Enhancement of Concrete Properties using Steel Fibers - Review

Islam Abdullah Aziz[*], Khalaf Ibrahem Mohammed[**]

[*]*Mechatronics Department, Engineering College ,Mosul University, Iraq*
[**]*Civil Department, Engineering College , Mosul University, Iraq*
[*]*islamabd@uomosul.edu.iq* , [**]*kimjebouri@uomosul.edu.iq*

Abstract

Concrete is one of the most widely used building materials in the world. However, one of the undesirable properties of concrete as a brittle material is its low tensile strength and ability to flex. This brittle behavior leads to sudden failure without warning. Therefore it requires reinforcement in order to be used as a building material on a large scale, this reinforcement is in the form of continuous steel bars that are placed in the concrete structure at the appropriate locations to withstand the imposed tensile and shear stresses. On the other hand, they are generally short, discontinuous, and randomly distributed throughout the concrete member to produce a composite building material known as FRC. From this point of view, this review came to clarify the practical benefit of using this technology to inform researchers and workers in the construction sector about it and to provide modern sources for those wishing to conduct more research in the field of strengthening the mechanical properties of concrete in addition to the benefits of using steel fibers in improving the bending and shearing of concrete beams.

Key words- Compressive Strength, Steel fibers, Shear, Splitting Stress, Flexure.

I. INTRODUCTION

Concrete structures are exposed to great damage as a result of some natural disasters such as earthquakes and hurricanes, or as a result of exposure to shock loads such as explosions[1]. From it, which is represented in various forms, such as the appearance of cracks in the beams due to the high flexural and shear forces[2].

There are many ways and means by which the efficiency of the reinforced concrete members is raised, the increase in the dimensions of the members sections was the means that has the first place among other means, as this method works to strengthen the concrete members and increase their bearing [3], or increase the proportion of reinforcement in the concrete section , or the use of pre-stress arming [4].

In view of the additional economic cost resulting from the use of these solutions, the researchers pushed to use the technique of reinforcing concrete with steel fibers during the casting process to improve its mechanical properties [5] as well as its resistance to moisture, corrosion, heat, harsh weather conditions and the chemical agent, in addition to strengthening the bending and shearing areas of the beams at the lowest cost [6]. .

There are a large number of fibers that are used to improve the properties of concrete, and there are several ways to divide their types, for example, according to the type of fiber material, and they are divided into natural, organic (such as cellulose, hemp, bamboo) or synthetic such as (steel fibers, titanium, glass, carbon, polymeric) [7]. Or it can be divided according to its physical and chemical properties such as (density, surface roughness, chemical reactivity, fire resistance and flammability) or divided according to mechanical properties such as (tensile strength, modulus of elasticity, ductility and surface adhesion properties) [8].

Or divided according to the geometric characteristics related to the shape of the section, length, diameter. Where the section of the fibers can be circular, rectangular, square, triangle, flat, irregular or polygonal [9]

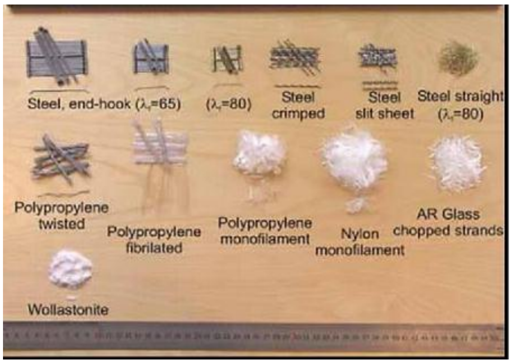

Figure (1): The most common types of fibers [10]

II. STEEL FIBER

Steel fibers are generally made of carbon steel or stainless steel, where the latter is used in facilities that require the use of corrosion resistant steel fibers [11]. The tensile strength of these fibers ranges between (200-2600 MPa), and the maximum elongation ranges between (0.5-5%) and the modulus of elasticity is around (200GPa) [12] In order to improve the bonding between the components of the mixture, it is preferable that the fibers have a high aspect ratio and even the latter must have limits, as very thin fibers with a aspect ratio (Long/Diameter) greater than (100) tend to cling to each other and this reduces It is workability and is likely to adversely affect the mechanical properties of hardened fibrous concrete [13] The following figure shows the different shapes of steel fibers [14].

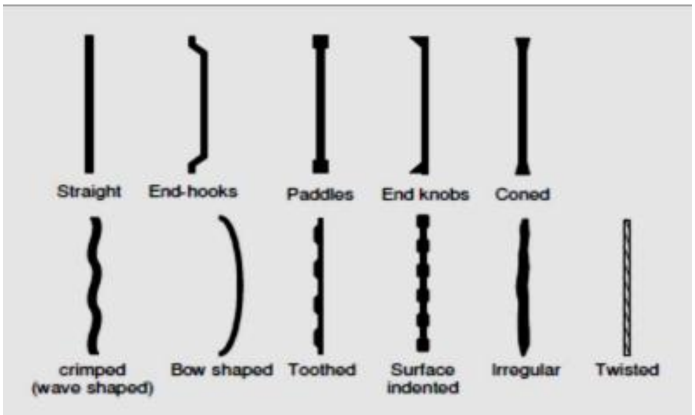

Figure (2): Different types of steel fibers

III. MECHANICAL PROPERTIES OF CONCRETE

Focus will be on the research that studied the effect of adding steel fibers on the compressive strength, splitting tensile, flexure strength, modulus of elasticity and ductility and reviewing them from the oldest to the newest.

The researchers Neves and Fernandes [15] presented a practical study on the effect of changing the percentage of adding silica dust on the mechanical properties of concrete in the presence of fixed proportions of steel fibers in the mixture. The results showed an improvement in the compressive and tensile strength by increasing the silica dust with the fibers.

To compare the use of different types of steel fibers on the mechanical properties of concrete, the researchers presented Khdhum et al. [16] Casting models of standard cubes and cylinders with dimensions (100 * 200 mm) were examined at ages (7-28-60) days using two types of steel fibers, the first type of (Crimped Fiber) with volume ratios (0.25-0.5-1.5)% The second type is (Strength Fiber) at rates (1-2)%, and after examining the models, it was found that the best percentage of fibers to increase the resistance to compression and tensile cleavage was by volume ratios (1.5%) for the first type and (2%)for the second type.

In contrast to previous studies that focused on concrete beams, only the study presented by researchers Kosmatka et al. [17] On ordinary concrete slabs, they concluded that the addition of fibers by (1%) led to an increase in ductility (100%) and energy absorption capacity (300%), as well as an improvement in the mechanical properties of concrete.

And to study the (stress-strain) relationship of fiber-reinforced concrete between researchers Fanella and Naaman [18], there is an increase in the area under the curve as a result of the increase in stress and strain values, in comparison with laboratory models that do not contain steel fibers. To study the effect of ductility when adding steel fibers, researchers Colin and Johnston [19] mentioned by conducting a practical study on the behavior of concrete beams equipped with steel fibers, where 30 models were examined with dimensions (100 * 100 * 500 mm) and the variables adopted in the research are the volumetric ratio Taken for fibers in concrete (0.5, 0.75, 1%), the results of examining these models showed an increase in the ductility of the beams by (65-80%) due to the volumetric ratios (0.5) and (75%)at the volumetric ratio (0.75) and the ductility increases to two and a half times when Volume ratio (1%) compared to fiber-free thresholds.

In the same context, but by using self-compacting concrete, the researchers Al-Ta'an and Al-Neemie [20] showed an improvement in the results of compression and flexion of the beams used in their study, which were with dimensions (100 * 100 * 500 mm) when adding fibers to the concrete mixture. Similar results to the study presented by researchers Mollaahmadi et al. [21] on self-compacting concrete, but using two types of fibers (steel and glass), and they found that the tensile and flexural strength in the presence of fibers is equivalent to two to three times of the flexural strength and tensile strength without it, while the values of the mean deviation are as large as one tenth times that of fiber-free ones.

Among the research that relied on the change in the aspect ratio of the fibers was presented by the researchers Shende and Pande [22] from conducting a practical study using standard cylinders (150 * 300mm) to find out the effect of adding steel fibers on the fission tensile strength and in volumetric ratios of steel fibers from the volume of concrete (0-1-2-3 %) with the use of the aspect ratio of (50-60-67) for each percentage of the steel fibers used in the study. After conducting laboratory tests of the models, the researchers found that the highest value of the tensile tensile strength of the mixtures was when the percentage of steel fibers was (3%) and at a ratio of (50) compared to the reference mixture, where the percentage increase in the tensile strength of the mixtures was (15-19-29) for fiber ratios (1-2-3 %), respectively. Based on the results of this study and using the same fiber ratio and aspect ratio, the researchers presented Shende et al. [23] In the following year, a practical study was conducted on a concrete mixture with weight ratios (1:1.43:3.04/0.35) in order to draw the relationships between the aspect ratio and the mechanical properties of concrete represented by compressive strength, tensile strength and flexural strength, and the following figure shows the relationships that researchers concluded in their study the operation.

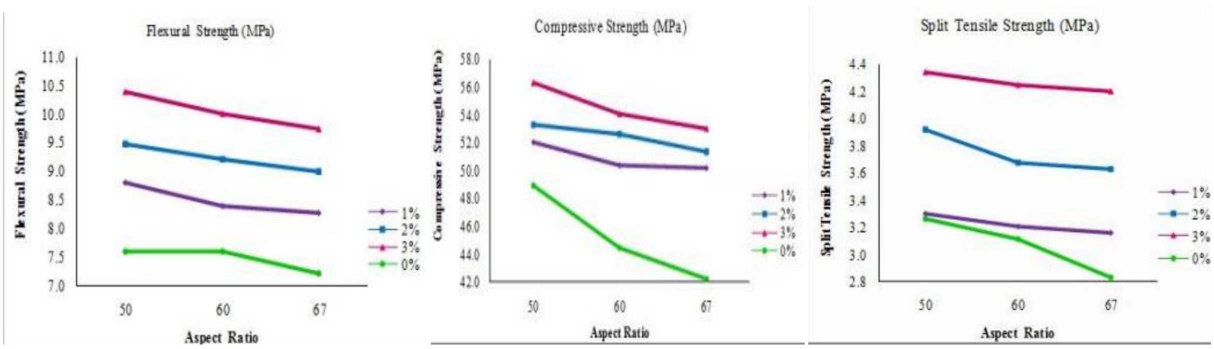

Figure (3): The relationships deduced from the study [23]

The researchers Shende and Pande [24] conducted a practical study on the effect of different types of steel fibers with different volume ratios ranging between (0-3%) on ordinary concrete. The researchers concluded in general that adding steel fibers to the concrete mixture had a positive effect on all mechanical properties of the concrete mixture, especially It bears compressive and tensile strength. This was confirmed by researchers Chen and Hwang [25] for their study of the effect of steel fiber content, as well as the combined effect of rice husk ash and water-reducing plasticizer. The practical results showed that the use of steel fibers in high-performance concrete leads to a distinctive improvement of the mechanical properties of concrete. This is also what the researchers found Pawade et al. [26] From their study of the fracture standards of reinforced concrete when adding fibers of different lengths and diameters, they concluded that the value of the fracture standards has a direct relationship to the lengths and volume ratio of the fibers, while it has nothing to do with the diameters of the fibers.

Among the studies that dealt with the effect of adding fibers on the modulus of elasticity and strain to concrete is the study presented by researchers Gul et al. [27] Where seven concrete mixes were used, one of which was considered a reference mix without steel fibers and three of which were added steel fibers of a type (HK0750) and three mixtures. Steel fibers of the type (HK0735) were added in each mixture. The volume ratios of the fibers were (0.5-1-1.5%). After conducting laboratory tests on standard cylindrical models, it was found that the steel fibers increase the modulus of elasticity, and the highest values were recorded. At the rate of (1.5%) of the fibers for both types, it was also found that the same volumetric ratio of the fibers increases the strain values when examining the cylindrical models in comparison with the reference mix. And because the steel fibers affect the workability of the concrete mixture, the researchers conducted Shireesha et al. [28] A practical study to study the mechanical properties of concrete by adding steel fibers at a rate of (0-3%) with the addition of a plasticizer additive at a rate of (1%) of the weight of the cement used. With a length of (60 mm) and a diameter of (0.75 mm) with an aspect ratio of (80), and after conducting the tests at the age of (28) days, the researchers found an increase in the compressive strength, tensile strength, and bending compared to the fiber-free reference mixture.

By studying an approach to what was presented by the researchers [15] using silica dust with steel fibers, the researchers Sarsam and Azzawi [29] presented a study on the mechanical properties of ordinary and high-strength concrete reinforced with steel fibers in volumetric ratios (0-3%) and silica dust ranging from (0-10%) By using standard cylinders and cubes to prepare the models, the researchers deduced relationships between the compressive strength of cylinders and standard cubes with the presence of different proportions of steel fibers and silica dust.

In order to find out the effect of adding fibers to the concrete mixture at different ages between the researchers Prasaad and Jegidha [30] that the fibers increase the values of resistance to compression, cleavage tensile and flexural for all ages, this came after they conducted a practical study on laboratory models at ages (7,14,28) where they were used Steel fibers with proportions ranging (0-3%) and by a proportion of (50) using standard cubes (150 * 150 * 150 mm), cylinders with dimensions (200 * 100 mm) and concrete beams with dimensions (1200 * 200 * 100 mm) to check the flexure. Among the studies that used fly ash, also known as chimney ash, which is one of the residues of coal combustion, as it is used as a substitute for cement, is the empirical study by researchers Huda et al. [31] In order to identify the best percentage of fibers added to the concrete mixture to give compressive strength (30MPa) with weight ratios (10-20-30%), and all these ratios were tested on (4) concrete mixtures with fiber content (0-1 -1.5-2 %)by volume. After conducting laboratory tests on concrete cubes, it was found that the percentage of fibers that give the required compressive strength is (1%), with a percentage of volatile materials (10 %) fly ash.

For the same reason mentioned by the researchers [28] Sawant et al. [36] An empirical study on the effect of adding steel fibers to the concrete mixture at a percentage of (2.5-5-7.5-10 %) in the presence of a plasticizer of the type (Metakaolin) added as a percentage of the weight of cement at an amount of (5-10-15-20%) Pouring four concrete mixes in addition to the reference mix designed to give a compressive strength (60MPa). The researchers, Raveendra and Venkateswara [32] also conducted a practical study in the presence of a plasticizer of the type (Couplast sp 430) using standard concrete cubes with dimensions (150 * 150 * 150 mm) and unreinforced concrete beams with dimensions (500 * 100 * 100 mm) to see the effect of changing the proportion of Steel fibers have resistance to compression and flexure. The fibers used were hooked-end steel, and the percentages were (2-2.5-3-3.5)%, as shown in Figure (4). After conducting laboratory tests, it was found that the best percentage of fibers to increase the compressive strength is (2.5%) and decreases as the fibers exceed this percentage, while the resistance to flexure increases with the increase in the percentage of fibers.

s.no	Properties	Description
1	Length of fiber (*l*)	60mm
2	Thickness (diameter) of fiber (*d*)	0.75mm
3	Aspect ratio (*l*/*d*)	80
4	Tensile strength	2000MPa
5	Specific gravity	7.8
6	Modulus of elasticity	200Gpa

Figure (4): The shape and specifications of the fibers used in the study [32]

Among the practical research that dealt with the use of steel fibers with unconventional concrete is the study of researchers Yanxia et al. [33] Through the use of different types of steel fibers on the mechanical properties of lightweight high-resistance concrete (HLAC), where three types of fibers were used (being micro (M), end-hooked (H), corrugated (C)) (12) concrete mixtures were used in addition to the reference mixture, and the percentage of steel fibers for each of the three types ranged between (0-3%) and after conducting laboratory tests, the researchers found that the resistance to compression and flexure increases with an increase in the percentage of fibers of the types (M & H) while it was fluctuating. For type (C), while the fission tensile strength increases with the increase in the percentage of fibers and for all types compared to the reference mixture. The researcher also studied Venugopal [34] by using concrete to which recycled rubble from building rubble was added with a percentage of (50-100%) of coarse aggregate, as steel fibers were added at rates of (0.5-1-1.5%). The researcher concluded that the compressive strength decreases as the percentage increases. Round aggregate without the presence of fibers in it, where the resistance to compression, flexure and splitting tensile increases when adding fibers and in the presence of rounded aggregate.In the same context, the study presented by the researchers Ahmed et al. [35] on low-resistance concrete, as a concrete mixture with weight ratios (1:1.5:3/0.5) was used to give compressive strength (15MPa) and to know the effect of adding steel fibers at rates (1,2,3,4%) on the mechanical properties of concrete. Its specifications are (length 35mm) and (diameter 0.55mm), the aspect ratio is (64) and after conducting the laboratory examination, it was found that the best percentage of fibers is (2%) to increase the resistance to compression, tensile, and flexure at the age of (7.28) days. It was noted that the more The percentage of fiber was more than (2%), and the results were counterproductive compared to the control mixture. And based on the same variables mentioned by [22,23], the researchers presented Chaitanya et al. [37] Where a concrete mixture was designed to give compressive strength (20MPa) and by weight ratios (1:1.96:2.63/0.45) and three types of fibers were used with an aspect ratio of (50-60-67%) and after examining laboratory models it was found that increasing the aspect ratio It works to reduce the values of compression, splitting tension and flexure.

IV. FLEXURAL STRENGTH OF CONCRETE BEAMS

The practical research that dealt with the study of the behavior of reinforced concrete beams and slabs for flexure and mid span deflection when adding fibers and reviewing them from the oldest to the newest will be addressed.

The researcher Noghabai [38] concluded by examining 16 models of beams with dimensions (150 * 250*2000 mm), which are armed with longitudinal rebar for flexural resistance, in addition to rings to withstand shear, that the fibers increase the flexural and shear in addition to reducing the mid span deflection compared to the control beam. The studied is the compressive strength of concrete and the volume ratios of the added fibers, which are practical results similar to what the researchers reached by Behbahani et al. [39] for their study on two groups of reinforced concrete beams with different compressive strength (30 & 50MPa), and for each group steel fibers were added at a ratio of (0.5-1- 1.5-2%), with a number of (10) beams for the two groups, including two beams without fibers, and they were considered as control beams, and the dimensions of the models were (120 * 170 * 2400 mm.) After conducting a laboratory examination of the models, it was found that the Mid span deflection measured at the maximum load (Ultimate Load) decreases with an increase in the percentage of added fibers, while the best percentage for increasing the maximum load for failure and for all beams is (1%) and decreases as the percentage of fiber increases. In the same context of research that studied flexure load The average level for reinforced concrete beams, but using different types of steel fibers, was presented by the researchers, Vasant and kalurkalu [40] Where three different types of fibers were used, the first commercially denoted (FSF) with specifications of length (60 mm) and diameter (1 mm) and the second type symbolized by commercial (HSF) with specifications of length (40 mm) and diameter (2 mm) and the third type symbolized by (WSF) with a length (30 mm) and (0.45 mm) in diameter. (8) beams were used for each type of fiber, with dimensions (120 * 240 * 2400 mm). Fibers were added at rates ranging (0-3%). After conducting a laboratory examination, the researchers found that the best fibers were to reduce the mid span deflection At the maximum load are the types (FSF) and (HSF), while the best percentage that gave the largest value for the failure load is (3%) for the same types.

In contrast to previous studies, researchers Johnston and Colin [41] presented a study on self-compacting slabs by analyzing the flexural strength and calculating the mid span deflection in the presence of steel fiber The researchers concluded that the addition of fibers led to an increase in flexural resistance by (7-20)% and a decrease in deflection (10-33%) compared to the control beams.. The researchers also presented Cardosoa et al. [52] A study to find out the effect of adding steel fibers on the flexural strength of self-compacting concrete beams and the variables adopted by the researchers are (fiber type, fiber addition ratio, compressive strength), where three types of fibers were used, the relationship was (length / aspect ratio) for the three types. They are (33/44), (33/60), (50/67). Fibers were added at a rate of (0-3%), and the concrete beams used were (150 * 150 * 550 mm) and a number of (48) models were divided into two groups, the first group having compressive strength (20Mpa) and the second (40 MPa) and after examining the models at the age of (28) days, it was concluded. The researchers found that beams with compressive strength (40MPa), 3% fiber content and a lower aspect ratio were the ones that gave the highest values for flexural load and deflection reduction.

Among the research that took into account the theoretical and practical comparison of adding steel fibers to concrete beams, the researchers presented AL-Kaissi et al. [42] Using steel fibers, the details of which are shown in Table (1), with volume ratios (0.4-0.8%) , where the weight ratios of the concrete mixtures to the beams were (1:2:2/0.4) and the dimensions of the models were (100 * 100 * 700 mm) with a number of (6 models) and after conducting the laboratory test practically, numerical modeling (3D) was used theoretically using the computer code (ABAQUS) and after conducting the triple static curvature examination of the cusp models (SFRC) the values of precipitation, stress and strain were obtained, and the theoretical results showed that these values increase with the increase in the percentage of fibers In addition, there is a good match between the practical and theoretical results, according to the researchers.

Table (1): Specifications of the fiber used[42]

Commercial Name	Configuration	Property	Specifications
Dramix ZC 50/0.5	Hooked Ends	Density	7860 kg/m^3
		Ultimate Strength	1130 MPa
		Modulus of Elasticity	$200x10^3$ MPa
		Strain at Proportion Limit	$5650 x10^{-6}$
		Poisson's Ratio	0.28
		Average Length	50 mm
		Nominal Diameter	0.5 mm
		Aspect Ratio (L_f/D_f)	100

For a study similar to what was presented by the researchers [40] of adopting different types of steel fibers as variables in their research, the study presented by Tamil et al. [43] By conducting a practical comparison using two types of fibers (Fiber Poly Propyleue) and (Hybrid Fiber) and studying their effect on the flexural strength of (4) concrete beams, two were considered as control beams without fibers, and the dimensions and reinforcement of the beams are shown in Figure (5) After conducting a laboratory examination on the lintel, it was found that the best results for flexural resistance were at the lintel added to it with steel fibers (Hybrid Fiber), where the increase in flexural resistance reached (58%) at the age of (28) days compared to the control beam, followed by the lintel added to it with type fibers. (Fiber Poly Propyleue) with an increase of (29%) compared to the control beam.

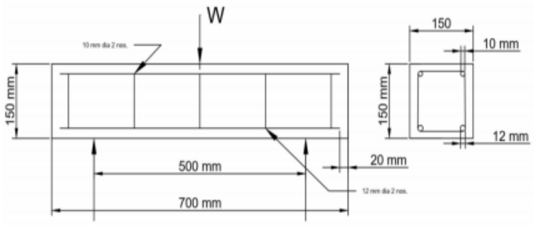

Figure (5): Dimensional and Reinforcement specifications for the used beams[43]

Among the research that adopted the change in the aspect ratio of the fibers to study the flexure was presented by the researchers Tabassum et al. [44] To know the effect of adding steel fibers of two different types to the aspect ratio, which is (50 & 70), and at rates ranging (0-3%) for both types, the study was conducted on (9) beams, one of which was considered a control beam. The first and the second were at the percentage of fibers (3%) compared to the control beam and at the age of examination (28 days). These results are similar to the researchers Yang et al. [46] For their practical study when using steel fibers with different tensile stress and aspect ratios (50 & 70) on concrete beams models with compressive strength (25 -30 MPa). The researchers concluded that the higher the tensile strength of the steel fibers with the stability of the compressive strength led to an improvement in the behavior of concrete beams for flexural and deflection and a reduction in the number and width of cracks with increasing loads. Among the practical research that dealt with comparing the value of the loads for the appearance of the first crack in a beams designed for failure by flexure, in addition to measuring the width of the cracks, is the introduction of Hasan et al. [48] Where they found that steel fibers had a clear effect on delaying the appearance of the first crack and on increasing the number and width of cracks compared to beams without steel fiber , which is identical to what the researchers reached [46] in terms of the applied loads and the appearance of cracks on the examined beams.
Among the studies that took into account the cyclic loads presented by the researchers, Ranjbaran et al. [45] Where (7) models of reinforced concrete beams with dimensions (250 * 250 * 2300mm) were used, one of which was considered as a control beam. Steel fibers were added at a ratio of (1-2-4%), and after applying cyclic loads on the models, it was found that the best Percentage of the increase in flexural load at the percentage of fibers (2%), and the following figure shows the model upon examination and the relationship (load - deflection) at the percentage of fibers (2)%, where the increase compared to the control beam is (83.87)%.

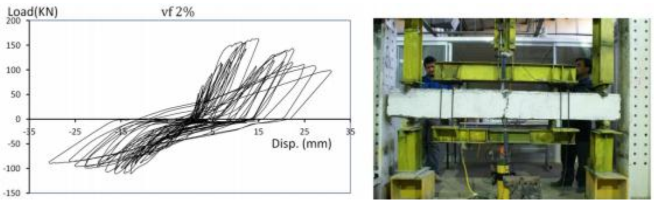

Figure (6): Examination model and relationships for the study[45]

Among the research that examined the effect of adding fibers to concrete beams with high compressive strength, was presented by Choi et al. [47] Where (9) concrete beams with dimensions (150*150*550 mm) and compressive strength (80MPa) were used, one of which was considered a control beam and two types of steel fibers were used, the first type with tensile stress specifications (1200MPa) and the second type with tensile stress (1600MPa). And the percentage of adding fibers was (0-3%) of the concrete volume. After conducting a laboratory examination on the models, it was found that the best percentage to increase the flexural tolerance and reduce the deflection compared to the control beam was of the second type. The researchers reasoned to increase the aspect ratio and increase the tensile strength of the fibers was The main reason for the increased flexural strength of concrete beams.
The researchers presented Abbass et al. [49] An empirical study to make a comparison between the effect of adding steel fibers to hollow and solid concrete beams on flexural strength, where two groups of beams (4) hollow and (4) solid were used, and each group had a control beam without steel fibers, and the percentage of added fibers for each group was (0.5- 1-1.5%) and the dimensions of the models used are shown in Figure (7), and after conducting a laboratory examination, it was found that the best percentage of increasing the endurance for flexure was (1.5%) for the models of the two groups. The researchers also concluded that the fibers increase the ductility and delay the appearance of the first crack compared to the control beams.

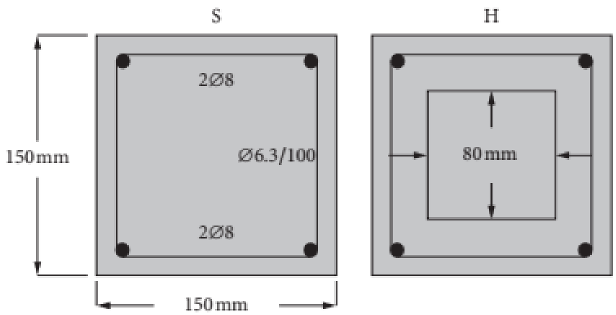

Figure (7): Dimensional and Reinforcement specifications for the used beams[49]

One of the theoretical studies that dealt with the use of steel fibers in strengthening the medial flexure of reinforced concrete beams was presented by the researcher Scyh [50] through three-dimensional modeling of the beams using one of the finite element theory programs, which is the program (Midas FEA V1.1), where the following equations were used in the application of the mathematical model in the analysis program for the purpose of defining the behavior of fibrous concrete in the tensile region after shedding the loads:

$$\sigma_r = f_{ctf}\{2(\frac{\varepsilon_r}{\varepsilon_{to}}) - (\frac{\varepsilon_r}{\varepsilon_r})^2\} \qquad 0 \geq \varepsilon_r \leq \varepsilon_{t0}$$

$$\sigma r = f_{ctf}\{ 1 - (1- \frac{f_{tu}}{f_{ctf}}) (\frac{\varepsilon r - \varepsilon t0}{\varepsilon t1 - \varepsilon t0}) \} \qquad \varepsilon_{t0} \geq \varepsilon_r \leq \varepsilon_1$$

$$\sigma_r = f_{tu} \qquad \varepsilon_r > \varepsilon_{t1}$$

$$\varepsilon_{t0} = \frac{f_{ctf}}{E_{cf}}$$

$$\varepsilon_{t1} = \eta\, \tau_d\, V_f\, \frac{\overline{l_f}}{d_f}$$

where $\eta = 0.405$ and $\tau_d = 4.12MPa$

The results of the theoretical three-dimensional modeling showed great accuracy and convergence in comparison with the practical results of previous studies adopted by the researcher, in which the percentage of fibers (0.75%) was added, which led to an increase in the flexural strength to approximately (32%).

The researchers Ali et al. [51] An empirical study on (6) concrete beams with dimensions (150*150*1800 mm) symbolized (B1) to (B6) in order, beam (B1) was considered as control beam and beams (B2-B3-B5) Steel fibers were added to Half of the depth and in the middle third of the length of the models and the proportion of steel fibers (0.5-1-2%) by volume. The beams (B4-B6) were added in the middle third of the beam length and in full depth at a rate of (1-2%) respectively. After conducting a laboratory examination, it was found that the beam (B6) gave the highest values, as the force applied when the first crack appeared (P_{crack}) was (56.8 kN) while it was in the control beam (40 kN) and the maximum load ($P_{ultumate}$) was (153.5 kN) while it was in the control beam (141.5 kN) and the following figure shows the models after the examination

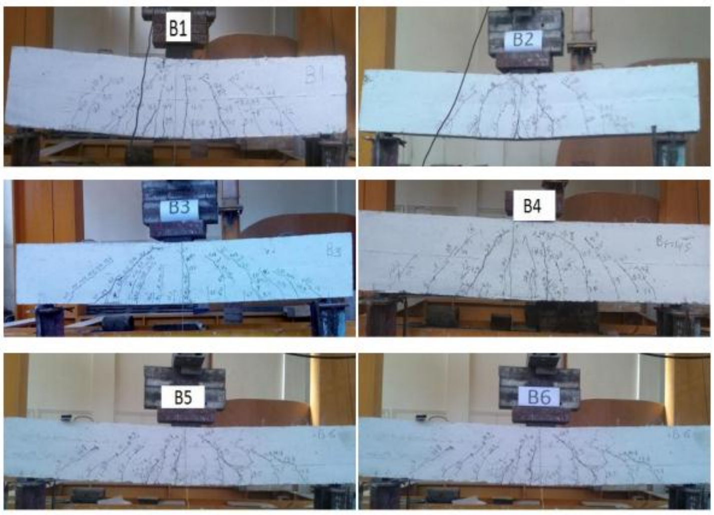

Figure (8): Forms failure after Testing [51]

V. SHEAR STRENGTH OF CONCRTE BEAMS

The researchers presented Kwak et al. [53] A practical study using (12) concrete beams with dimensions (125 * 250 * 2400 mm) to know the shear behavior of concrete beams after adding fibers and in proportions (0-0.5-0.75%) of the concrete volume. The beams were designed to failure shear, and after conducting a laboratory test on the models by applying a load with a simply support, the researchers concluded that the higher the percentage of steel fibers give the higher values of the nominal and ultimate shear failure compared to the control beams. This is what was also reached by researchers Endgington and Williams [54] that the presence of fibers in concrete works to increase shear stresses as well as reduce cracks and avoid sudden failure by increasing ductility. In a different study from what was presented by adding fibers to the slabs, the researcher Williamson [55] stated that any increase in the proportions of steel fibers and the thickness of the slab leads to an increase in shear stresses and the ductility of the slab after conducting a practical study of the shear behavior on (14) fiber-reinforced concrete slabs. Relied in the research are the volumetric ratios of the fibers, the thickness of the slab, and the strength of concrete. The researchers also concluded Archana et al. [61] The addition of fibers increases the values of shear stresses for high strength concrete slabs, as they found that the equations proposed by the Australian Code [62] can be applied for concrete strength up to (100MPa). Among the practical studies to know the effect of adding steel fibers on the behavior of deep concrete beams and beams containing openings was presented by the researchers AL-Sarraf et al. [56] By dividing the beams into two groups, the first group consists of (6) deep solid beams, and the second group consists of (6 deep beams) containing openings in the trunk area (Web) and the percentages of fibers used are (0-0.5-1.0%) From the concrete volume and the aim of the study was to know the effect of adding fibers with the change of the ratio of shear space to depth (a/d). Shear to depth and the following figure shows the details of the models used in the study.

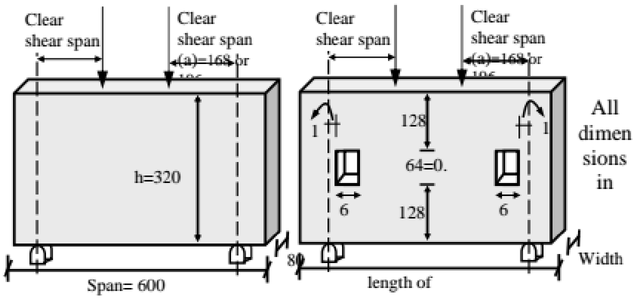

Figure (9): Models used in the study[56]

Among the research similar to studies [53,54] that dealt with adding fibers in different proportions to the shearing behavior, was presented by the researchers Lana et al. [63] Using (4) reinforced concrete beams with dimensions (2700 * 300 * 150 mm) and concrete compressive strength (30 MPa), one of which was considered as a control beam where the minimum reinforcement of stirrups was used and the shear space ratio to depth was adopted by (2.4) and the use of fibers Steel in proportions (0-0.5-0.8-1%) of the concrete volume and after examining the beams at the age of (28) days, the researchers concluded that the maximum shear load that the beams endured was at the beam added to it (1%) of the fibers, which amounted to (179.8 kN) in comparison With the control beam, which was the maximum shear load of (129.3 kN), as well as the study presented by Daniel et al. [57] to find the effect of adding steel fibers with a ratio of (1-2%) with specifications of length (35 mm) and aspect ratio (65) on (6 concrete beams) with dimensions (150 * 390 * 2600 mm), where the researchers concluded that adding steel fibers increases the shear bearing in addition to it works to reduce the width of the cracks visible in the shear areas and the best results were at the addition of (2%) and suggested The researchers can reduce the shear reinforcing stirrups when adding steel fibers and this is what Balgude et al. [58] has presented by conducting an experimental and theoretical study with Shear behavior of deep concrete beams and without reinforcing stirrups by adding steel fibers only, where (18) deep beams with dimensions (90 * 360 * 600 mm) and steel fibers used were (0-1.5-3%) and the beams were divided into two groups, the first group The ratio of the shear space to depth (a/d) is (0.6) and the second group is (0.74). After examination, the researchers concluded that the fibers increase the shear load when the first crack appears, where the load rate according to the percentage of adding fibers to the first group is (92 -111 -121.5 kN) and for the second group (100.5 -131 -149 kN) respectively, as well as good agreement was obtained with the results of theoretical research that dealt with the study of shear for the same type of beams. The researchers Mashrei and Ali [64] also confirmed that steel fibers have the ability to compensate for reinforcement collars (Stirrups) to resist shear in reinforced concrete beams under normal flexural loads and for specific loads according to the dimensions of the concrete section. This is also the view of the researcher Tantary [67] when he used (7) concrete beams without reinforcing stirrups with a total length of (1200 mm) and steel

fiber ratios (0-0.5-0.75-1%) , as he concluded that the shear bearing increases with the increase in the proportion of steel fibers (even in the absence of Shear stirrups) also depends on the ratio of shear space to depth (a/d), and the researcher also concluded that the failure form changes from shear failure to flexural failure when the percentage of steel fibers increases.
One of the studies that used steel fibers with prestressed beams was presented by researchers Tadepalli et al. [59] By studying the shearing behavior on (6) beams in the form of (I-Sectio), the variables were the use of two different types of fibers, the first type (Long Fiber) with specifications of length (60 mm) and diameter (0.75 mm) and tensile stress (1400MPa) and the second type (Short Fiber) with a length of (30 mm), diameter (0.55 mm) and tensile stress (1100 MPa). After conducting a laboratory examination, the researchers concluded that increasing the percentage of fibers for the two types increases the shear strength compared to the control beam, in addition to delaying the appearance of the first crack in the shear area and reducing the width of the cracks. The following shows the dimensions of the beams used

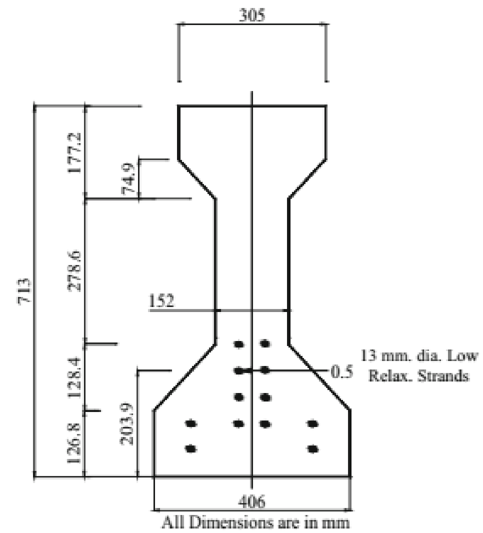

Figure (10): beams used in the study. [59]

Among the studies that dealt with the use of steel and glass fibers on the shear resistance of beams was presented by Abdul Zaher et al. [60] Using (12) concrete beams with dimensions (130*30*12cm), as the percentage of addition to the two types was (0-0.2-0.4-0.6%) of the concrete volume, the beams were divided into two groups, the first without reinforcing stirrups, and the second was adding stirrups Reinforcement and after examining the samples in the laboratory, the researchers concluded that for the first group, the bearing of the concrete beams for shear in the presence of steel fibers is better than that of glass fibers. The second containing shear reinforcing rings is (23.9Ton) when steel fibers are added and (22.5Ton) for fiberglass reinforced beams.
Among the research that dealt with the measurement of strain and hardness, in addition to the shear behavior of concrete beams, was presented by researchers Zhao et al. [65] Using (11) concrete beams with dimensions (2100*300*150mm) and using flexural and shear reinforcement with high yield stress (641.9MPa), steel fibers with percentages ranging (0-3%) were used and after laboratory testing On the beams, the researchers concluded that the shear bearing increases with an increase in the proportion of steel fibers compared to the control beam, in addition to that it works to increase the hardness and reduce the strain on the concrete section and the strain in the stirrups, in addition to its effectiveness in reducing the number and length of cracks as a result of shedding loads.
Among the research that adopted the change in the aspect ratio of the fibers to study the shear was presented by the researchers Xue et al. [66] From a practical study on (19) concrete beams, it was divided into three groups, the dimensions of the models of the first group (1625 * 300 * 150 mm) and the number of (8) beams, and the second group with dimensions (1900 * 300 * 150 mm) with the number of (7) beams, and the third group with dimensions (2175*300*150mm) and with a number of (4) beams for each group, four different types of steel fibers were used, namely (Cutting off- Shear Sheet-Steel ingot Milling-Low alloy steel) to find out the best type to increase the shear strength of the concrete beams and after conducting a laboratory test In general, the researchers concluded that the steel fibers increased the shear resistance, and the researchers reasoned this to the fact that the aspect ratio for all types of steel fibers used was convergent, and the following figure shows the failure of shearing of the beams used in the study.

Figure (11): The failure of the models used in the study[66]

One of the studies that dealt with the type of failure and shear behavior of reinforced concrete beams was presented by researchers Torres and Eva [68] using (10) concrete beams without stirrups reinforcement and dimensions (100 * 120 * 970mm) steel fibers were used in proportions (0.0-0.3-0.6-0.9- 1.2%) with the specifications of length (60mm), diameter (0.75mm), tensile stress (1225MPa), and after examining the models, the researchers concluded that the percentage of steel fibers (1.2%) of the concrete volume can compensate for the use of the minimum shear reinforcing and the type of failure was for the beams For all ratios, shear failure, except for the beams that used (1.2%) steel fibers, the type of failure was Flexure Failure, and the following figure shows the models upon inspection

Figure (12): Models used in the study[68]

In the same context of studying the type of failure and shear behavior when adding steel fibers, what was presented by Yuan et al. [69] If (5) concrete beams with high compressive strength and dimensions (300 * 500 * 4900 mm) were used in all beams, the flexural area was fully reinforced, and the variable was the distances between the shear stirrups as follows: -

1- The first beam, symbolized by (NS-N), was without stirrups reinforcement and without steel fibres.

2- The second beam, symbolized by (105S-N), was with stirrups reinforcement with a diameter of (8mm) and the distance between the stirrups (105mmc/c) and without steel fibres.

3- The third beam, symbolized by (158S-N), was with stirrups reinforcement with a diameter of (8mm) and the distance between the stirrups (158mmc/c) and without steel fibres.

4- The fourth beam, symbolized by (210S-N), was with stirrups reinforcement with a diameter of (8mm) and the distance between the stirrups (210mmc/c) and without steel fibers.

5- The fifth beam, symbolized by (NS-SF), was without stirrups reinforcement and using steel fibers with a percentage of (0.75%) of the concrete volume.

After examining the beam, it was concluded that the type of failure for all beams is Shear Failure, and that the beam (NF-SF) gave good resistance to shear strength, where the percentage of increase in shear was (13.2%) compared to the beam (NS-N), but it varies. Increase and decrease with the rest of the beams armed with stirrups to resist shear. As well as the empirical study of researchers Li et al. [70] Through the use of (10) concrete beams with dimensions (150 * 400 * 3200 mm) that were reinforced for flexion from the bottom with (2ϕ25) and from the top (2ϕ8) and stirrups for shear strength (ϕ6@200mmc/c), steel fibers were added with a ratio of (0.0 -0.4-0.8-1.2-1.6%) , two of the beams were considered as control beams without steel fibres , and the rest of the models were two beams for each percentage of fibers. After examining the models, the researchers concluded that the best percentage of shear strength was (1.6%), as the load rate at the time of emergence was The first crack is in the shear area (103.1 kN), while it was at the control beam as a load rate (77.7 kN), and the failures of all beams are shear failure, except for the beam with fibers added at a rate of (1.6%) where the failure was by flexure only.

VI. CONCLUSIONS

Through the current research, which represents a review of the importance of steel fibers in strengthening concrete members, the following can be concluded:

1- Reinforcement with steel fibers led to improved performance in flexural resistance and an increase in the failure load of concrete members.
2- An increase in the bearing of the shear forces of the concrete members with the addition of steel fibers.
3- Steel fibers have proven to be effective in improving the mechanical properties of concrete.
4- Steel fibers have the ability to increase ductility in addition to bearing the weather conditions of the concrete members.
5- Delaying the appearance of cracks in the bending and shearing areas, in addition to reducing the width of the cracks when loads are increased
6- Conducting more research to know the effect of adding steel fibers to concrete members subjected to kinetic loads (earthquakes). In addition To study the effect of adding fibers to areas exposed to torsion moments.
7- It is necessary to conduct more research to study the flexural and sliding behavior of composite beams (steel-concrete) after adding steel fibers to the concrete part because the research that dealt with this field is very limited.

REFERENCES

[1] Ashour S.A. and Wafa F.F., "Effect of Steel Fibers on The Flexural Behavior of HighStrength Concrete Beams with Low Flexural Reinforcement", The Fourth Engineering Conference, Vol. 2, 2003.
[2] Liu H. Y., Wang L. C., Song Y. P., and Wang H. T., “Experimental study on mechanical properties of steel fiber high strength lightweight aggregate concrete”, Journal of Building Structures, Vol. 28, No. 5, pp. 110–117, 2007.
[3] Miao B., Chern J. C., and Yang C. A., “Influences of Fibre Content on Properties of Self-Compacting Steel Fiber Reinforced Concrete", Journal of the Chinese Institute of Engineers, Vol. 6, No. 4, pp. 523-530, 2003.
[4] Alshihri M. M., Azmy A. M., and El-Bisy M. S., “Neural networks for predicting compressive strength of structural light weight concrete” , Construction and Building Materials, Vol. 23, No. 6, pp. 2214–2219, 2009.
[5] Samman T. A ., Wafa F. F., Radain T. A., "Mechanical Properties of Normal and HighStrength Concrete with Steel Fibers", JKAU Eng.Sci.Journal, Vol.12, 2009.
[6] Gulzar A., Kshipra K., “A Review Study on Steel Fiber Reinforcement Material with Concrete”, IJLRST, Vol. 5, Issue 3, 2016.
[7] Layssi H., Mahoutian A. and Shekarchi M., "Durability Properties of Polypropylene Fiber Reinforced Concrete", Proceedings of the 11th International Conference on Durability of Building Materials and Components (DBMC), Istanbul, Turkey, 11-14 May, 2008.
[8] Jusoh W., Ibrahim I. and Sam A., “Flexural Behavior of Reinforced Concrete Beams with Discrete Steel – Polypropylene Fibers”, MATEC Web of Conferences, 2017.
[9] Farediwala M., “Improving the Mechanical Properties of Conventional Concrete by Using Fiber”, International Journal of Advanced Engineering Research and Studies, 2015.
[10] Park X. and Rew P. Y., ”Constitutive behaviors of steel fiber reinforced concrete under uniaxial compression and tension”, Constr Build Mater, Vol.233, 2017.
[11] Li F. Y., Cao C. Y., Cui Y. X. and Wu P. F., “Experimental study of the basic mechanical properties of directionally distributed steel fibre-reinforced concrete” , Advances in Materials Science and Engineering, 2018.
[12] Altun F., Haktanir T. and Ari. K., “ Effects of steel fiber addition on mechanical properties of concrete and RC beams”, Construction and Building Materials, Vol.21, No. 3, pp. 654-661, 2007.
[13] Swamy R.N. and Ali S.A.R .,"Punching Shear Behaviour of one Reinforce Slab-Column connections made of Steel Fibre Concrete” , J.ACI Journal, Vol.7, 2012.
[14] Wang X. Z., He J., Mosallam A. S., Li C. X. and Xin H. H., “effects of fiber length and volume on material properties and crack resistance of basalt fiber reinforced concrete (BFRC)” , Advances in Materials Science and Engineering, 2019.
[15] Neves R.D. and Fernandes J.C.O, " Compressive behaviour of steel fibre reinforce " , Structural Concrete, 2005.
[16] Khdhum M.M., Esaa M.S. and Hashem K.S., "Effect of shape and type of steel fiber on same mechanical properties of reinforced concrete", Babylon University Magazine, Vol.12, No.5, 2006.
[17] Kosmatka S.H., Kerkhoff B. and Panarese W.C., "Design and Control of Concrete Mixtures", Portland Cement Association, 2009.

[18] Fanella D.A. and Naaman A.E., “stress-strain properties of fiber reinforced mortar compression”, ACI journal ,Vol.8, pp.457-483, 2010.
[19] Colin D. and Johnston H., “Fiber reinforced cements and concretes” , Advances in concrete technology ,Vol. 3, 2011.
[20] Al-Ta’an S. A. and Al-Neemie Z. S., "Fresh and Hardened Properties of Steel Fibres Reinforced Self- Compacted Concrete", International Jour. of Applied Engineering Research, Vol. 6, No. 13, pp. 1565-1578, 2011.
[21] Mollaahmadi E., Haji S.and Javaheri M.R., "An Experimental Investigation into the Effect of Polypropylene Fibers on Mechanical Properties of Concrete", Journal of American Science, 2011.
[22] Shende.A.M. and Pande.A.M, "Experimental study and prediction of tensile strength for steel fiber reinforced concrete", International Journal of Civil and Structural Engineering , Vol.1, No.4, 2011.
[23] Shende A.M., Pande A.M. and Gulfam M., "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade" , International Refereed Journal of Engineering and Science (IRJES), Vol.1, Issue 1, PP 43-48, 2012.
[24] Shende.A.M. and Pande.A.M., “Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade”, International Refereed Journal of Engineering and Science , Vol. 1, 2012.
[25] Chen Y.Y. and Hwang C.L., “Study on Electrical Resistivity and Chloride Ion Penetrability Behavior of Concrete Material“, Journal of the Chinese Civil and Hydraulic Engineering, Vol.13, pp. 293–302, 2012.
[26] Pawade P.Y., Pande A.M. and Nagarnaik P.B., "Effect of Steel Fibers on Modulus of Elasticity of Concrete" , International Journal of Advanced Engineering Sciences and Technologies (IJAEST), Vol 12, No.2 , 2013.
[27] Gul M., Bashir A. and Naqash J., "Study of Modulus of Elasticity of Steel Fiber Reinforced Concrete",International Journal of Engineering and Advanced Technology (IJEAT), Vol.3, Issue 4, 2014.
[28] Shireesha N. , Bala M. S. and Nagesh G., "Experimental Studies on Steel Fiber Reinforced Concrete" , International Journal of Science and Research (IJSR), Vol. 4 , Issue 9, 2015.
[29] Sarsam K. and Azzawi Z. M., "Mechanical Properties of High-Strength Fiber Reinforced Concrete", Eng. & Tech. Journal, Vol.28, N0.12, 2015.
[30] Prasad K.R. and Jegidha K.J., " Experimental Study on Behaviour of Steel Fiber Reinforced Concrete", International Journal of Engineering Science and Computing, Vol. 7, Issue 3, 2017.
[31] Huda S., Ahmad A. and Khan Z.R., "An Experimental Study of Fly Ash Concrete with Steel Fiber Hooked Endes to Obtain Strength of M30 Grade", International Journal of Civil Engineering and Technology (IJCIET), Vol.8, Issue 3, pp 282–291, 2017 .
[32] Raveendra P. G. and Venkateswara R. K., "Experimental Study on Behaviour of Polymer Modified Steel Fiber Reinforced Concrete", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 5, 2018.
[33] Yanxia Y. , Jilei L. , Zhiyin Z., Zongbin W. and Qiongwu P., "Experimental Study of High-Strength Steel Fiber Lightweight Aggregate Concrete on Mechanical Properties and Toughness Index", Advances in Materials Science and Engineering, Vol. 20, 2020.
[34] Venugopal M.E., "Experimental Investigation of concrete wiyh Steel Fiber and Study of the Mechanical Properties of Recycled Aggregate Concrete", International Journal of Scientific & Engineering Research, Vol. 11, Issue 3, 2020.
[35] Ahmed j., Nasr R. and Zaid A., "Evaluating the Effects of Flexure Cracking Behavior of Beam Reinforced with Steel Fibers ", Journal of Green Engineering (JGE), Vol.10, Issue.9, 2020.
[36] Sawant V. V. , Pise C. P. and Lakade G. D., " Experimental Study on High Performance Steel Fibre Reinforced Concrete using Metakaolin", International Journal of Engineering Research & Technology (IJERT), Vol. 10, Issue 02, 2021.
[37] Chaitanya J. D., Manikanta G., Taraka V., Abhilash G. and Kasim P., " Experimental Study on Steel Fiber Concrete ", ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 19, 2021.
[38] Noghabai K. , “ Beams of Fiberous Concrete in Shear and Bending“, Experiment and Model. Journal of Structural Engineering (ASCE), Vol.126, No.2, pp 243-251, 2011.
[39] Behbahani H.P., Nematollahi B. , Mohd A.R, and Lai F. C., "Flexure Behavior of Steel-Fiber-Added-RC (SFARC) Beams with C30 and Classes of Concrete", International Journal of Sustainable Construction Engineering & Technology, Vol. 3, Issue 1, 2012.
[40] Vasant. B., Jatale and Kalurkar L. G., " Flexural Strength of High Strength Steel Fiber-Reinforced Concrete Beams with Stirrups", Journal of Engineering Research and Application, Vol. 3, Issue 6, pp.1580-1586, 2013.
[41] Johnston C.D and Colin D., “Fibre Reinforced Concrete”, Progress in Concrete Technology CANMET, Energy, Mines and Resources, 2014.
[42] AL-Kaissi Z. , Daib A.S. and Abdull-Hussain R.R., " Experimental and Numerical Analysis of Steel Fiber Reinforced Concrete Pavement ", Journal of Engineering and Sustainable Development, Vol. 20, No. 06, 2016.
[43] Tamil M. , Dasarathy A. K. and Thandavamoorthy T.S., "A Study of Flexural and Bending Strength of Steel, Polypropylene and Hybrid Fibre Reinforced Concrete without Adding Admixture", International Journal of Engineering & Technology, Vol.7, pp. 278-282, 2018.

[44] Tabassum N., Biswas P , Saiful I. and Moinul I. , " A study on the Compressive and Flexural Strength Behavior of Steel Fiber Reinforced Concrete Beam ",International Journal of Advanced Research (IJAR), Vol. 6, Issue 8, pp.557-567, 2018.
[45] Ranjbaran F., Rezayfar O. and Mirzababai R., "Experimental investigation of steel fber-reinforced concrete beams under cyclic loading", International Journal of Advanced Structural Engineering, 2018.
[46] Yang I. H., Joh C., and Kim K. C., "A comparative experimental study on flexural behavior of high-strength fiberreinforced concrete and high-strength concrete beams" , Advances in Material Science and Engineering, Vol. 2018, 2018.
[47] Choi W., Jung K., and Yun H., " The Influence of Steel Fiber Tensile Strengths and Aspect Ratios on the Fracture Properties of High-Strength Concrete", www.mdpi.com/ Journal/materials, 2019.
[48] Hasan A., Nyazi M. and Yassin I., "Effects of Polypropylene Fiber Content on Strength and Workability Properties of Concrete", Polytechnic Journal, Vol.9, pp. 7-12, 2019.
[49] Abbass A., Abid S., and Mustafa O., "Experimental Investigation on the Effect of Steel Fibers on the Flexural Behavior and Ductility of High-Strength Concrete Hollow Beams", Advances in Civil Engineering, Vol.2019, 2019.
[50] Scyh L.," Effect of adding steel fibers on the flexural behavior of reinforced concrete beams", www.researchgate.net/publication, 2019.
[51] Ali W.A., Ibrahim A. and Ebead U., " Flexural Behavior of RC Beams Strengthened with Steel Fibers", International Journal of Applied Engineering Research, Vol. 15, No. 5, 2020.
[52] Cardosoa M., Lameirasa R.M. and Capuzzoa V., " Influence of concrete strength, fiber content and aspect ratio in the residual flexural strength of steel fiber reinforced selfcompacting concrete", IBRACON Structures and Materials Journal, vol. 14, No. 5, 2021.
[53] Kwak Y.k.,Ebrahed M.O. and Kim J., "Shear Strength of Steel-Reinforced Concrete Beams without stirrups", ACI Structures Journal, 2002.
[54] Endgington D.J. and Williams R., "Steel fiber reinforced concrete", Current paper CP 69/74 Building research establishment Garston Watford , 2010.
[55] Wiliamson G.R., "The Effect of Steel Fibers on Compressive Strength of Concrete Fiber Reinforced Concrete", Detroit .Michigan (USA), 2010.
[56] Al-Sarraf S.Z., Al-Shaarbaf I. and Diab S., "Effect of Steel Fiber on The Behavior of Deep Beams With and Without Web Opening", Eng. & Tech. Journal, Vol. 29, No. 1, 2011.
[57] Daniel D., Fernanda G., Romildo and Moacir A., "Shear strength of steel fiber-reinforced concrete beams",Acta Scientiarum. Technology, vol. 36, no. 3, pp 389-397, 2014.
[58] Balgude V.V., "Experimental Study on Crimped Steel Fiber Reinforced Concrete Deep Beam in Shear", IOSR Journal of Mechanical and Civil Engineering, Volume 11, Issue 2, PP. 24-39, 2014.
[59] Tadepalli P.R., Hemant B. and Thomas T. C., " Shear Strength of Prestressed Steel Fiber Concrete I-Beams", International Journal of Concrete Structures and Materials, Vol.9, No.3, pp.267–281, 2015.
[60] Abdul-Zaher A.S., Laila M. A., Tawfic Y.R. and Hammed O., "Shear Behavior of Fiber reinforced concrete beams", Journal of Engineering Sciences, Vol.44, No.2, pp. 132 – 144, 2016.
[61] Archana P., Ashwini N. N., Sanjana R., Harshita V. and Dinesh S. M., "Study of Strength of Polypropylene Fiber Reinforced Concrete", International Journal of Engineering Research & Technology (IJERT), Vol.6, pp. 8-11, 2017.
[62] Australian Standard AS 3600, Published by the Standards Association of Australia Standard House, 80 Arthur ST, North Sydney, N.S.W, 1988.
[63] Lana D., Santos D. and Gomesa L.D., Medeirosb A.B. and Macedob M.," Experimental analysis of the efficiency of steel fibers on shear strength of beams", Latin American Journal of Solids and Structures, 2018.
[64] Mashrei M. A. and Ali A. S., "Effects of Polypropylene Fibers on Compressive and Flexural Strength of Concrete Material", International Journal of Civil Engineering and Technology (IJCIET), Vol.9, pp. 2208–2217, 2018.
[65] Zhao J., Liang J. and Shen F., " Experimental Study on Shear Behavior of Steel Fiber Reinforced Concrete Beams with High-Strength Reinforcement", www.mdpi.com/ Journal/materials, 2018.
[66] Xue X., Hua X. and Zho J.," Test and prediction of shear strength for the steel fiber–reinforced concrete beams", Advances in Mechanical Engineering, Vol.11, No.4, 2019.
[67] Tantary M.A., "Prediction of Shear Strength of Steel Fibre Based Concrete Beams without Shear Stirrups", International Journal of Recent Technology and Engineering (IJRTE), Vol.7, Issue.6, 2019.
[68] Torres J.A. and Eva O.L.," Influence of Fiber Content on Shear Capacity of Steel Fiber Reinforced Concrete Beams", www.preprints.org, 2019.
[69] Yuan T.F., Yeol D., Yang J.M. and Young S., "Shear Capacity Contribution of Steel Fiber Reinforced High-Strength Concrete Compared with and without Stirrup", International Journal of Concrete Structures and Materials, 2020.

[70] Li C., Zhao M., Jie L. and Mingshuang Z. , " Effect of Steel Fiber Content on Shear Behavior of Reinforced Expanded-Shale Lightweight Concrete Beams with Stirrups", www.mdpi.com/ Journal/materials, 2020.