuration of slab concrete shape using four deferent steel fibre percentage, they are $V_f = 0, V_f = 0.75, V_f = 1, V_f = 1.25$

4.2 EFFECT OF STEEL FIBRE DIFFERENCES BASED ON AMBIENT TEMPERATURE

The load-deflection curves were obtained from the centre position of the slab. The ANSYS system is used to measure the geometric changes of the slab, including deflection changes and failure shape under different temperature and load values.

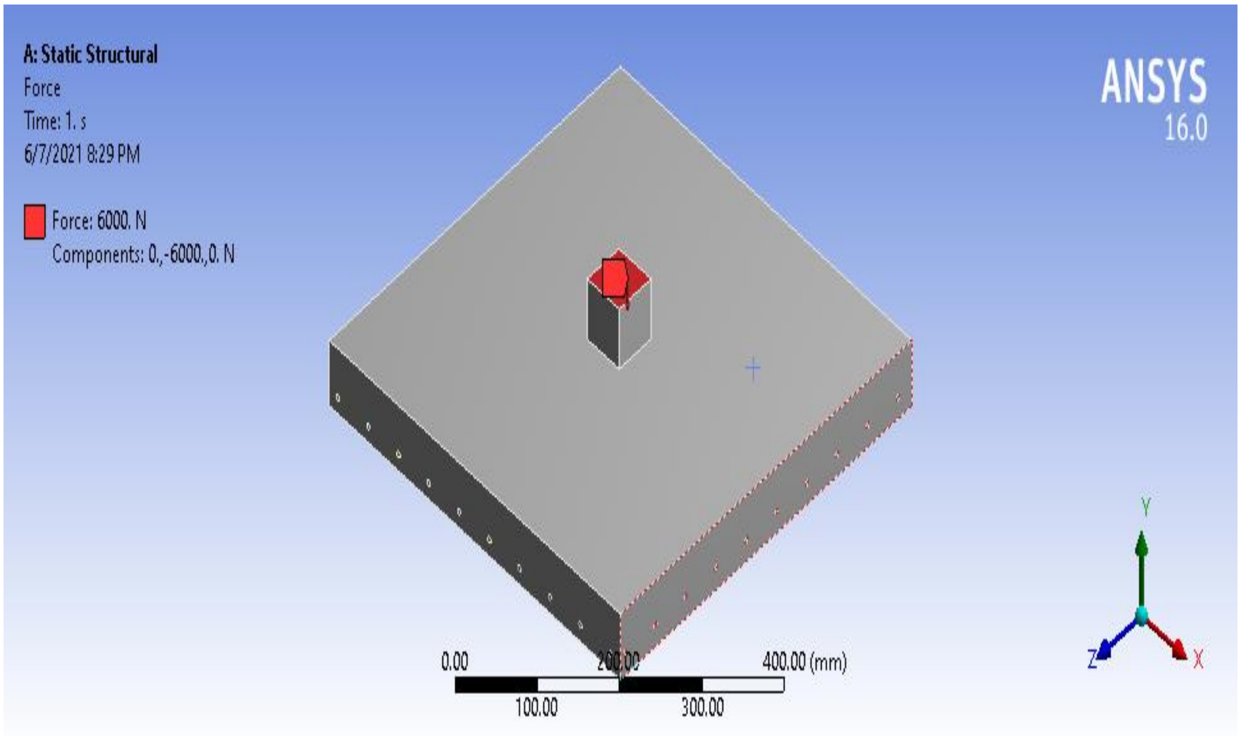


Figure 4.6: Location of the force.

These measurements can be correlated with the load and displacement data allowing visual observation to be related to the applied force and displacement. All the ANSYS figures provides a comparison of the force-displacement response for all tested slab models. The loading was carried out in different values (20 ,40, 60) KN. The results of steel-fiber reinforced concrete slab model is shown in the figures 4.7 to 4.10.

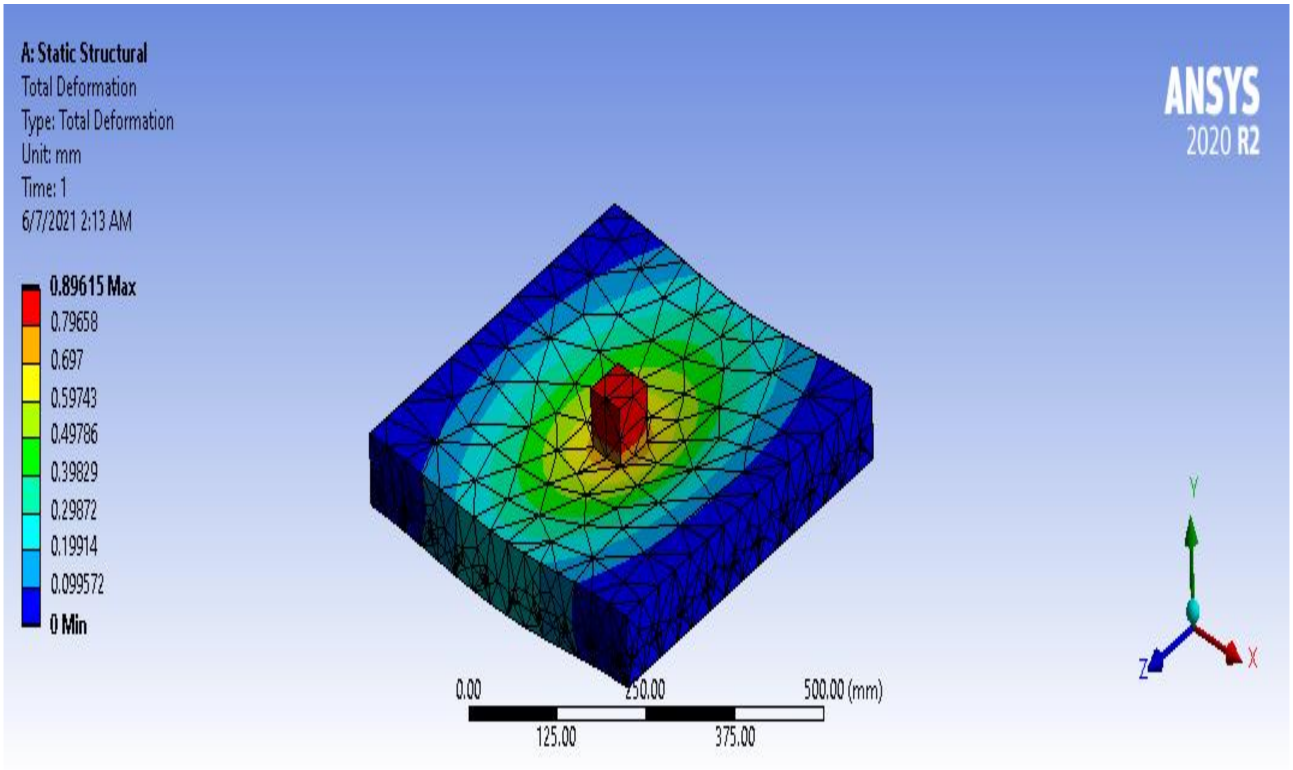


Figure 4.7: Results of G1 group, test 1

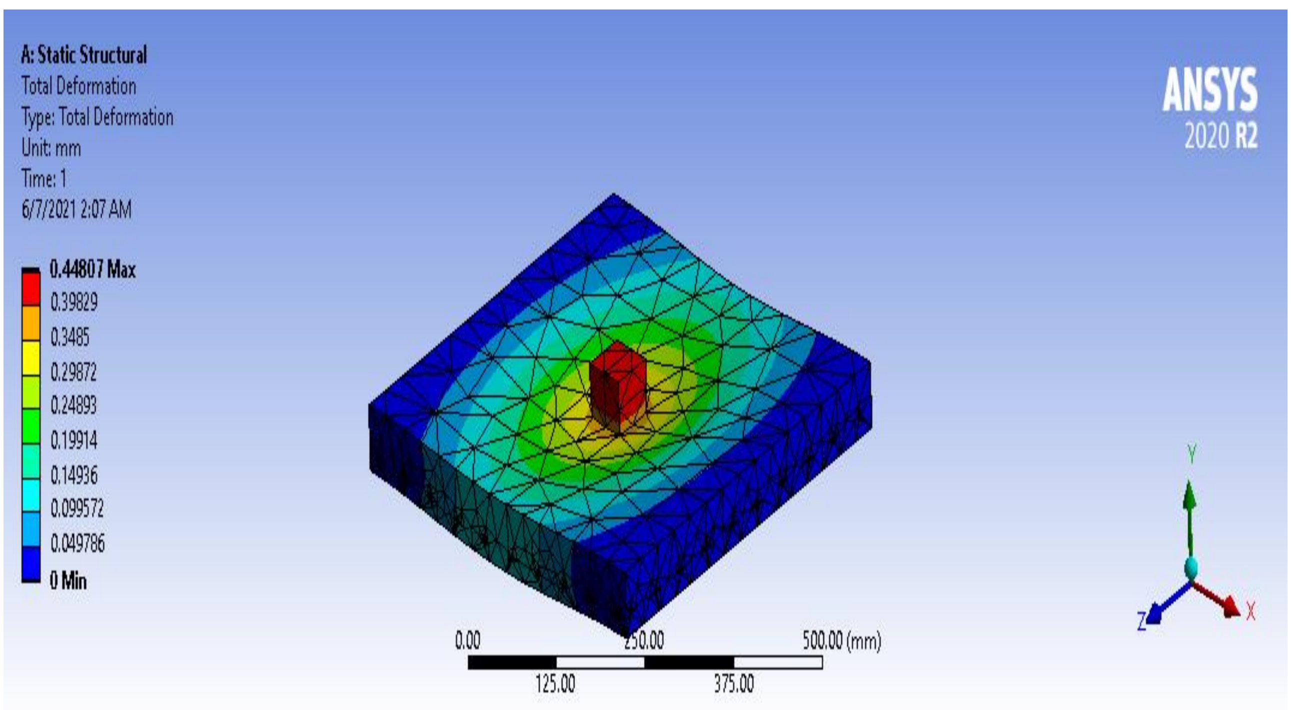


Figure 4.8: Results of G1 group, test 2

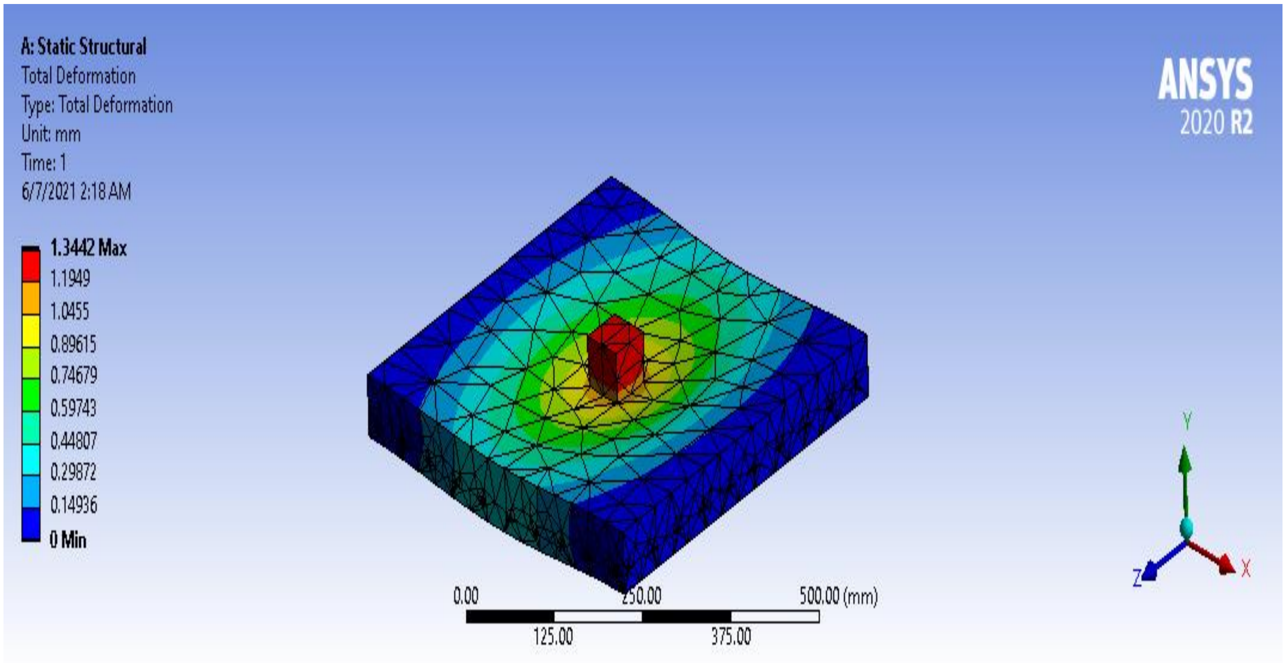


Figure 4.9: Results of G1 group, test 3

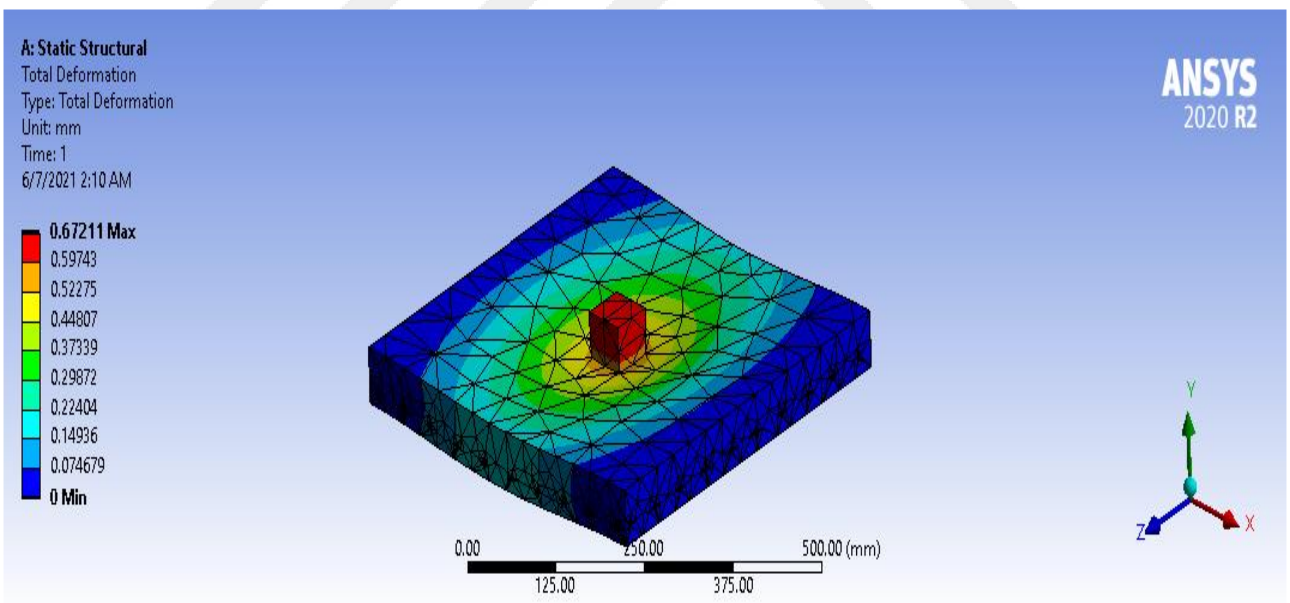


Figure 4.10: Results of G1 group, test 4

The results of Group G1 is the control group in ambient conditions, the deflection results can be seen in figure 4.7 to, Figure 4.10 which indicates that when the specimens at ambient conditions, increasing the steel fiber dosages by 0.75% leads to lower deflection values, then by increasing the steel fiber dosages by 1% or 1.25% the deflection remain nearly similar to the specimen without steel fiber for the center

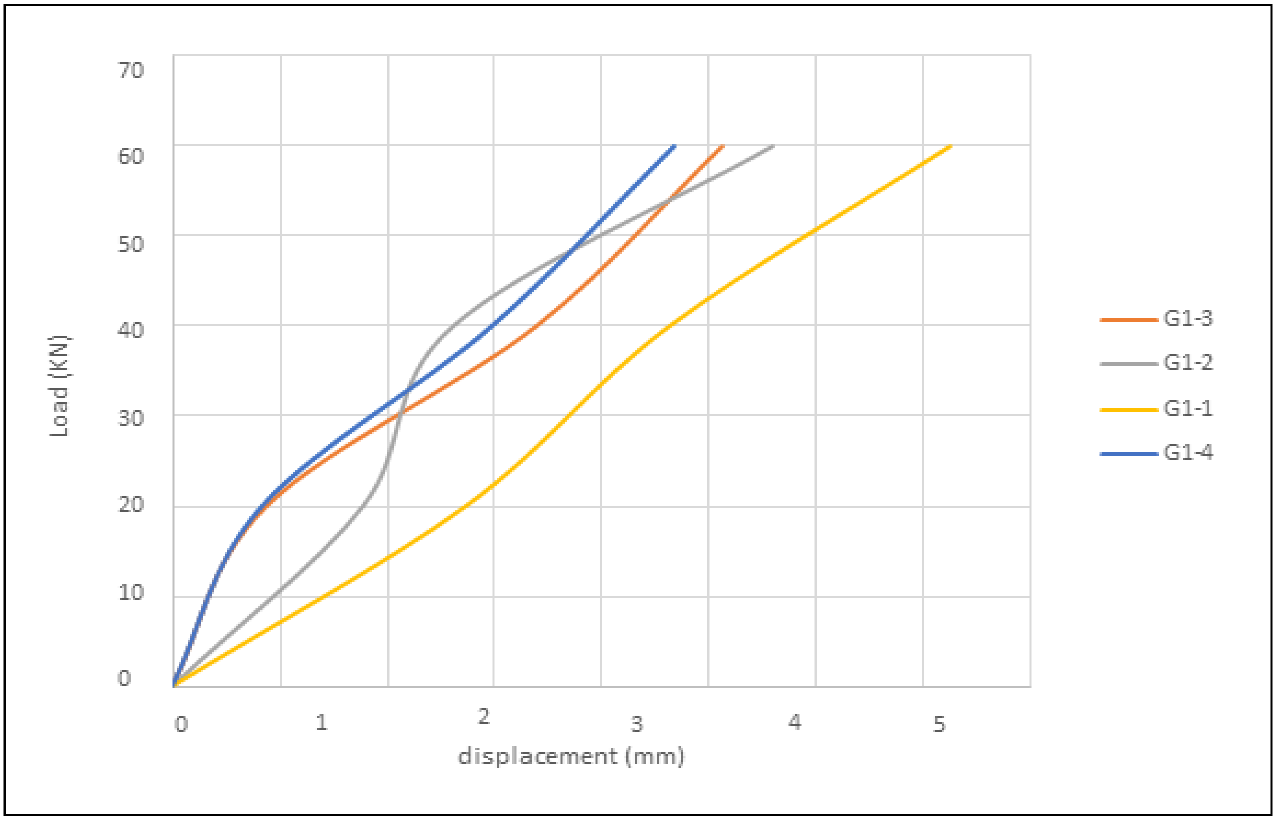


Figure 4.11: Plot the test results for G1 group

4.3 EFFECT OF STEEL FIBRE DIFFERENCES BASED ON 100°C

Concrete material is considered a chemically inert material. it does not burn and it is not able to combust. In addition, it is a substance that cannot release gases or vapors in the presence of high heat, nor does it produce any molten substances while exposed to fire or high heat. These features make concrete a material that is not capable of increasing latent heat during burn, unlike many other materials that are used in buildings such as aluminum metals, and plastics. Concrete is a material with relatively poor thermal conductivity and is suitable for fire safety design because it acts as a barrier between it and fire areas, making it able to protect neighboring areas from fire. In this part of this study, the behavior of concrete that is exposed to high heat as a result of burn was studied. The results of the concrete behavior can be observed through the figures 4.12 to figure 4.15.

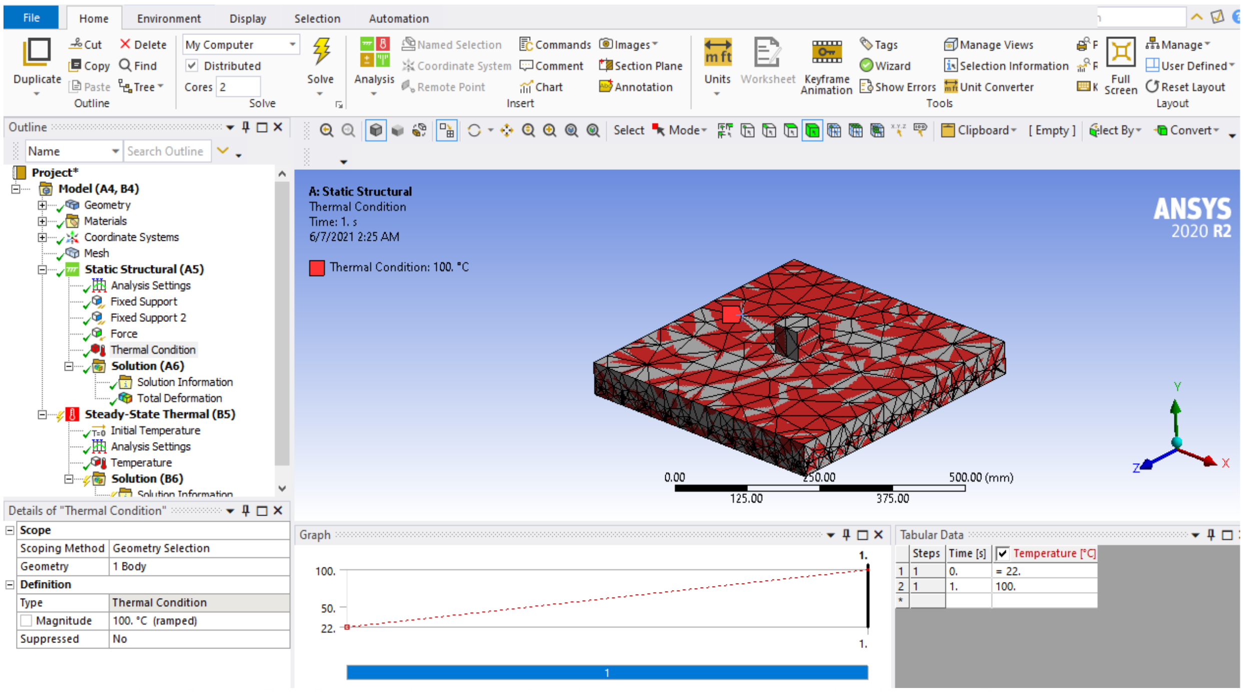


Figure 4.12: Applying heat on the slab model

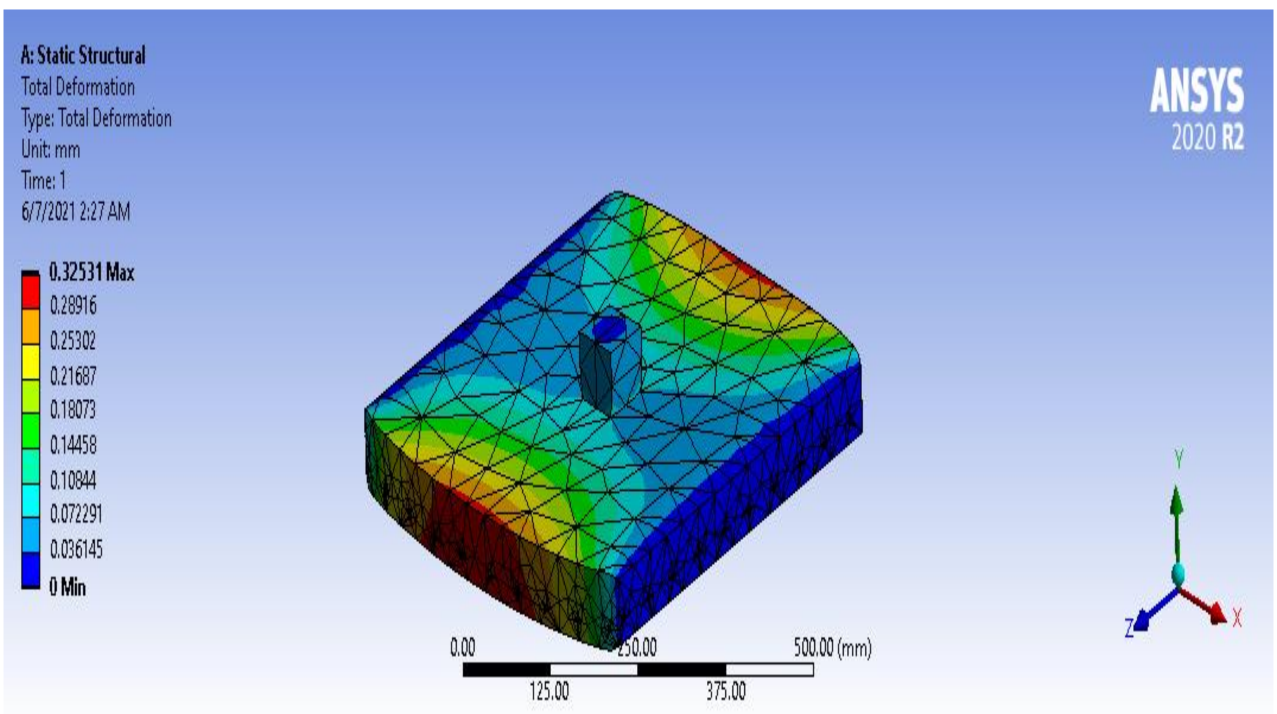


Figure 4.13: Heat effect on the slab model in test 1

they indicate that when the burning temperature is constant 100 °C, increasing the steel fibre dosages causes lower deflection values as it can be seen in the result of the located centre load results.

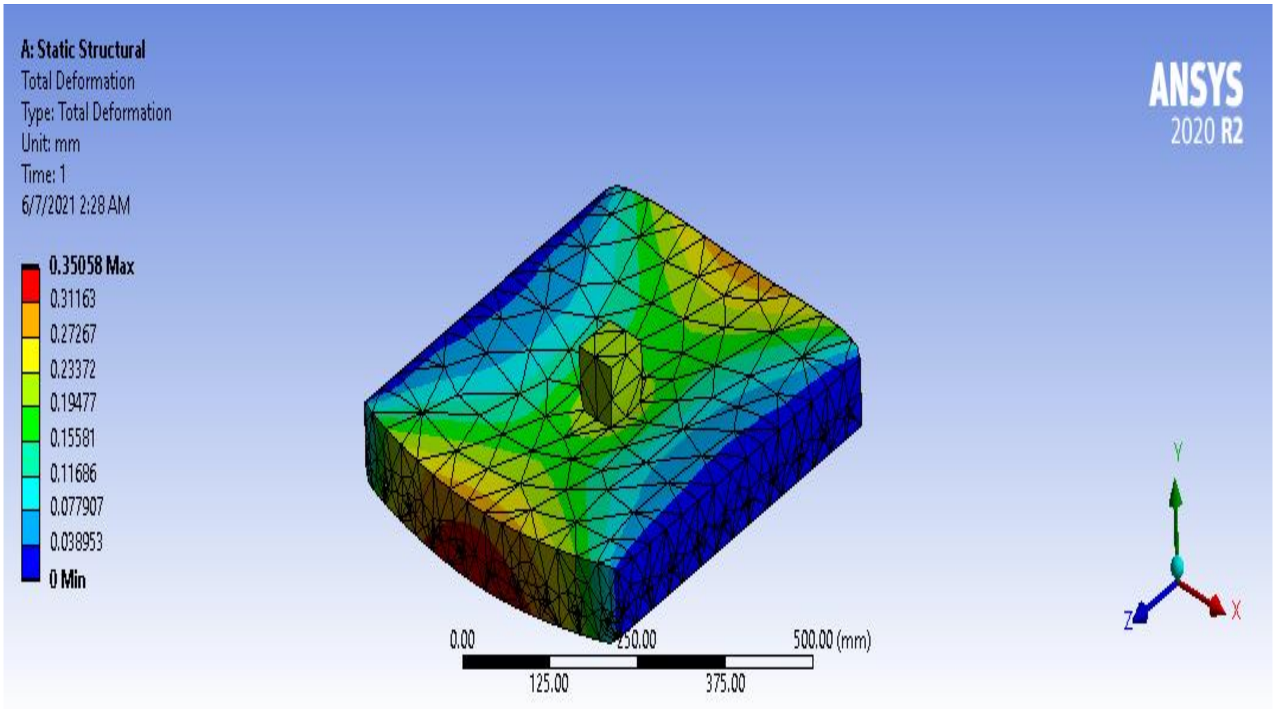


figure 4.14: Heat effect on the slab model in test 2

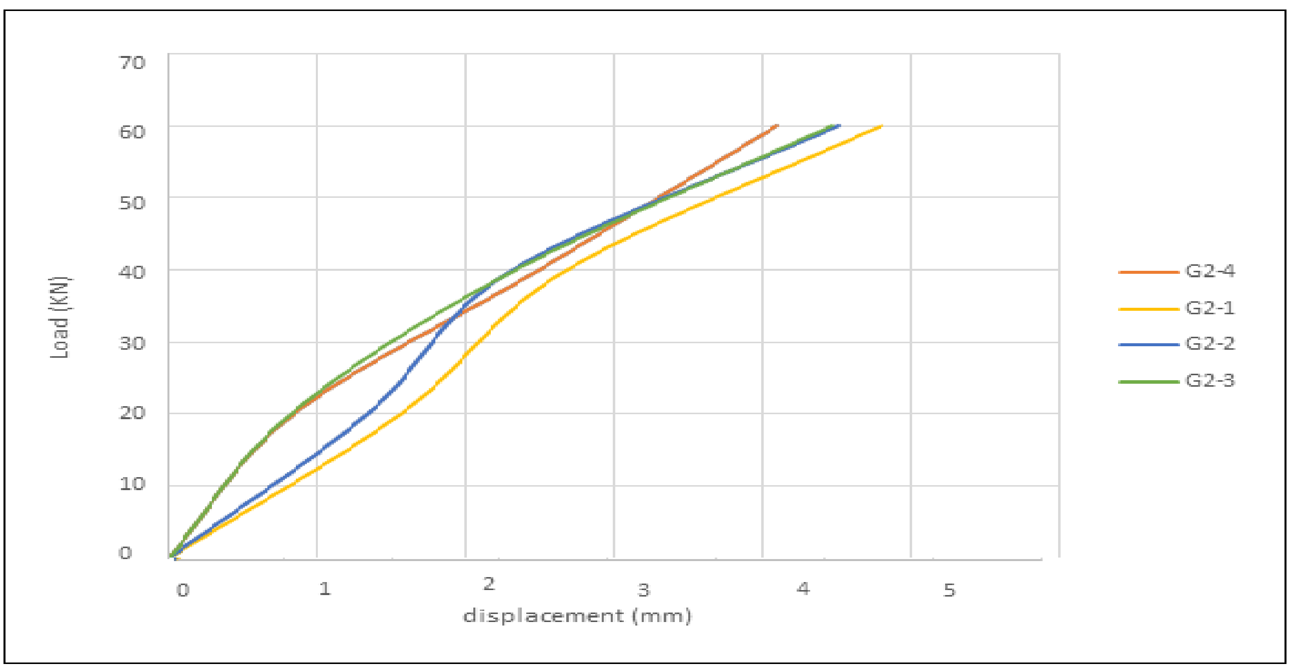


Figure 4.15: Plot the test results for G2 group

4.4 EFFECT OF STEEL FIBRE DIFFERENCES BASED ON 200°C

The next step in concrete test is by increasing the temperature to 200°C. In general, the fire leads to expose the concrete to high temperature effect, which in turn leads to the shock the material and cause a great damage due to the so-called temperature shock of the material. The reason for this shock is the expansion of the outer layers under the influence of heat, while the inner layers remain in their natural state without expansion. The reason for the discrepancy or difference in the responses in expansion as a result of heat effect is due to (the phenomenon of differential expansion of concrete). This phenomenon causes a separation of the concrete layers, and consequently the layers will be separated from each other. The same situation can occur in the rapid cooling process, where the temperature of the concrete is very high as a result of absorbing a large amount of heat. The sudden cooling process with sprinklers and water hoses leads to a rapid cooling of the surface while it remains inside the concrete hot, which leads to the separation of the layers of concrete.

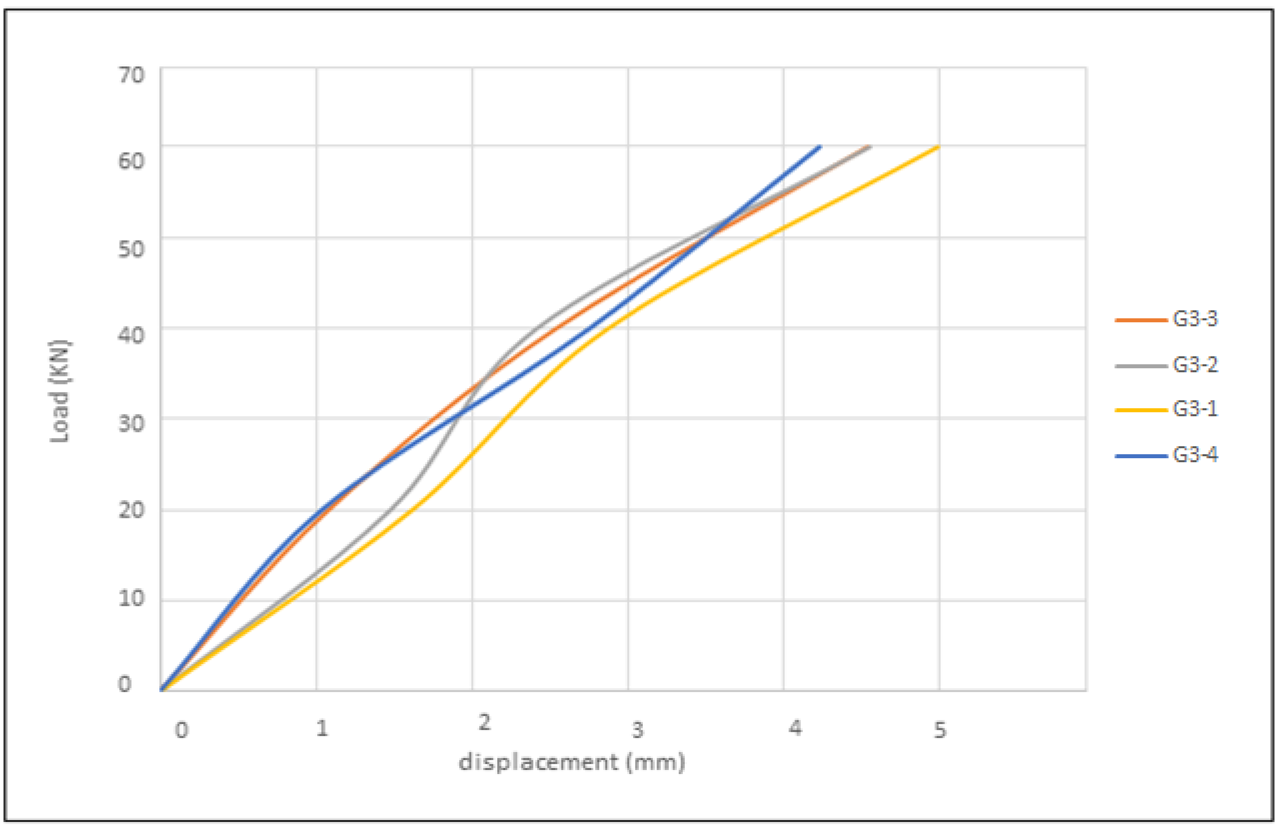


Figure 4.16: Plot the test results for G3 group

As shown in Figure 4.16 the deflection curve starts similar in all specimen of groups for the first 15 kN of loading then it diverges giving different results. For this group, the deflection shows that when the burning temperature is constant 200 °C, increasing the steel fiber dosages causes higher deflection values. The final step is to test the concrete under 300°C. In this temperature as shown in Figure 8 the deflection curve starts similar in all specimens of other group G3 for the first 20 KN of loading then it diverges giving different results. For group G4, the deflection results indicate that when the burning temperature is constant 300°C, increasing the steel fiber dosages causes slightly lower deflection values.

4.5 EFFECT OF STEEL FIBRE DIFFERENCES BASED ON 300°C

The final step is to test the concrete under 300°C. In this temperature as shown in Figures 4.17 the deflection curve starts similar in all specimens of other group G3 for the first 20 KN of loading then it diverges giving different results.

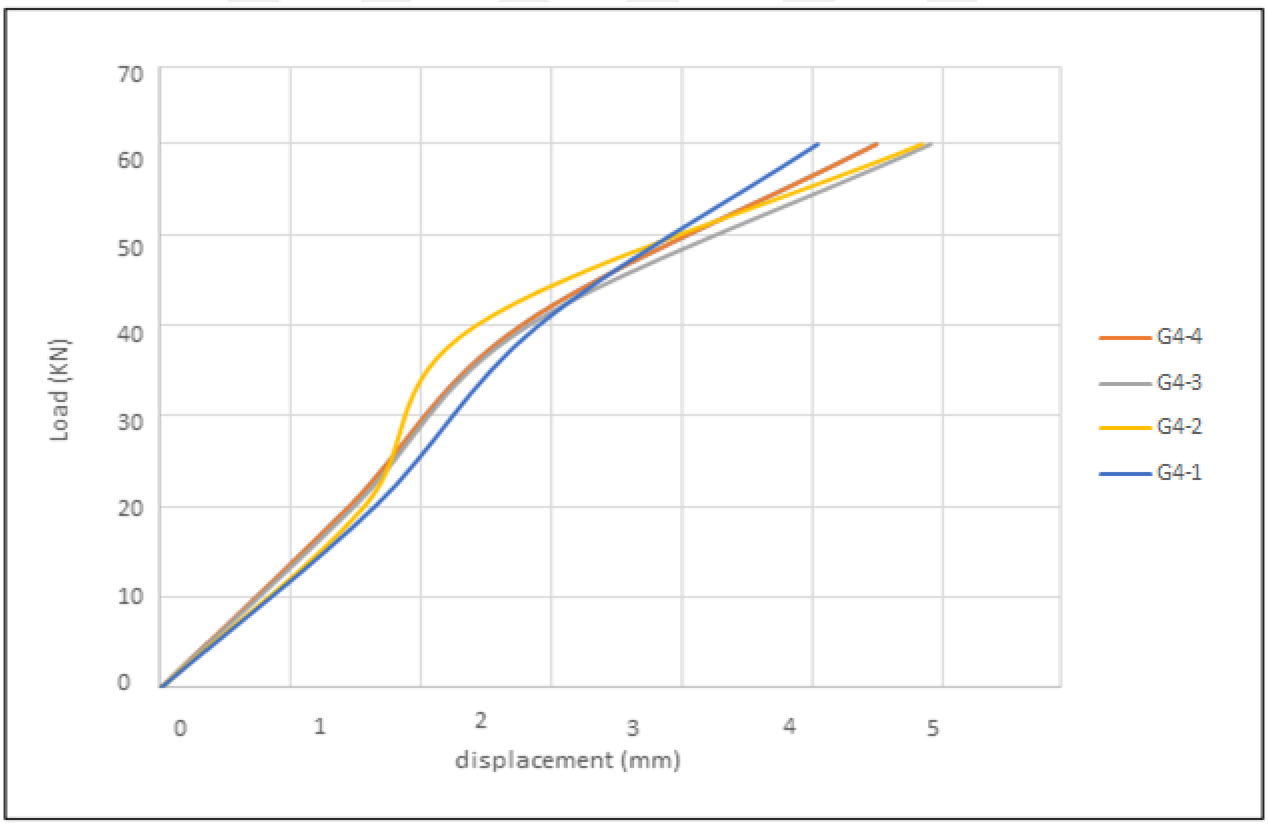


Figure 4.17: Plot the test results for G4 group

For group G4, the deflection results indicate that when the burning temperature is constant 300°C, increasing the steel fiber dosages causes slightly lower deflection values.

4.6 FAILURE MODE

The observed details, such as type of failures was categorized visually as shown in figures 4.18. In general, the punching shear effect with different punching shapes, the shape of failure is changed between the slab with different temperature that have.

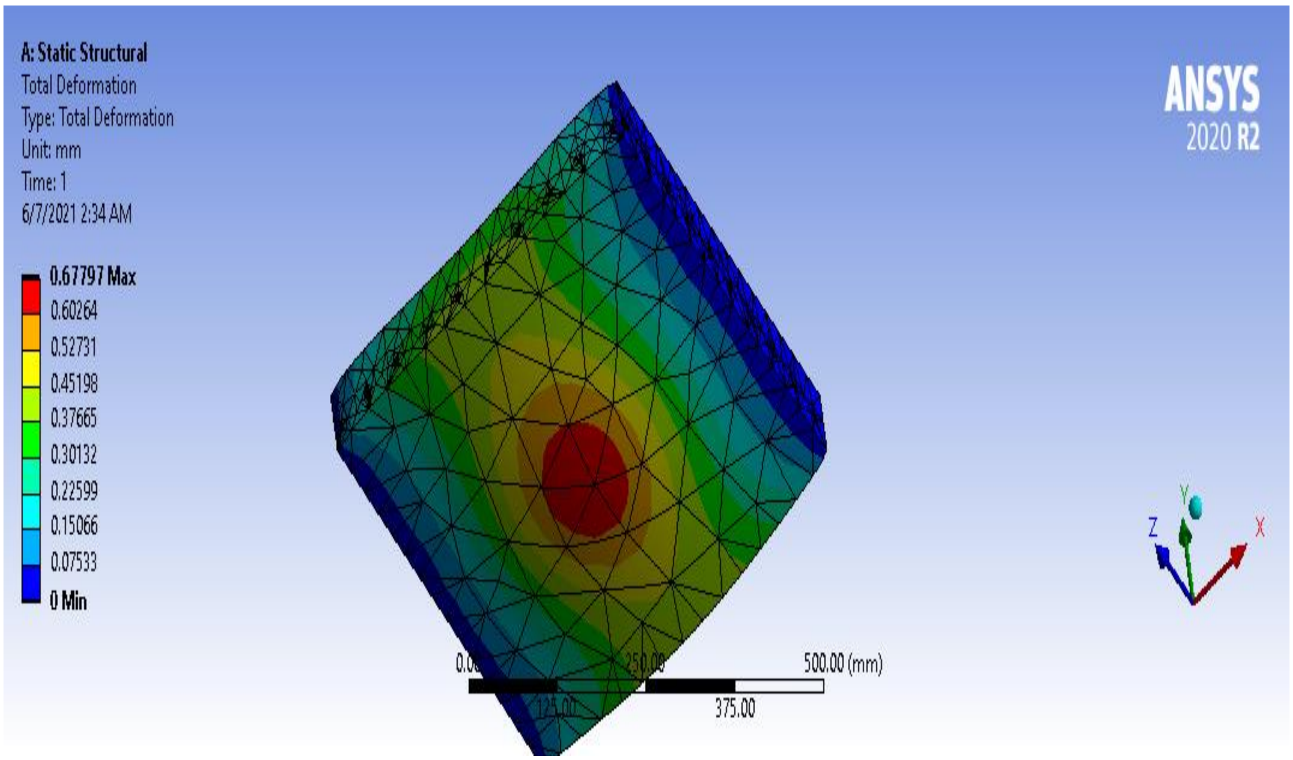


Figure 4.18: Failure Mode at 100Oc

also the radius of failure circle is increased in slabs G3, G4 by the increase the slab heat to 200°C and 300°C respectively.

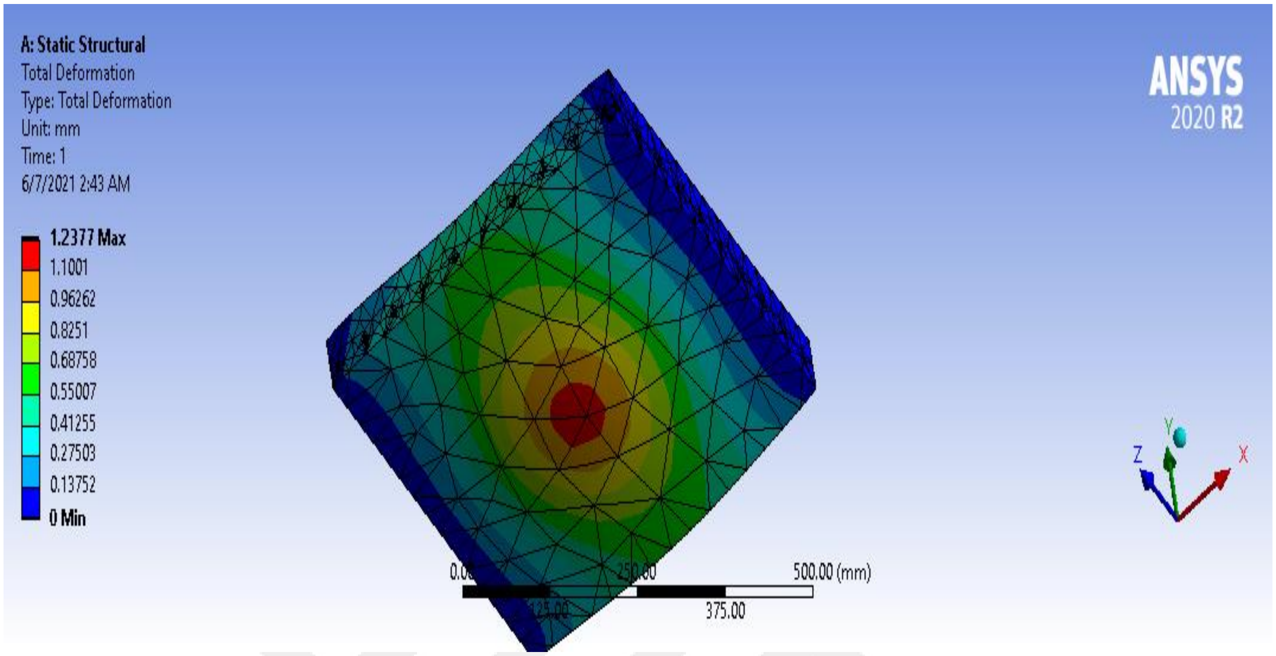


Figure 4.19: Failure Mode at 200oC

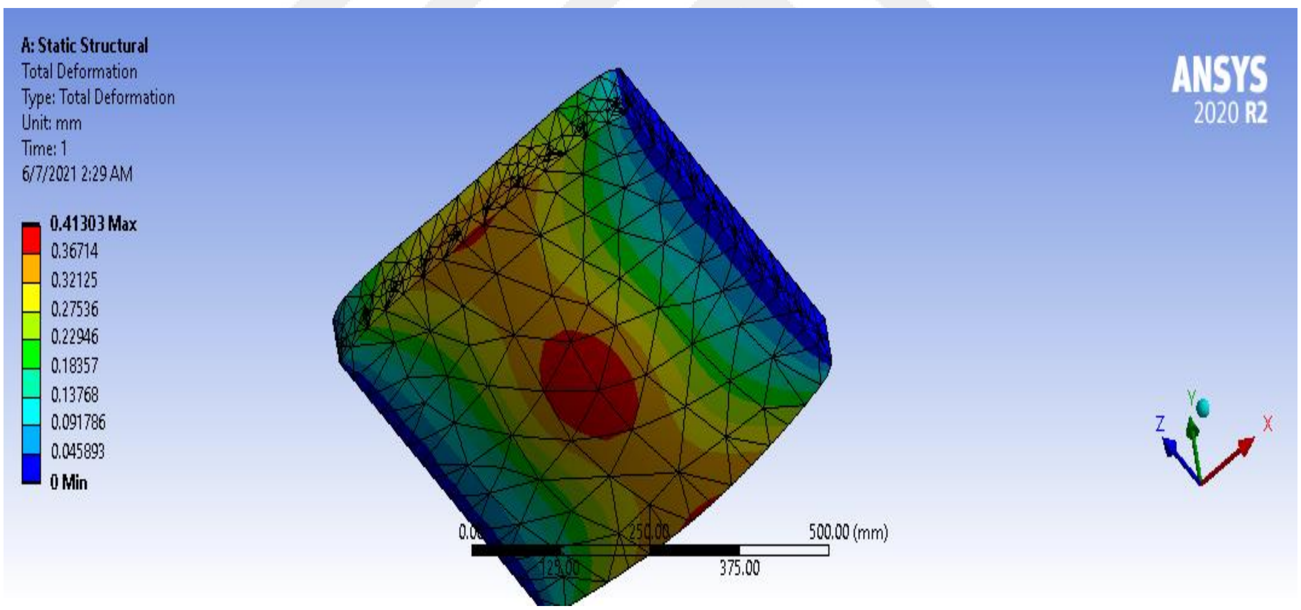


Figure 4.20: Failure Mode at 300oC

it can be notice also that the shape of failure in low temperature is circular and became elliptic in high temperature.

5. CONCLUSION AND RECOMMENDATION

This chapter presents the achievements of the research methodology and work in addressing the research gaps. The process of this work provides a sequence of operation and conditions to process a real slab case study by using ANSYS software. The main contribution in this study is the investigation of shear strength behavior of two-way slab panels based on different steel fiber reinforcement and heat effect. The practical basis for this thesis is to find out the concrete behavior when applied different load on the slab and exposed to different heat effect. The chosen load was from (10 to 60) KN and the exposed heat was from (ambient temperature to 300^{o}C). From the present work, it can be concluded the following issues:

a. The optimum displacement in room temperature obtained when the steel fibre percentage was is 1.25 based on low and high load effect, but in the range of 30 to 50 KN, the best results obtained from fiber percentage was is 0.75.

b. At 100 °C, adding fiber led to lower deflection values and the best deflection value is obtained from adding 1% of steel fiber.

c. At 200 °C, adding fiber led to higher deflection values and the worst deflection value is obtained from adding 0.75% for low load and 1.25% of steel fiber for high load.

d. At 300 °C, the best deflection value is obtained from adding 0.75% of steel fiber

5.1 Future works

In the ongoing research, a new investigation for concrete material need for higher temperature such as (500 to 1000)^{o}C based on different slab design conditions.

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