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Civil Engineering Department

INVESTIGATION OF FIBER-REINFORCED CONCRETE SLABS INCORPORATING DUNE SAND AS SAND REPLACEMENT

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

﴿ وَيَسْأَلُونَكَ عَنِ الرُّوحِ ۖ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلًا ﴾

سورة الأسراء الآية 85

صدق الله الْعَلِيُّ الْعَظِيمُ

DEDICATION

To the first teacher of humankind, the Prophet Mohamed (peace be upon him)

To my dear mother and dear father

To my dear sisters

To the companion of my life my dear wife

To my sons

To all of these, I dedicate this study, I hope from Allah, that it will be a window of knowledge and useful to society

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Ahmed Mejbel

SUPERVISOR CERTIFICATION

I certify that the preparation of this thesis entitled "**Investigation of fiber – reinforced concrete slabs incorporation dune sand as sand replacement**" was presented by "**Ahmed Mejbel Jber**", and prepared under my supervision at the University of Misan, Department of Civil Engineering, Collage of Engineer, as a partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Structures).

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In view of the available recommendations, I forward this thesis for discussion by the examining committee.

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EXAMINING COMMITTTEE'S REPORT

We certify that we, the examining committee, have read the thesis titled **(Investigation of Fiber-Reinforced Concrete Slabs Incorporating Dune Sand as Sand Replacement)** which is being submitted by (**Ahmed Mejbel Jber Al-Jabri**), and examined the student in its content and in what is concerned with it, and that in our opinion, it meets the standard of a thesis for the degree of Master of Science in Civil Engineering (Structures).

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ABSTRACT

The environmental problems of sand dunes, the most important of which is the creep of this sand on the roads and its sudden spread in the ground and others, can be addressed by using it as a fine aggregate in concrete. The aim of the thesis is to study the effect of using sand dunes as a replacement for sand in fiber-reinforced concrete slabs. The study was divided into two parts;

The first part included a study of the effect of using sand dunes as a partial and total replacement of sand on the mechanical and physical properties of reinforced concrete mixtures with single and hybrid steel fibers. The second part included a study of the effect of using sand dunes as a replacement for sand on the structural behavior of steel fiber-reinforced concrete slabs.

The experimental program of the thesis included the use of six replacement ratios (by weight) for sand dunes (0%, 20%, 40%, 60%, 80%, 100%).24 concrete mixes were cast, (6) without fibers, and (18) mixes reinforced with steel fibers. Two types of fibers were used in this study, micro straight steel fibers with a length of 13 mm and macro steel fibers (hooked ends) with a length of 50 mm, (single and hybrid), with a constant ratio of 1% of the concrete volume. The mechanical tests for the first part include compression, split tensile and flexural strength, while physical tests carried out were, dry density, absorption, ultrasonic pulse velocity of concrete, static and dynamic modulus of elasticity, in addition to slump test.

The tests included the second part, which includes testing Twenty-four simply-support concrete slabs with dimensions (thickness,width,length) (80 × 800 × 800) mm were tested, with the slab support system containing four column points at the corners on which the slab sits, under one center bearing point in the middle of the slab. Where the maximum failure load, ultimate deflection, strain, ductility of the fiber-reinforced slabs, absorption energy, stiffness, as well as failure pattern were obtained. The results of the first part tests showed that the workability decreases with

all replacement ratios of sand dunes in steel fiber reinforced concrete, and improvement in mechanical properties with increasing sand dune content in fibrous concrete mixtures. Concrete mixtures (40% Sand Dunes + 1% Hybrid Fiber), (20% Sand Dunes + 1% Hybrid Fiber), and (20% Sand Dunes+ 1% Long Fiber) achieved the highest compressive, splitting tensile, and flexural strength, with an increase of 26.6%, 52.9 %, and 45.3%, respectively, for the above mixtures, compared to the mixtures without fibers. This increase is due to the fineness of the sand dune grains that fill the voids and gaps between the gravel and sand when the replacement is partial, in addition to the role of fibers in increasing the cohesion and interconnection of the components of the mixture. The mechanical properties decrease when the dune content exceeds 60% for compressive strength and 80% for tensile and flexural strength compared to the control mixture. The results also showed an improvement in the physical properties with an increase in the dune content of the specimens reinforced with steel fibers up to the replacement ratios of sand dunes (80% for dry density, 40% for ultrasonic pulse velocity, 60% for absorption, static and dynamic While the test results of the slabs in the second part showed that the increase in the content of sand dunes leads to an increase in the ultimate failure load, absorption energy, and initial and effective stiffness of the replacement ratios (0%-40%) for all slabs reinforced with steel fibers, especially the longer fibers, with an increasing rate of about 5.6%,8.9%, 13.6%, and 22.4%, respectively, compared to the slabs reinforced with long steel fiber without sand dunes. While the ultimate deflection decreased with the increase of sand dunes in the long and hybrid fiber reinforced slabs at the replacement ratio of 40%. The failure pattern for all slabs is a flexural failure, and the crack path is linear between the up and down directions of the slab.

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LIST OF SYMBOLS AND ABBREVIATIONS

FRC	Fiber Reinforced Concrete
HPFC	High-performance fiber reinforced concrete
DSFC	Desert sand-based fibrous concrete
W/C	Water to cement ratio
HPC	High-performance concrete
RCP	Rapid chloride penetration
PVC	Polyvinyl chloride
CFST	Concrete Filled Steel Tube
DSC	Desert Sand Concrete
RC	Control Reinforced Concrete
SFRC	Steel Fiber Reinforced Concrete
SW	Seawater
DSS	Dredging Sea Sand
PVA	Polyvinyl Alcohol
PP	Polypropylene
RCA	Recycled Concrete Aggregates
NA	Natural Aggregates
D.S	Dune Sand
N.S	Natural Sand
S.F.S	Steel Fiber Short
S.F.L	Steel Fiber Long
H.S.F	Hybrid Steel Fiber
S	Short
L	Long
HY	Hybrid
L.O.I	Loss On Ignition
l	length
w	width
t	thickness
D	Diameter
P	Maximum Load
RO	Reverse Osmosis
0%D.S+1%S.F.S	0%Dune Sand + 1% Steel Fiber Short
0%D.S+1%S.F.L	0%Dune Sand + 1% Steel Fiber Long
0%D.S+1%H.S.F	0%Dune Sand + 1% Hybrid Steel Fiber
γ_c	Concrete unit weight
S.P	Superplasticizer

ASTM	American Society for Testing and Materials
ACI	American Concrete Institute
BS	British Standards
EN	European Standard
IS	Indian Standard
CEB	Comite Euro-International du Beton
Fr	Modulus of rupture
f_{cu}	compressive strength
f_c^-	Cylinder compressive strength
Ft	Splitting Tensile strength
W.A	Water Absorption rate
UPV	Ultrasonic pulse velocity
Ed	Dynamic Modulus of Elasticity
E	Static Modulus of Elasticity
E_C	Code equation for Static Modulus of Elasticity
V	velocity
μ	Poisson's ratio
ε	Strain
LVDT	Linear Variable Displacement Transformer
DSC0%	Dune Sand 0% Concrete Slab
FRDC0%-S	Fiber Reinforced Dune Sand concrete 0% - Short fiber
FRDC0%-L	Fiber Reinforced Dune Sand concrete 0% - Long fiber
FRDC0%-H	Fiber Reinforced Dune Sand concrete 0% - Hybrid fiber
0%D.S+1%S.F.S	0%Dune Sand + 1% Steel Fiber Short
0%D.S+1%S.F.L	0%Dune Sand + 1% Steel Fiber Long
0%D.S+1%H.S.F	0%Dune Sand + 1% Hybrid Steel Fiber
Pu	Ultimate failure load
Δu	Ultimate deflection
PY	Yield load
Δy	Deflection at Yield load

LIST OF EQUATIONS

CHAPTER ONE: INTRODUCTION

1.1 General

For thousands of years, human has been searching for materials that are used in building and construction, so he used mud, stones, and wood in that construction until the era of the emergence of civilizations began. So materials and tools for construction progressed, including the use of sand, gravel, water, and binder material in construction. The increase in the human need for construction is no less important than his need for water, food, and energy, so it was necessary to search, discover and develop the basic and necessary materials needed for construction. From these materials are the composition of concrete, which consists of natural raw materials, which are sand, gravel, and water, in addition to the binding material represented by cement. With the passage of time and the emergence of cultural and urban expansion and the increase in population density, the demand for raw materials used in construction increased. The demand for the provision of building materials increased significantly at a time when these materials began to gradually deplete. Therefore, it was necessary to find alternatives to these materials for use in the manufacture of concrete and construction. Among these natural materials that are widely available in abundance are sand dunes, which have begun to spread and expand dramatically, especially in the southern, central, and western regions of Iraq. Several researchers and scientists presented a description of dunes sand .Longwell et al. [1],described the dune sands as rock fragments that were blown by the wind to form sands that later gather and form small plateaus that are sometimes circular, longitudinal, or irregular sometimes figure. While Holm [2], explained that sand dunes are a topographic phenomenon that arises from the air and consists of sand from natural sources, and it is found in any environment where sand is available and it is free to move. Gleen [3], described it as a group of hills or a series of sediments that are dispersed by the wind, and they usually have a small slope facing the wind and another side, more steeply, that is shaded by the wind, called the slippery surface. In spite of the difference in the above descriptions, the difference is not great because dunes are a natural form of the earth's surface that consists of soft sediments, and it consists of erosion processes and carving rocks of the earth's crust, Then comes the wind factor, which is the most important factor in the formation of sand dunes, which helps to transfer the product of rock fragments.

1.2 Sand dune problem in Iraq

Iraq is one of the countries that experienced a severe environmental impact that led to the emergence of large amounts of sand dunes due to high temperatures, lack of rainfall, increased drought, and the spread of winds. These and other factors contributed to the emergence of the phenomenon of desertification in Iraq, where large areas of agricultural land were transformed into barren and open lands prepared to be areas for gathering sand dunes, which began to gradually increase and approach the cities, especially the areas of southern Iraq. The increase in sand dunes causes environmental problems that have a negative impact on the land, as lands and roads are transformed into areas that embrace the dunes. The phenomenon of sand dunes is considered dangerous during its gathering due to the difficulty of treating it on the ground, as its fine grains are always mobile and unstable due to it dune's movement by wind, as this movement leads to the spread in large areas of land and transportation routes and works to impede the movement of cars in addition to many environmental problems resulting from it. Sand dunes are a source of concern to many researchers and specialists in various fields because they are an inexhaustible material. Aggregate makes up about two-thirds of the volume of concrete and is made up of fine aggregate (sand) and coarse aggregate (gravel). The regions of Iraq are characterized by the presence of large quantities of sand dunes that are constantly increasing without finding solutions to these quantities and benefiting from them in order to preserve the environment and reduce their negative impact. The question here is how can sand dunes be exploited as a fine aggregate in concrete instead of sand and benefit from it as a natural resource that is abundantly available and used as one of the materials in the production of low-cost concrete, as well as its use in concrete applications and building materials. Thus, reducing its environmental problems when transforming it from a material that has a negative impact on nature into a basic and useful material that enters the production of concrete. So the researchers tried to answer this question by using this material that is characterized by fineness, and to indicate its suitability as one of the components of concrete represented by fine aggregates, and to use it completely or mixed with natural graded sand for the purpose of improving the grains of this fine mixture.

1.2.1 Dune sand in Misan city

Sand dunes are a group of sediments of different sizes and spread by wind, often sourced from loose sedimentary rocks or igneous metamorphic rocks due to erosion and weather factors represented by rain and wind. Sand dunes are distributed in large areas of Iraq as shown in Figure 1.1[4], where they are distributed in most areas of western, central, and southern Iraq due to the high temperatures in these areas, the increase in wind speed, and the low rainfall quantities. Some human factors have also exacerbated the problem of desertification and the increase of sand dunes in Iraq, which led to the occurrence of various environmental phenomena, including the increase in large areas of land containing sand dunes, reaching (67,000) thousand acres for the year 2017 in the areas of Misan Governorate [5].These sand dunes were distributed in the areas of Ali Al- Gharbi, Ali Al -Sharqi, and Al-Kumait, north Misan Province. The sand dunes in these areas are characterized by their fine grains and they spread quickly and suddenly over the main roads in those areas, and their thickness may reach two meters or more, as shown in Figure 1.2[5]. Also, sand dunes are found in the areas of Chailat, and Al-Tayyib, northeast of Misan province in large quantities. As well as the Al-Batera area, west of Misan governorate, which contains large amounts of sand dunes, 65 km away from the center of Al-Amarah city. The sand dunes of this area were used in this study and as in Figure 1.3.

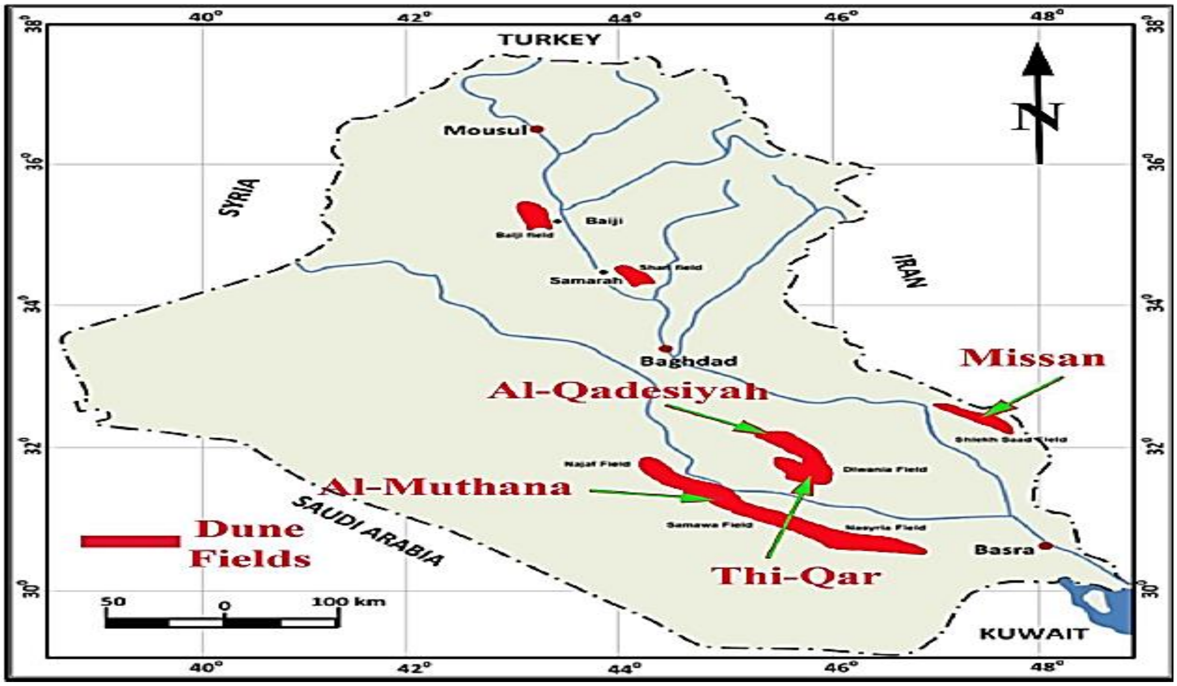


Figure 1.1 Spatial distribution of sand dunes in Iraq [4].

Figure 1.2 Dunes covering a street in Ali Al- Gharbi district [5].

Figure 1.3 The sands of the dunes in the Al-Batera region.

1.3 The Fibers

A long time ago, materials have been used to help strengthen building materials, including fiber additives. Where natural fibers were used in various building materials. Horsehair was used to strengthen masonry mortar and plaster, while straw was used to make mud bricks. With the discovery of the technology (Hatschek) for the production of asbestos fibers in 1898[6]. The extensive commercial use of fibers in cement paste began in the fifties of the last century, the issue of fiber-reinforced concrete attracted the attention of many scientists and researchers at the time. Once the health concerns associated with asbestos fibers are recognized, it became necessary to find an alternative to this material in concrete and other building materials. Steel fibers, glass, and synthetic fibers were used in concrete in the 1960s [6]. We can give a general description of the fibers used in construction as small and chopped parts added to the concrete mix or any other mixture and it is considered a reinforcing material for it and distributed randomly within the concrete body, unlike the reinforcing bars that are used in construction. These fibers are of different types and shapes, and their properties differ from one type to another. Such as natural plant fibers and animal fibers, as well as steel fibers, glass, carbon, and others, as for their shapes, they can be of circular, square, or polygonal cross-section, either long or short fibers.

1.3.1 Types of Fibers

Fibers are characterized by their shapes, types, and properties. There are large numbers of them used to improve concrete properties and for reinforcement .It can be classified according to the origin of the material from which it is composed into natural plant fibers. The natural plant fibers such as hemp, cellulose, bamboo, and straw, which have been used in building materials for a long time, and while the synthetic fibers which were manufactured from raw materials such as steel fibers, glass, carbon, and polymeric fibers, as shown in Figure 1.4 [7]. Each of these varieties has different physical and chemical properties such as density, color, chemical activity, roughness or softness, fire resistance, specific weight, as shown in Figure 1.5 [8].As well as its mechanical properties such as Young's modulus, tensile strength, and maximum elongation, as shown in Figure 1.6 [8].

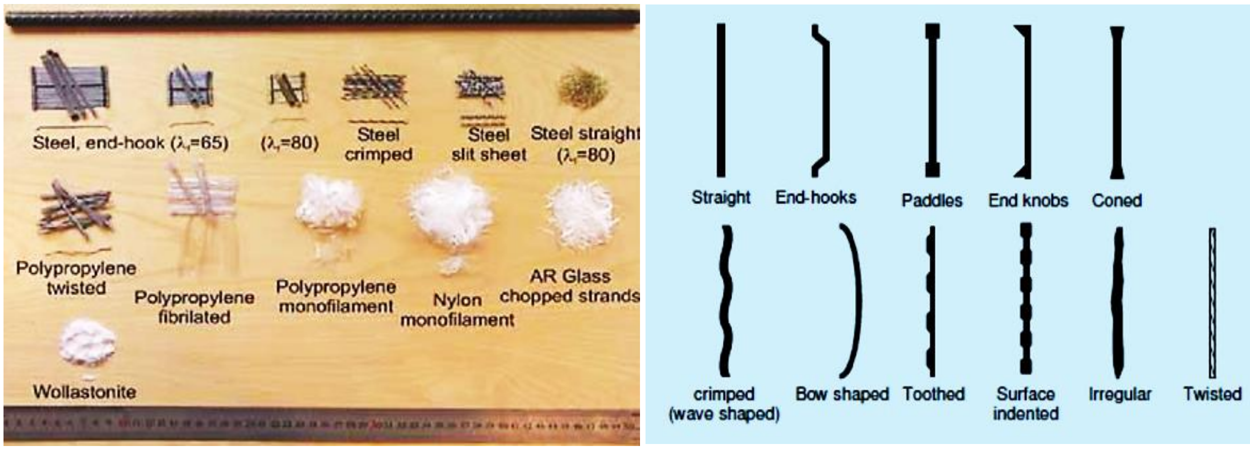


Figure 1.4 Various types of commercially available fibers [7].

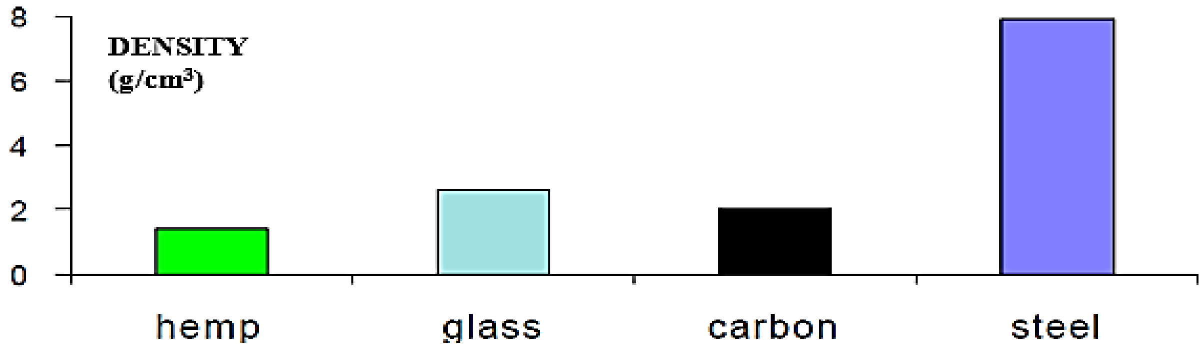


Figure 1.5 Comparison of the density of some types of fiber [8].

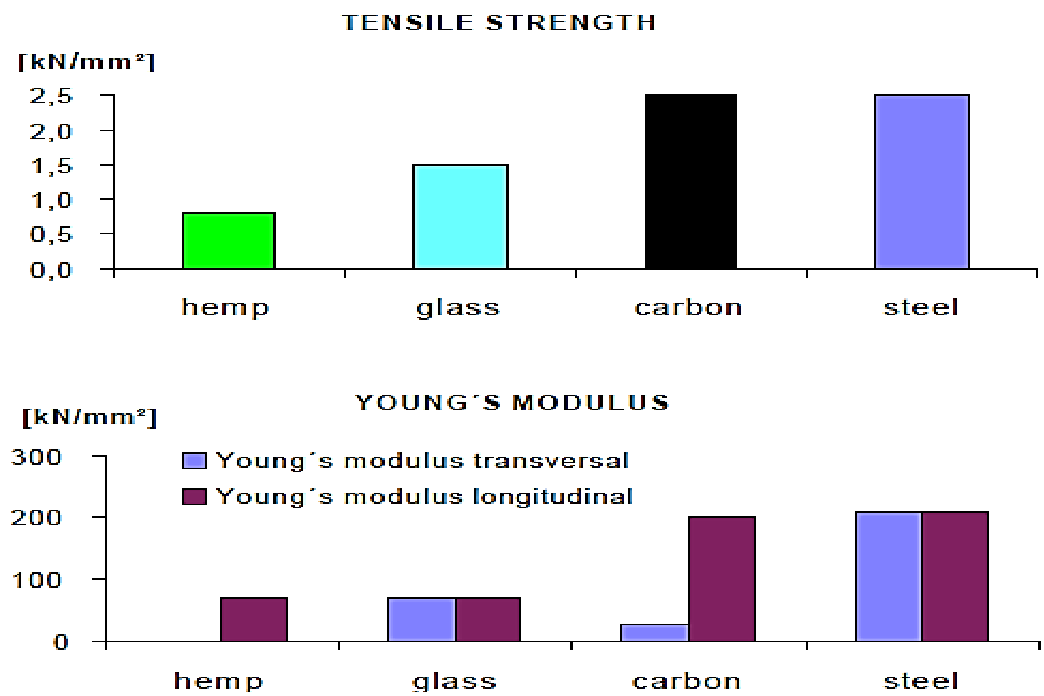


Figure 1.6 Tensile strength and Yong's modulus of some types of fibers [8].

As well as other properties of the fibers are represented in the shape of the geometrical section such as length and diameter, as most of these fibers have a cross-section of circular or square, or polygon, as shown in Figure 1.7 and Table 1.1.

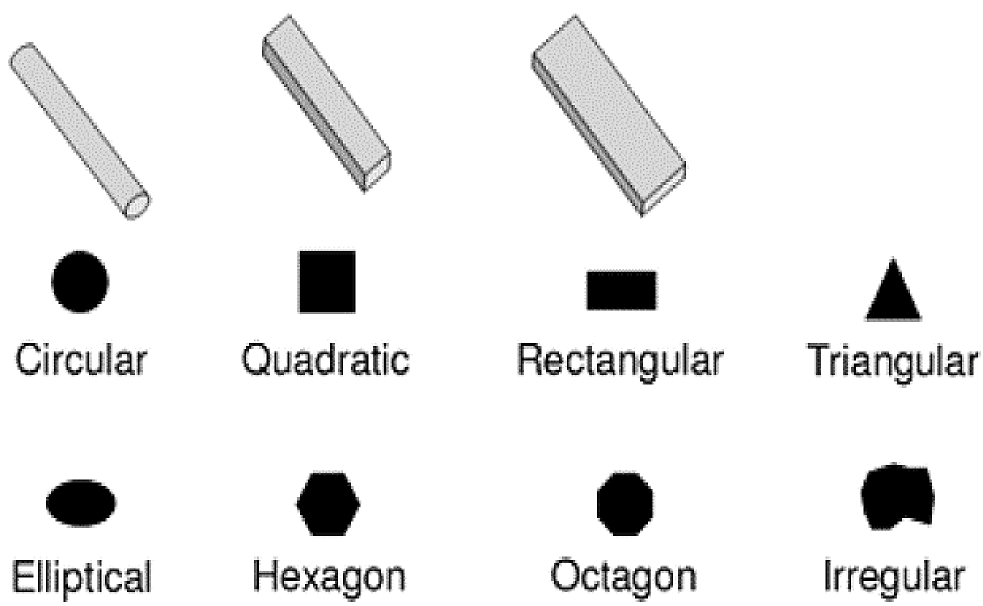


Figure 1.7 Cross-sectional shape of some types of fibers [7].

Table 1.1 The physical properties of different types of fibers [7]

Type of Fiber	Diameter (micrometer) [μm]	Specific gravity [g/cm^3]	Tensile strength [MPa]	Elastic modulus [GPa]	Ultimate elongation [%]
Metallic					
steel	5-1000	7.85	200-2600	195-210	0.5-5
Glass					
E glass	8-15	2.54	2000-4000	72	3.0-4.8
AR glass	8-20	2.70	1500-3700	80	2.5-3.6
Synthetic					
Acrylic (PAN)	5-17	1.18	200-1000	14.6-19.6	7.5-50.0
Carbon (low modulus)	7-18	1.6-1.7	800-1100	38-43	2.1-2.5
Carbon (high modulus)	7-18	1.7-1.9	1500-4000	200-800	1.3-1.8
Nylon (polyamide)	20-25	1.16	965	5.17	20.0
Polyester(PET)	10-8	1.34-1.39	280-1200	10.18	10-50
Polyethylene (PE)	25-1000	0.96	80-600	5.0	12-100
Polypropylene (pp)	10-200	0.90-0.91	310-760	3.5-4.9	6-15.0
Polyvinyl(PVA)	3-8	1.2-2.5	800-3600	20-80	4-12
Natural- organic					
Cellulose(wood)	15-125	1.50	300-2000	10-50	20
Bamboo	50-400	1.50	200-440	33-40	-
Jute	100-200	1.02-1.04	250-350	25-32	1.5-1.9
Natural-inorganic					
Asbestos	0.02-25	2.55	200-1800	164	2-3

1.3.1.1 Steel Fibers

Steel fibers were chosen for this investigation due to their low cost and availability in the local markets in different shapes and dimensions, with aspect ratios ranging from 25 to 100 with different cross-sections. Steel fibers are characterized by having Young's modulus of 210 MPa, a density of 7850kg/m^3, and tensile strength ranging from (200-2600) MPa, and their lengths ranging from (6.4-76) mm, the diameters are between (0.2-1) mm .The percentage of fiber added to concrete varies between (0.5-3%) of the volume of concrete [9]. and its shapes vary such as straight, hook-end, wavy, concave fiber, and others.

This study was add steel fibers to concrete to increase its efficiency and quality. These fibers are used as concrete reinforcement, to avoid shrinkage and cracking, and increase the resistance of concrete. It is also known that ordinary concrete weak in tensile strength when cracks appear and is considered a brittle material when exposed to loads. For the purpose of improving the properties of concrete, a large number of researchers have concluded that adding fibers to ordinary concrete leads to improving the mechanical properties of this concrete and increases its durability. [10]–[13].

1.3.2 Advantages of steel fibers in concrete

Adding steel fibers to the components of the concrete mixture helps to produce concrete with better specifications than regular concrete, and it also, improves its mechanical properties in general. The advantages of adding steel fibers to the concrete mixture are:

1- Improve flexural strength, increase energy absorption capacity, develop ductile behavior before reaching the final collapse stage of concrete, and improve the durability and sustainability of concrete [10].

2- Increases the tensile strength of concrete and helps in improving the flexural resistance .It works to seal cracks and connects both ends of the cracks. And it helps in distributing the stresses received by these fibers from inside or outside the concrete and distributes them evenly throughout the concrete body. These fibers have a major role in the post-cracking stage. It also improves the ductility of concrete [11].

3- Improve the shear resistance of concrete and increase the punching shear resistance of concrete slabs. Steel fibers contribute to improving all mechanical properties of concrete and help in giving a positive role to concrete, especially when used in earthquake-prone locations [12].

1.3.3 Differences and similarities between reinforcing bars and Fibers.

Both fibers and reinforcing bars play the same role, which is to resist all tensile stresses except for some differences between them, which are:

1-The fibers are distributed throughout the concrete body, unlike reinforcing bars, which are only held in place.

2-There is no space between the piece of fiber and the outer face of the concrete, as the fibers intertwine with the concrete, unlike reinforcing bars, where there is a space between the center of the bar and the concrete face.

3-Most of the fibers are short and vary in length and the distance between them is close in contrast to the reinforcing bars, which are long and with a fixed distance between one rod and another.

4-The work of fiber and adding it to the components of the concrete mix does not require the hands of workers specialized in rebar, and it is quick to work, more economical, and reduces the cost of construction, unlike reinforcing bars that require rebar workers (blacksmiths) to measure, cut, spread and connect the reinforcing bars, thus increasing the cost of construction.

1.3.4 Types of concrete with fiber

Fiber concrete consists of a mixture of cement, sand, gravel, water, and fibers, and some plasticizers may be added to it to improve its workability, and according to the number, shape, and type of fibers added to it, can classify concrete into two main classes:

1-Single fiber reinforced concrete: a concrete that contains one type of fiber, which may be glass, steel, or other fibers. Concrete is called according to the type of fiber added to it.

2-Hybrid fiber concrete: a concrete that contains two or more types of fibers, and each type of these fibers differs from the other type in different physical and engineering properties such as length, shape, and type. Adding this different mixture of fibers in the concrete in order to take advantage of the properties of each type of fiber in concrete, a feature may not be available in one fiber and be present in the other type. This difference in the diversity of fibers is attributed to a number of factors, the most important of which is the development of the properties of this concrete, including [13]:

A- When we use two types of fibers, one of them may be short, characterized by high tensile strength and stiffness, and the other type used has a high Young's modulus. This lead to fiber reinforced concrete, and the role of the first type of fiber is to increase the resistance of concrete, while the role of the second type of such fiber additive (long) is to reduce large cracks, as well as increase the durability of concrete.

B- The role of long fibers is to bind large cracks, while the other type, less long, is to bind small cracks.

1.4 The aims of the research

The main aims of this study is to address the problem of sand dunes that cause many environmental problems and to benefit from them as an alternative for sand in concrete in partial and total ratios because it is an available and cheap material with the addition of fibers to it to increase its efficiency and quality. The addition of sand dunes to the concrete mix will benefit in achieving two main goals: The first is an environmental benefit represented in the scaling and reduction of sand dunes and their utilization into concrete and building materials. The second is an economic benefit represented in the lower cost of materials.

The objectives of the work scientifically are to know the optimal ratios for using sand dunes as an alternative to sand, meaning to know the suitability of this sand as a fine aggregate in concrete and to study the effect of fiber. The study of the physical and mechanical properties of this concrete. The study of the behavior of concrete slabs reinforced with single and hybrid steel fibers and containing sand dunes as a partial and total alternative for sand.

Therefore, in this study, will invest the presence of large quantities of sand dunes and introduce it into concrete as a fine aggregate instead of sand with the addition of fibers to it to obtain sustainable concrete that differs in its properties from ordinary concrete by introducing a natural alternative to one of the components of concrete and using it in various fields of construction as a cheap material it is widely available as a building material in the future.

1.5 Thesis Layout

This study consists of five chapters:

• **Chapter One**: This chapter provides a general introduction to the material of sand dunes and their use in concrete, and its environmental problems. The chapter also deals with adding fibers to concrete, knowing the types of fibers and their advantages in concrete, as well as knowing the objectives of this research.

• **Chapter Two**: This chapter presents a review of previous studies and research and results, then look at some previous research that uses sand dunes as an alternative for sand in concrete, with the addition of fibers to it. Other studies on its uses in concrete members such as beams, and slabs, have been reviewed, studying their properties and behavior.

• **Chapter Three**: In this chapter, the raw materials used in the concrete mixtures for this research were presented . The details and properties of these materials with the replacement ratios of sand dunes . The addition of fibers in concrete, as well as work steps, methods of casting and curing, and types of tests for specimens.

• **Chapter Four**: Deals with presenting the results of tests and comparing them with the results of reference tests and drawing the relationships between these results and discussing and evaluating the results.

• **Chapter Five**: The most important conclusions obtained as a result of the tests conducted during this investigation, in addition to some recommendations and proposals that document this study and ways to improve and update it for future studies and research.

CHAPTER TWO: LITERATURE REVIEW

2.1 General

During the past forty years and due to global climatic changes, Iraq suffers from the formation and expansion of sand dune fields, where many new sand dune fields were born. In addition, the old sand dune fields expanded their geographical area greatly, and this is the reason for desertification. This has caused severe environmental problems that affected the community health and caused dangerous environmental pollution.

For addressing these dangerous problems, many methods have been used to limit the expansion of sand dunes and try to use these dunes to prevent their expansion and reduce their environmental risks. The world began to accept the use of recycled materials or replace the raw materials with alternative materials in various types of facilities because of their environmental and economic importance, as many countries imposed the necessity of using used materials such as recycled aggregates.

Therefore, some countries, such as Canada, have prohibited the establishment of new projects in the public sector using virgin materials only, but have imposed an obligation to resort for recycling the material. Usually, the dunes sand used in some facilities such as trench backfill material, stabilization of soft subgrades, and sub-base and pavement shoulder construction. In this chapter, a literature review is presented that deals with the latest studies, experiments, and conclusions that most researchers focused on. And reviewed the results of the studies in this domain. Studies related to the use of dune sand as an alternative for sand in different ratios in concrete and the effect of this material on the mechanical and physical properties of concrete when it is used alone or combined with fibers will be reviewed. As well as determining the optimal proportions of replacement in concrete, and its effect on the behavior of the concrete members.

2.2 Previous Studies Concerning Use of Dune Sand in concrete mixtures

In 2007, Al-Harthy et al. [14], studied the properties of concrete made from dune sand in Oman. Reference concrete mixtures with a compressive strength of not less than 40 MPa were prepared, and dune sand was used as an alternative to sand for the ratios (10-100%) in concrete. The properties of concrete were studied in terms of workability, compression, tensile strength, and modulus of elasticity. The test results showed an improvement in the workability up to a replacement percentage (50%) as an alternative to sand, and the workability and compressive strength decreased when dune sand was used above the percentage (50%), where the decrease in the compressive strength was less than 25% compared to the reference specimen when dune sand was used of ratio 100%.

In 2013, Abu seif. [15], offered an experimental investigation regarding the performance of the concrete made with dune sand with several replacement ratios. Twenty representative dune samples were collected with several properties. Several tests were conducted on the dune sands to assess chemical, physical, mechanical quality, and mineralogical. Specific gravity, fineness modulus, absorption, and sand equivalency. Dune sands can be used as fine aggregates in cement mortar mixtures whenever suitable sand materials are not economically available. The researched dune sands are chemically and compositionally capable of manufacturing mortar without alkali attack. When the cement/sand ratio was not less than 1:2 and the dune sand content was not more than 70% of the total volume of fine aggregates, the workability of the dune sand mortar was acceptable. At a consistent mix ratio of 1:3:2 with dune sand under 70%, the compressive strength of dune sand cement mortar reached good strength.

In 2014, F.Medjber et al. [16], investigated the possibility of improving the mechanical properties of the high-performance fiber reinforced concrete (HPFC) made with dune sand and metallic fibers. The concrete mix made with portland cement included the use of several additives besides the dune sand and metallic fibers such as the electro-filter dust, silica fume, and superplasticizer. Regarding the obtained outcomes, the heat treatment of concrete showed a good enhancement in the flexural and compressive strength in comparison with untreated concrete (for both cases, with and without fibers). The mechanical properties of the tested concrete revealed an improvement in the microstructure of the cementitious matrix due to the fiber's existence and heat treatment. The study concluded that it is the possibility of producing concrete with good specifications and good performance that enables it to replace the traditional materials as it is an inexpensive concrete. In comparison with silica fumed concrete, the concrete behavior investigated in this study may be acceptable in terms of concrete material cost. The study also proved that the use of sand dunes as a fine aggregate material in concrete has an effect on the mechanical properties, but these properties can be improved through the use of steel fibers that can to resist cracks and control the failure pattern in addition to improving the flexural resistance, where the value of the improvements reached 15.9 MPa.

In 2015, the mechanical properties of the high-strength concrete made with desert sand were investigated by Liu et al. [17], six different replacement ratios of desert sand in western China were used as parameters to explore their effect on the compressive strength of concrete. Experiments indicated that using desert sand to mix high-strength desert sand concrete was feasible. The ideal desert sand replacement ratio for high strength desert sand concrete was 0 to 40%, providing guidance on the practical application of high strength desert sand concrete.

In 2019, Che et al. [18], investigated the behavior of the desert sand-based fibrous concrete (DSFC) from China’s Mu Us desert, which focused on the uniaxial tensile test, compression test, ductility, and workability. The used parameters were the effect of water to cement ratio (w/c), the ratio of desert sand replacement, sand to cement ratio. According to the results obtained from this study, by choosing a certain and appropriate percentage of w/c content and another suitable amount of dunes, it is possible to control the workability and ductility of the concrete. The mechanical properties are clearly and greatly affected when using a high percentage of w/c, as it reduced the tensile and compressive strength of concrete. With regard to the use of sand dunes, the increase in its percentage had a very small effect on the compressive and tensile strength, even if the replacement percentage was up to 100%. One of the most important conclusions of this study is to indicate the possibility of using desert sand as an alternative to natural sand, as it provides high workability and good ductility, in addition to its slight effect on the properties of mechanical concrete.

In 2019, Y. Kog. [19], presented a study on high-performance concrete (HPC) made from sand dunes in real projects (construction of a 2 km tunnel in Singapore). Two types of concrete, class C41.5, containing sand dunes, with a replacement ratio of 38%, were used as an alternative to sand for casting the tunnel, and class C 50 concrete which has a 35% replacement ratio dune sand for casting the tunnel piles. Silica fume and ground-granulated blast furnace slag were used, as well as fly ash for treating low workability, w/c at 0.33 and 0.32. Durability, compression, and temperature tests were carried out on the tunnel concrete. The results of cores and cubes showed that the high-performance concrete has achieved all the requirements for the durability of the tunnel in terms of water absorption (1.5%) and rapid chloride penetration (RCP) (442-575) c˚, as well as all the requirements of high heat in the specifications, and high compressive strength of specimens (52.7- 54.8) MPa. The study concluded that high-performance concrete can be produced from sand dunes with a good durability performance, and that the use of sand dunes of more than 35% leads to reducing the cost of concrete.

In 2019, Yeshwanthi Roy et al. [20], explored the effect of dune sand and steel fibers on the mechanical properties of the concrete. The study parameters included modifying the conventional concrete mix by replacing the concrete component ratios with dune sand and the addition of steel fibers and silica fume. The modifying included partial replacement (up to 5%) of the cement by silica fume and natural sand by dune sand (up to 4%) while the steel fibers were added by (0.6%). The outcomes revealed that the use of silica fume with a replacement ratio of 5% resulted in higher compressive strength than ordinary concrete. When compared to ordinary concrete, impact strength, compressive, and split tensile, all showed an improvement of about (7-13) %. The addition of 0.6% of steel fibers prevented the concrete from brittle behavior, as the ductility of the concrete increased significantly, in addition to its role in improving the mechanical properties, as the tensile strength, the tensile strength increased by the addition of steel fibers although of its little proportion which was by up to 22%, which qualifies this type of concrete for use in structures that need strength high tensile strength, and ductility. In addition, the presence of steel fibers is considered complementary to the process of replacing natural sand with dune sand, as it eliminates its negative impact on mechanical properties.

In 2020, One of the most important experimental study presented by researcher Z. Li et al. [21], which deals with the effect of using dune sand as a percentage of natural sand on the shear strength of reinforced concrete beams. The experimental work included dividing the tested beams into three groups with several variables such as the replacement ratio of the dune sand, number of stirrups, and the ratio of shear span to depth. The study included an investigation of the crack pattern, strain at stirrups, and failure mode, in addition to the behavior in terms of the load-displacement relationship. The gotten results showed that the failure mode didn’t affect by the use of the dune sands which was unaffected although of the increase in its proportion as shown in Figure 2.1. Regarding the shear strength, the obtained results were compared to the calculation gotten by the current design codes but the comparison revealed that the design equation had a weak prediction of the shear strength of the concrete beam made with the sand dunes. Concerning the strain at the stirrups, the increase of the sand dunes decreased the strain. The deflection of the concrete beams increases with the increase of the replacement ratio of the dune sand. The ultimate shear strength improved considerably when the stirrup ratio was raised, but damaged deflection reduced insignificantly.

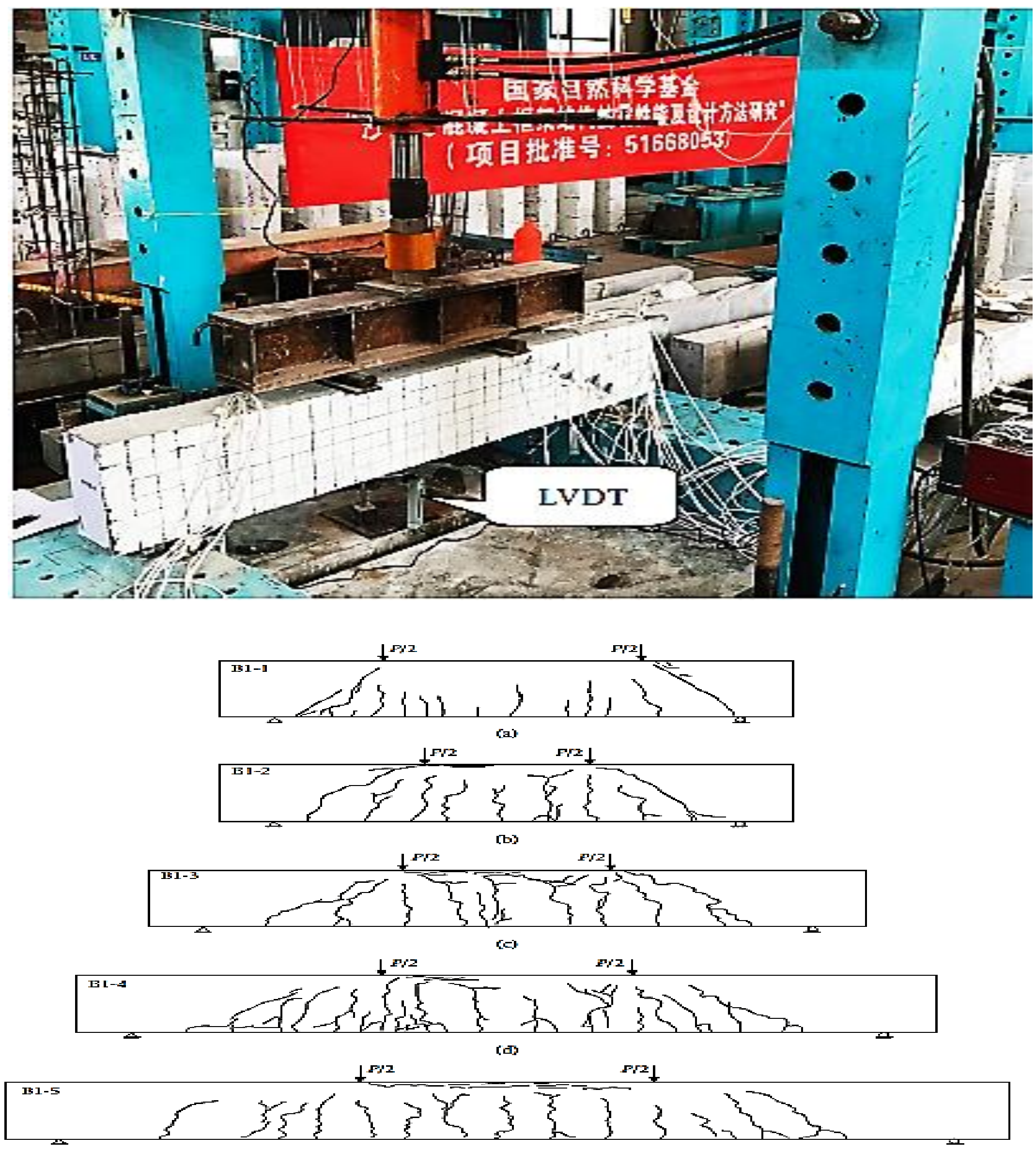


Figure 2.1 Concrete specimens tests by Li et al. [21].

In 2020, A. Mhawi. [22], used the ratios of partial replacement of fine aggregate in concrete with dune sand, polyvinyl chloride (PVC) waste, iron filings, and waste plastic bins, for the purpose of studying the axial behavior of steel tubular columns filled with concrete (CFST). Sixteen concrete mixtures were made that included one reference mixture and three mixtures for each material with replacement ratios of (15,25,50%), (2.5,5,10%), (1.25,5,10%), (2.5,5,10), (2.5,5,10%) and (2.5,5,10%) for dune sand, crushed polyvinyl chloride, polyvinyl chloride sawdust, iron filings, and waste plastic boxes, respectively. The results showed that the materials used as an alternative to sand improved the mechanical properties of concrete mixtures in terms of compressive strength, tensile strength and flexural strength with optimal replacement rates, which are (25% dunes sand), (2.5% polyvinyl chloride granules), (5% plastic boxes waste) and (10% Iron filings). The results of stub column (CFST) as well as for specimens with short and long columns showed an increase in the axial compressive load capacity when using percentages of 5% of PVC mulch for the main column and 50% of dune sand for specimens of short and long columns ranged between 8% and 24%, higher than the reference specimen. While the loading capacity of the short column specimens decreased when using 5% of waste plastic boxes and 5% PVC crushed compared to the reference specimen.

In 2021, Y.Liu et al. [23], investigated the behavior of the concrete made with desert sand (DSC). The study included several variables, the most important of which is the production of concrete containing dunes sand with several proportions of sand dunes with the treatment of variable temperatures for the purpose of analyzing the effect of temperature on concrete made of sand dunes. The results showed that the heat treatment of sand dune concrete led to an increase in the compressive strength, as it showed the highest value when the temperature reached between 200-300 degrees Celsius and started decreasing gradually after that to reach

700 degrees Celsius, where it showed the lowest value at that degree, where it reached the limits of 70% of its original strength. As for the flexural strength, it suffered from a gradual decrease in its strength when the temperature was increased. As for the tensile strength, it increased as is the case with the compressive strength. The conclusion of the study ensures the possibility of using desert sand in concrete, provided that its effect on the mechanical properties is reduced through heat treatment.

2.3 Previous studies concerning the use of Hybrid fibrous concrete and Slab reinforced with steel fibers

In 2004, A. Yurtseven. [24], presented an investigation regarding the mechanical properties of hybrid fibrous concrete. Nine mixtures were prepared, one of them for the plain concrete, and the remaining eight were fibrous concrete mixes. Six of the mixes were reinforced in a hybrid form. The number of fibers used was four different in size, two of which were high aspect ratio fibers and two were small in proportion. A proportion of the fibers estimated at 1% of the concrete volume was used, where many numerical analyzes were carried out to find out the effect of hybrid fibers on the mechanical properties of concrete. The use of high-strength micro-steel fibers to strengthen the matrix has proven to be effective. This result may be due to the high strength and dimensions combined with the fiber reinforcement, the compressive and tensile strength is clearly improved. Fiber concrete with a higher aspect ratio increased flexural strength better than concrete with a smaller aspect ratio. The greatest results were achieved by combining macro steel with micro steel fiber, the existence of steel fibers substantially increased energy absorption of the concrete member under flexural stress.

In 2005, the flexural behavior of concrete slabs reinforced with steel fibers was studied by Khaloo and Afshari. [25], testing of 28 fibrous concrete slabs under flexural loads to explore the effect of the length and ratio of steel fibers on the energy absorption of concrete slabs. The results indicated that the use of the higher ratio of steel fibers and longer fibers enhances the energy absorption more than the small ones. The show results revealed that the addition of fibers doesn't enhance the flexural strength only. It nonetheless increases the slabs' energy absorbability. The energy absorption of fibrous concrete of 0.5% was higher than plain concrete one by about 12 times. The fibrous slab with 1% fiber experienced nearly 2 times the energy absorption that of the ones with 0.5% fiber. At 1.5% of fibrous slabs, the energy absorption stood at about 1.5 times when compared with fibers of 1.0%. The resistance to cracking was quite weak in slabs with low fiber volume (0.5%). The improvement ratio of energy absorption decreased when the fiber ratio raised. Increased fiber reinforced concrete strength improves energy absorption capability. The gotten results from the experimental outcomes were compared with a theoretical calculation. The theoretical method resulted in higher energy absorption than that obtained in the experiment. Within the range of fiber volumetric percentages employed in the study, a design technique based on allowed deflection is proposed for SFRC (Steel Fiber Reinforced Concrete) slabs. The technique accurately predicts the resistive moment–deflection curve.

In 2008, M. Hadi. [26], presented an investigation regarding the behavior of fibrous slabs reinforced with polypropylene and steel fibers. Five slabs were fabricated and tested with dimensions of (82 × 82 × 8) cm. the experimental work included the fabrication of one reference slab without fibers and two of them were reinforced with steel fibers with a ratio of (0.5% and 1%) while the remaining two were reinforced with polypropylene fibers with the same ratio of the steel fibers (0.5% and 1%).The outcomes revealed that the higher compressive strength was achieved when the concrete slab was reinforced with 1% steel fibers at 28 days of age. The existence of more than one type of fibers increased the strength of the concrete and is considered more effective than one type. The results also showed that the slabs reinforced with steel fibers achieved a higher ductility and absorption energy than the slabs reinforced with polypropylene fibers at the ratios (0.5%,1%), while the slab reinforced with steel fibers by 0.5% achieved maximum deflection and was higher than the slab reinforced with polypropylene fibers. However, the 1% steel fiber slab achieved a maximum deflection lower than the 1% polypropylene fiber reinforced slab, as shown in Figure 2.2 .

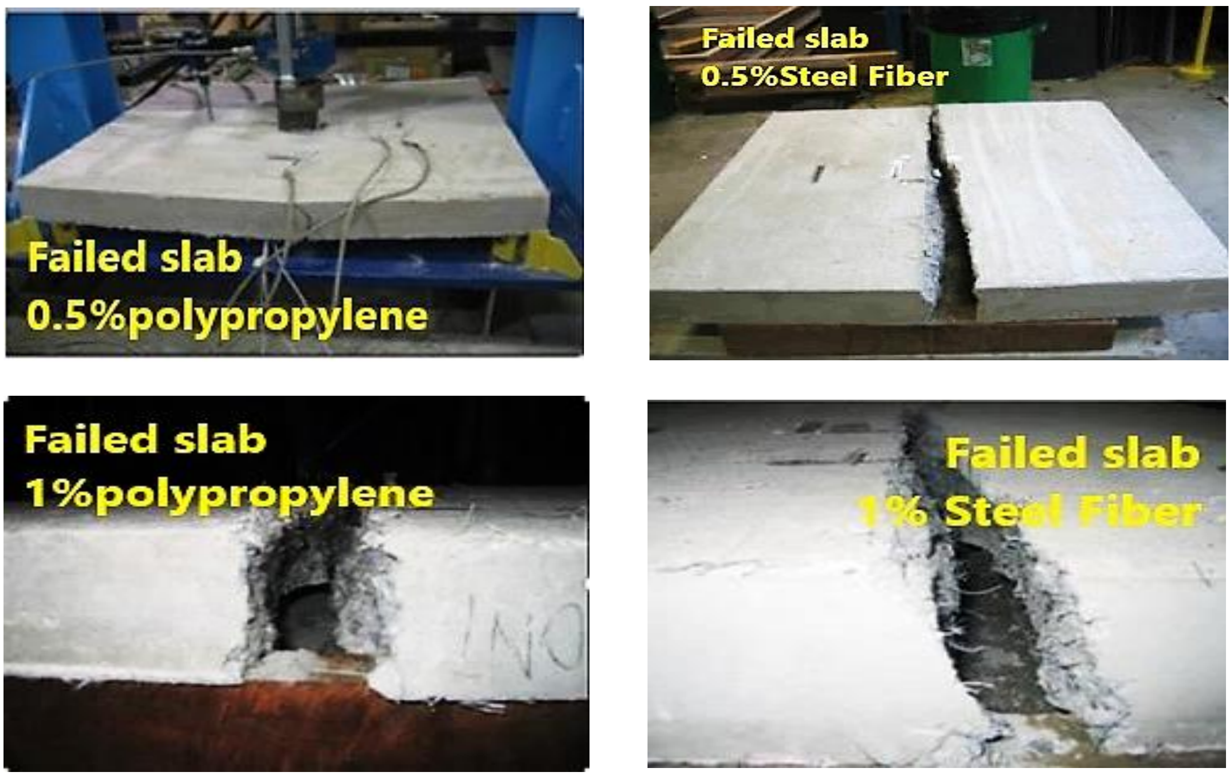


Figure 2.2 Testing of the concrete slab as presented by Hadi [26].

In 2012, J. Michels et al. [27], studies the use of steel fibers only as reinforcement in the concrete flat slab. The experimental study included the fabrication of an octagon slab with diameters of (2.34 and 1.9) m with thicknesses (20, 25, 30, and 40) cm and a square column with dimensions of (35 × 35) cm and (25 × 25) cm with variable compressive strength ranged between 40-54 MPa due to the increasing ratio of the steel fibers which was another parameter of the study. The outcomes revealed that the existence of steel fibers prevented the slab from failing in the punching shear. In view of the failure of all concrete slabs containing steel fiber to fail in flexural, the Yield Line theory was applied. Also, the results showed there was an improvement in the ductility when the steel fibers were added to the concrete mix. It should be noted that the enhancements occurred in the all-concrete properties such as the compressive strength, flexural strength, cracking behavior, toughness, and ductility. Regarding the other variables, the thickness increase enhanced the linear elastic limit by (350%) when increased from (20) cm to (40) cm. The conclusion of the study ensures the possibility of using steel fibers in concrete as an alternative to the steel reinforcement which enhances the mechanical properties, as shown in Figure 2.3.

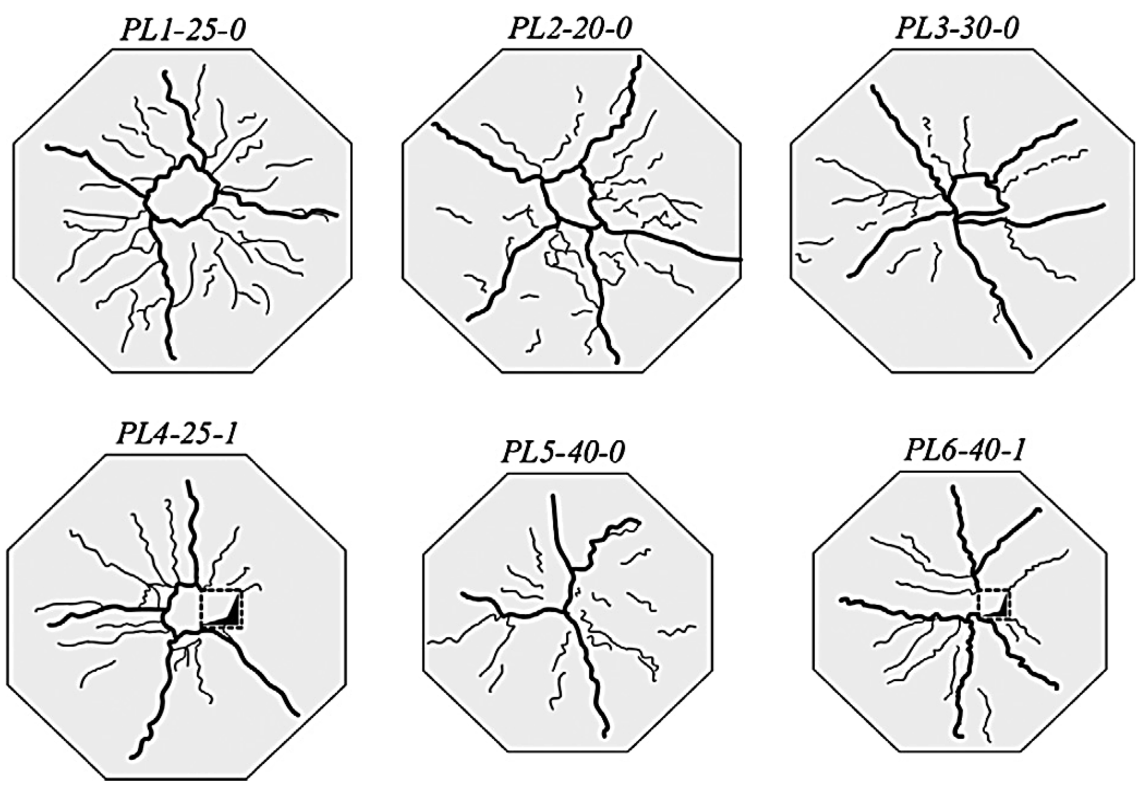


Figure 2.3 Crack pattern of the tested slab by Michels et al. [27].

In 2015, H. Singh. [28], presented an experimental study regarding the replacement of the flexural reinforcement of the concrete slab with steel fibers. The study dealt with the feasibility of using steel fibers as an alternative to conventional steel reinforcement in modeling concrete slabs of rectangular shape. The outcomes revealed that the presence of the steel fibers inside the concrete slab had the ability to resist the flexural strength at a value comparable to that obtained when the use of conventional steel reinforcement. But regarding the mid-span displacement, the control RC(Control Reinforced concrete) specimen showed a maximum displacement at the mid-span less than those of the steel fiber reinforced concrete slab, the first crack in the control RC slab, on the other hand, emerged earlier than in the SFRC (Steel Fiber Reinforced Concrete) slabs, as shown in Figure 2.4.

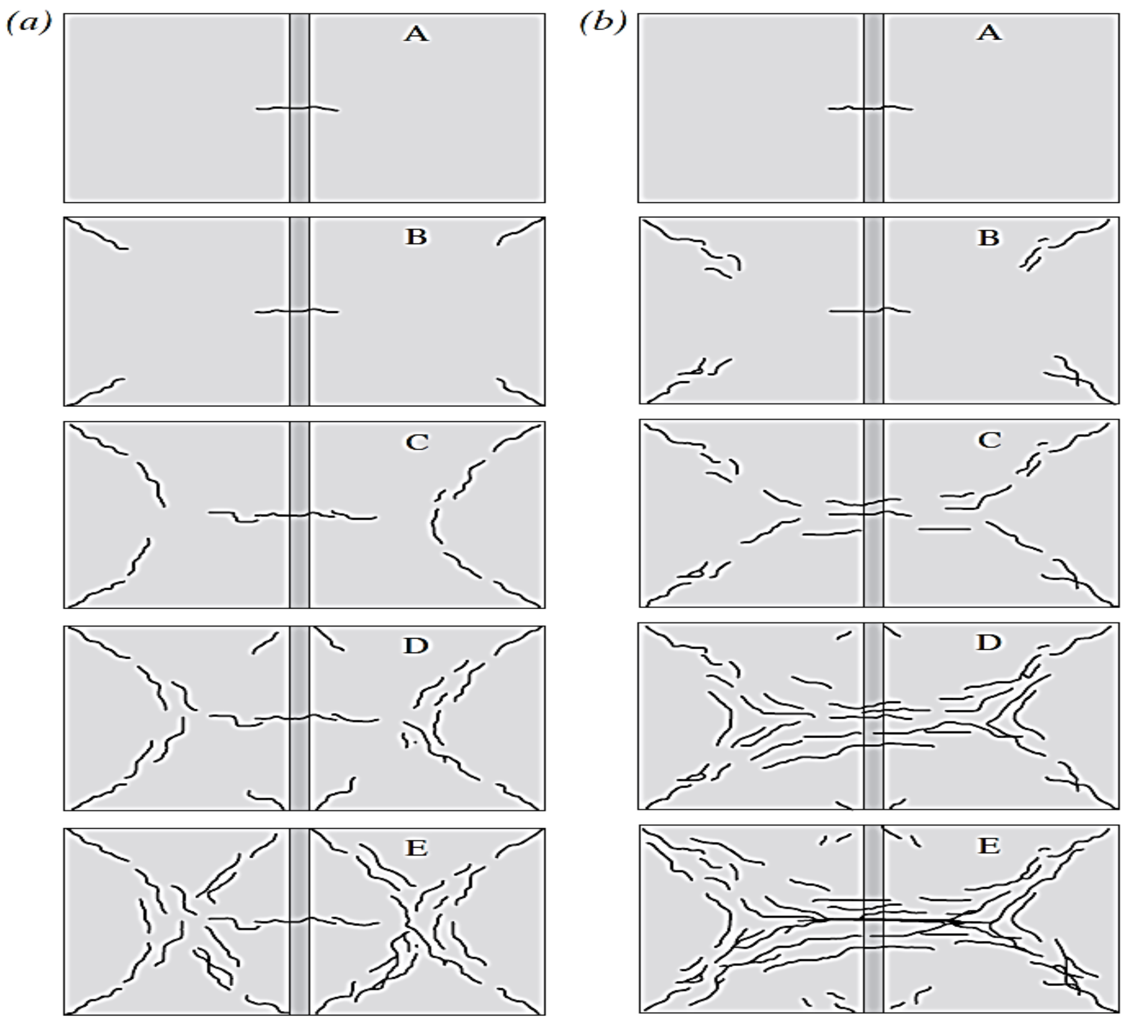


Figure 2.4 The crack pattern that developed in (a) an SFRC slab specimen (b) an RC slab specimen, by Singh [28].

In 2017, Pajak and Ponikiewski. [29], offered an experimental investigation regarding the behavior of the self-compacted hybrid steel fiber reinforced concrete. The variables included two kinds of steel fibers (corrugated and straight fibers) with variable lengths (6 and 35 mm) and the ratio of the fibers (1% - 3%). The results showed that the presence of fibers did not improve the workability of concrete, but it improved the density and consistency of concrete by a high percentage, which gives an indication that steel fibers cannot be used in a high ratio in self-compacting concrete. It is important to note that the increase of steel fibers proportions of more than 1% did not lead to a high increase in flexural strength. Regarding the compressive strength, the addition of two kinds of steel fibers enhanced the compressive strength by a certain percentage. The enhancement can be gotten when the use of a low ratio of long fibers (about 0.5%) and a higher ratio of the straight short fibers (1% -1.5%). The failure mode revealed that the longer corrugated fibers could control the large cracks whereas the short fibers controlled the small cracks and provided higher stiffness than those of longer fibers. Adding more than more types of steel fibers of several sizes will improve the mechanical properties of the concrete in better form than the use of one type, as shown in Figure 2.5.

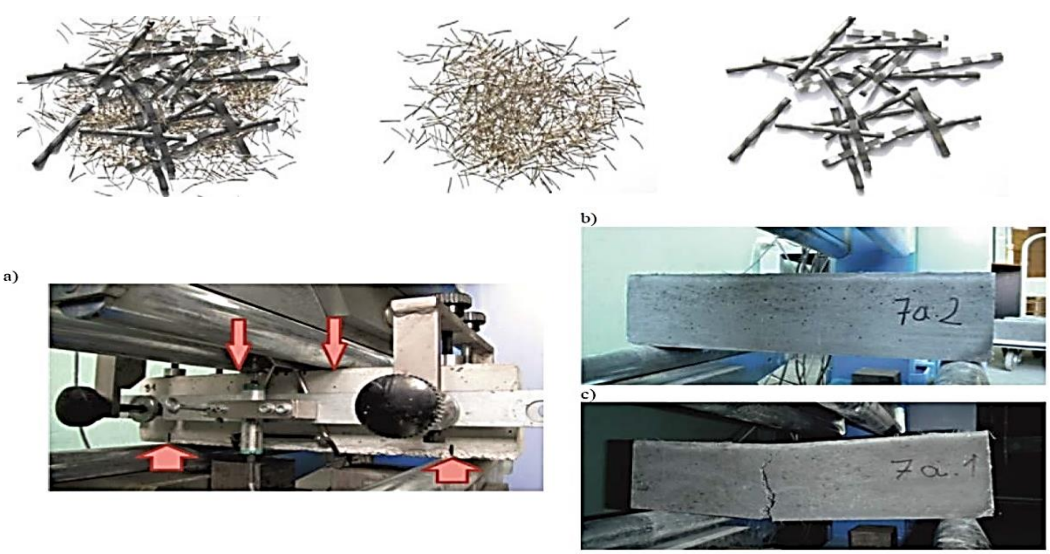


Figure 2.5 Concrete specimens tests by Pajak and Ponikiewski [29].

In 2018, Jomaa'H et al. [30], presented an experimental investigation regarding the replacement of the flexure reinforcement by steel fibers in the concrete slab. The experimental work included preparing the slab specimens of ordinary concrete, and then making concrete slabs by substituting two types of steel fibers as an alternative to the main reinforcing with ratios o of 0.125% 0.25%, and 0.375%. Mechanical properties such as flexural strength, compressive strength, and tensile strength were investigated. Concrete slabs with dimensions of 70 × 30 × 7 cm were fabricated and tested under concentrated line load to explore the behavior of the concrete under bending moment. A total of sixteen RC slabs were fabricated two of which represent the control specimens that were without steel rebar and another two were reinforced with steel. The remaining specimens were reinforced with ordinary and recycled steel fibers as alternative steel reinforcement. When the main reinforcing steel was replaced with steel fiber, the ultimate load and displacement decreased by (20.09%, and 51.91%) respectively. The ductility was enhanced with the use of steel fiber which showed maximum ductility by 3.77 when the replacement ratio was 0.25%.

In 2018, Iqbal Khan and Abbas. [31], presented a study on the effect of hybridization of steel fibers of different lengths and diameters (60 and 40) mm on the mechanical properties of high strength concrete. Different percentages of fibers were used in the hybridization while maintaining the total percentage of fibers at 1% of the concrete volume. The compression and flexural tests of fiber reinforced concrete were carried out. The results showed an improvement in the compressive and flexural strength of hybrid concrete compared to concrete without fibers. It was also noted that the incorporation of fibers of ratio (65% for length 60 mm and 35% for length 40 mm) showed that it was the best in improving compression and flexural.

In 2021, Vafaei et al. [32], studied the behavior of the hybrid fibrous concrete made with degraded sea sand. The effect of adding different types and percentages of fibers on the qualities of a high-strength concrete made with seawater (SW) and dredging sea sand (DSS) was examined in this experiment. For reinforcement, two kinds of synthetic fibers were utilized, polyvinyl alcohol (PVA) and polypropylene (PP), with volume fractions of 0.1%, 0.2%, 0.3%, and 0.5%. The properties of fresh and mechanical concrete were studied. The obtained outcome showed that the addition of DSS and SW enhanced the compressive strength in the first week in rate (11%) but decreased the compressive strength at 28 days in rate (10%). Changing failure mode and the concrete behavior had occurred from brittle to the ductile mode of failure when the use of the hybrid concrete way by using both types of fibers (PP and PVA fibers). Usage of both fibers (PP and PVA fibers) and when compared to regular SWSS concrete, resulted in a 17% and 23% improvement in splitting tensile strength. When SW and DSS are used in concrete. With the addition of the PP fibers, water absorption and sorptivity were significantly reduced, as shown in Figure 2.6.

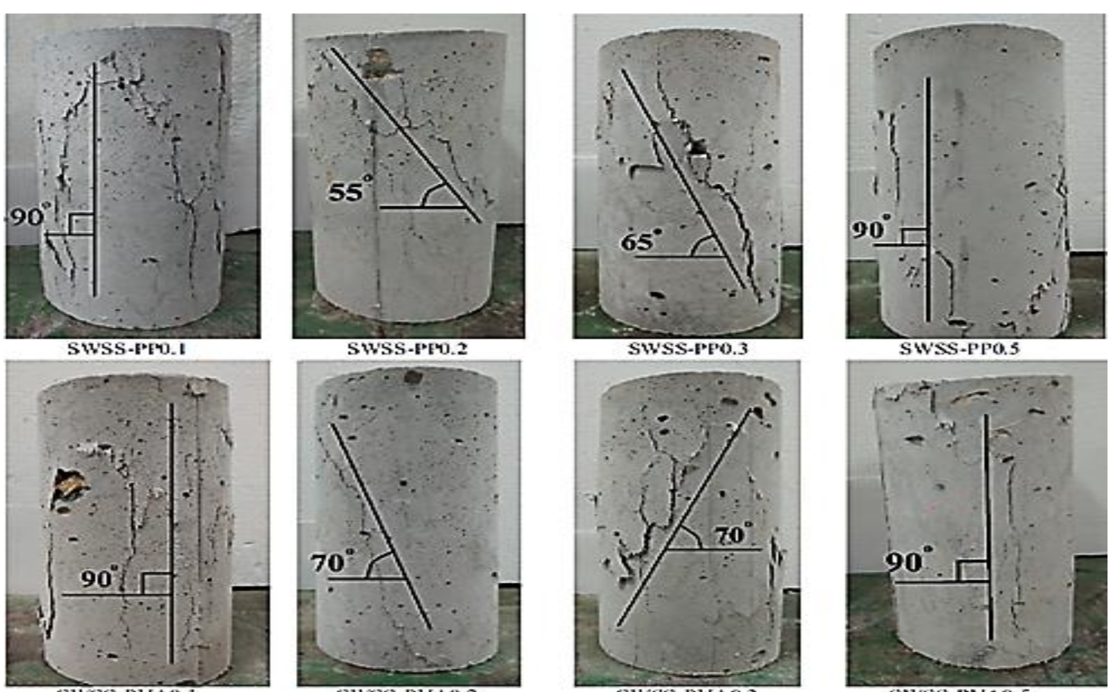


Figure 2.6 Concrete specimens tests by Vafaei et al. [32].

In 2020, W. Labib. [33] , presented an experimental study concerning the behavior of the hybrid fibrous concrete slab under punching shear loads. The purpose of this research is to see how hybrid steel-polypropylene fibers affect punching shear capability. The variables that were employed to determine these mixes were fiber type and volume. The prepared mixtures included the fabrication of single fiber concrete mix and hybrid fibrous concrete mix. single fiber concrete mix with steel fibers of (0.5%) was fabricated. Regarding the hybrid mixtures, mixes were fabricated by use of steel fibers of (0.5%) and polypropylene fiber with a ratio of (0.2%). Another hybrid mixture with a ratio of (1.5%) steel fibers and polypropylene fiber with (0.2%). To test the punching shear, the experimental program included testing the concrete circular slab with dimensions of (600 × 75) mm. Also, the compression and flexural strength test for cube specimens (15 × 15 × 15) cm and prisms (15 × 15 × 60) cm for concrete reinforced with single and hybrid fibers. The study found that hybrid fiber concrete mixes have a significantly higher punching shear capacity than plain concrete and strengthened concrete with a single fiber system. The enhancements occurred in the all-concrete properties such as compressive strength, flexural strength, cracking behavior, toughness, and ductility. The hybrid concrete provided higher efficiency in enhancing the improved mechanical properties of the concrete, especially the compressive and tensile resistance.

In 2021, N. Kachouh et al. [34], studied the flexural behavior of fibrous concrete made with dune sand and recycled aggregate. The experimental work included many variables such as the replacement ratio of the recycled aggregate (30%, 70%, and 100%) and steel fibers ratio (1%, 2%, 3%). The gotten results illustrated that the addition of the recycled aggregate affected negatively the compressive strength of the dune sand concrete and more affected the flexural strength, but when the steel fibers were added to the mix, the enhancement occurred in the toughness, compressive and flexural strength. The impact of RCA (Recycled Concrete Aggregates) replacement was insignificant in steel fiber-reinforced concrete. The first load and peak flexural load decreased with RCA replacement. Research showed that concrete mixes made with 100% recycled concrete aggregates, steel fiber reinforcement, and dune sand could be developed with improved flexural performance compared to conventional N.A (Natural Aggregates) -based concrete, as shown in Figure 2.7.

Figure 2.7 Concrete specimens tests by Kachouh [34].

2.4 Summary

The contents of previous studies on the use of dune sand in concrete as an alternative to sand are summarized and their content was reviewed according to different criteria, including dune sand replacement ratio, type of fiber added to concrete, its ratio, and effect. The results of the studies varied according to these variables, the following points which reached by the majority of previous studies, including: -

1- The researchers used dune sand as an alternative to sand in different ratios in the concrete mixtures. The results of the studies showed an improvement in the mechanical properties of concrete in terms of compressive and tensile strength, as well as workability, up to the replacement ratio (50%). The results of the studies also concluded that the use of high proportions of dune sand will negatively affect the mechanical and physical properties, including the concrete absorption of water, and weaken the workability, but its impact can be reduced by adding fibers.

2- The researchers used dune sand as an alternative to sand with silica fume and steel fibers in high-strength concrete using concrete heat treatment. The results of the studies concluded that it is possible to produce concrete with good specifications and an improvement in the properties of heat-treated concrete that enables it to replace conventional materials and produce concrete at a low cost.

3- The use of dunes sand does not affect concrete in chemical terms where studies have shown that dune sand can be used as a fine aggregate in concrete when sand is not economically available. The dune sand that has been researched is chemically and compositionally capable of making a mortar without alkaline attack when the ratio of cement to sand is not less than 1:2 and the content of dune sand is not more than 70% of fine aggregate.

4- The use of single steel fibers in concrete in proportions ranging between (0.5%-3%), the optimum ratio for using fibers in concrete is 1%, and steel fibers have better performance than polypropylene fibers. The studies also concluded that increasing the ratio of the fibers by more than 1% will not give an increase in the flexural resistance and weaken the workability and the inability to use it in self-compacted concrete.

5- The presence of more than one type of fiber in concrete increases its efficiency and is considered more effective than using one type. Researchers' work (Yurtseven, Pajak, Khan, and Labib).

6- The possibility of using steel fibers in concrete as an alternative to conventional rebar, where studies concluded that the presence of steel fibers inside the rectangular slab has the ability to resist flexural with a value similar to that obtained when using conventional rebar, while the deflection increases and the ultimate failure load decreases in slabs containing steel fibers.

The current study includes investigation of single and hybrid steel fiber reinforced concrete for slabs containing sand dunes as a partial and total alternative for sand, as well as for slabs without fibers with a support system is simply supported slab with four-point reactions at corner edges. As well as conducting tests comprehensive for concrete containing sand dunes and reinforced with steel fibers such as ultrasonic pulse velocity, density, static modulus of elasticity, dynamic modulus of elasticity, gradation classification, and calculating the fineness coefficient for each replacement ratio. The sand dunes used in this study is from the Al-Batera area in Misan, and coarse aggregate from the chilat site northeast of Misan. In this study, were used two different types of steel fibers, namely the short straight steel fiber and the hook end long steel fiber. Also, a constant ratio of W/C was used in all mixtures. The ratios of partial and total replacement of sand dunes were used because previous studies were not sufficient, so the replacement ratios were used more, in order to explore the effect of sand dunes more accurately on the properties of concrete.

CHAPTER THREE: EXPERIMENTAL WORK

3.1 General

For the purpose to extensively investigate the behavior of fiber concrete (FRC) for concrete slabs containing percentages of sand dunes, several procedures carried out. That includes material, testing, preparation of mixing ratios, manufacture of molds and tools, and all that was necessary to carry out the research work. These procedures must be carefully performed before pouring fibrous concrete. This chapter includes showing and evaluating the properties of natural and synthetic materials involved in the formation of concrete mixtures. Physical and mechanical properties, material details, proportions, concrete mix design, concrete slabs pouring, and test specimens shown for each proportion. The chapter also includes the use of sand dunes as a partial and total alternative for sand in concrete mixtures and reinforced with single and hybrid steel fibers and without fiber. A volumetric ratio of 1% of the fiber from the volume of concrete was adopted in this study. This ratio has been adopted based on most of the results of researchers in previous studies and is considered the best ratio of fibers in concrete. If it exceeds this ratio of 1%, it will cause problems in concrete, including concrete separation, and poor fiber spread. The chapter also contains the details of pouring concrete slabs and casting small specimens for each replacement ratio. In addition to conducting mechanical and physical tests of concrete specimens containing sand dunes as an alternative to sand and reinforced with steel fibers. Tests include compressive strength, flexural strength, split tensile strength, absorption, density, ultrasonic pulse velocity, static modulus of elasticity, dynamic modulus of elasticity for hardened concrete, and slump test of fresh concrete. It were poured (150 cubes), (144 prisms), (144 cylinders with dimensions of 200 × 100 mm), (24 cylinders with dimensions of 150 × 300 mm) for replacement ratios. Also casting (24) concrete slabs for each replacement ratio. All specimens were cast in the laboratory of the College of the Engineering / University of Misan. With all laboratory tests conducted in the construction laboratory of the college, except for the cement and absorption test in the laboratory of the Technical Institute in Architecture and the chemical examination of sand dunes in the laboratory of the National Center for Laboratories and Construction Research in Misan of the Ministry of Construction and Housing.

3.2 Experimental program

The experimental program is divided into two main parts. The first part includes a study of the physical and mechanical properties of concrete containing sand dunes as a partial and complete alternative to sand. This part includes the use of (6) different main ratios to replace sand dunes as a partial and total substitute for graded natural sand without adding fibers to it (reference). This part also includes the use of (6) different main ratios to replace sand dunes as an alternative to sand, and each main ratio contains three different ratios of adding steel fibers (short straight fibers with a length of 13 mm, hook-ended fibers with a length of 50mm, and short + long hybrid fibers) . A concrete slab is poured for each ratio with small specimens poured. For each ratio (6) specimens of standard cubes (150 × 150 × 150) mm to determine the compressive strength, (6) specimens of cylinders (100 × 200) mm to determine the split tensile strength. (6) specimens of the prism (100 × 100 × 500) mm to determine the flexural strength, and (1) concrete cylinder (150 × 300) mm to calculate the modulus of elasticity, and thus the total number of specimens for testing (462), in addition to casting (36) standard cubes of reference concrete with different ratios of sand dunes (experimental test). As well as casting 24 concrete slabs with dimensions (80 × 800 × 800) mm for each ratio. Mechanical tests are performed on the specimens for each ratio to knowing the resistance to compression, flexural, tensile, as well as physical tests, including density, modulus of elasticity, absorption, and ultrasonic pulse velocity test of concrete. The second part includes a study of the behavior of concrete slabs reinforced with single and hybrid steel fibers containing sand dunes as a partial and total alternative to sand and comparing them with slabs without fibers. Figure 3.1 and Figure 3.2 are flow charts of the practical program of the study showing the concrete mixtures and replacement ratios of sand dunes as an alternative to sand with or without steel fibers, as well as the types of tests.

3.3 Materials properties

Locally available natural and synthetic materials are used in this research, Ordinary Portland cement, fine aggregate represented by natural graded sand, sand dunes, coarse aggregate, pure drinking water for mixing, macro steel fiber (hooked-end) 50 mm long, micro straight steel fiber 13 mm long. As well as the use of the superplasticizer type Hyperplast PC 260 to improving the workability of the mixture and obtaining high density concrete.

3.3.1 Cement

In this research, ordinary Portland cement of Iraqi origin (karasta Lafarge) bagged (CEM II/A-L 42.5R) was used in all mixtures of this research .The properties of hardened concrete made using ordinary Portland cement are characterized by less water bleeding and a lower level of permeability with fewer cracks (according to the technical bulletin on the cement bag). Cement bags were kept in a dry place to avoid the effect of moisture .Table 3.1 and Table 3.2include the results test of the physical properties and chemical composition of cement, as the results showed that this type of cement conforms to the Iraqi standard specifications No. (5) / 2019. [35] and No. (5) / 1984 [36]. The tests were conducted in the laboratory of the Technical Institute in Al-Amarah / Iraq.

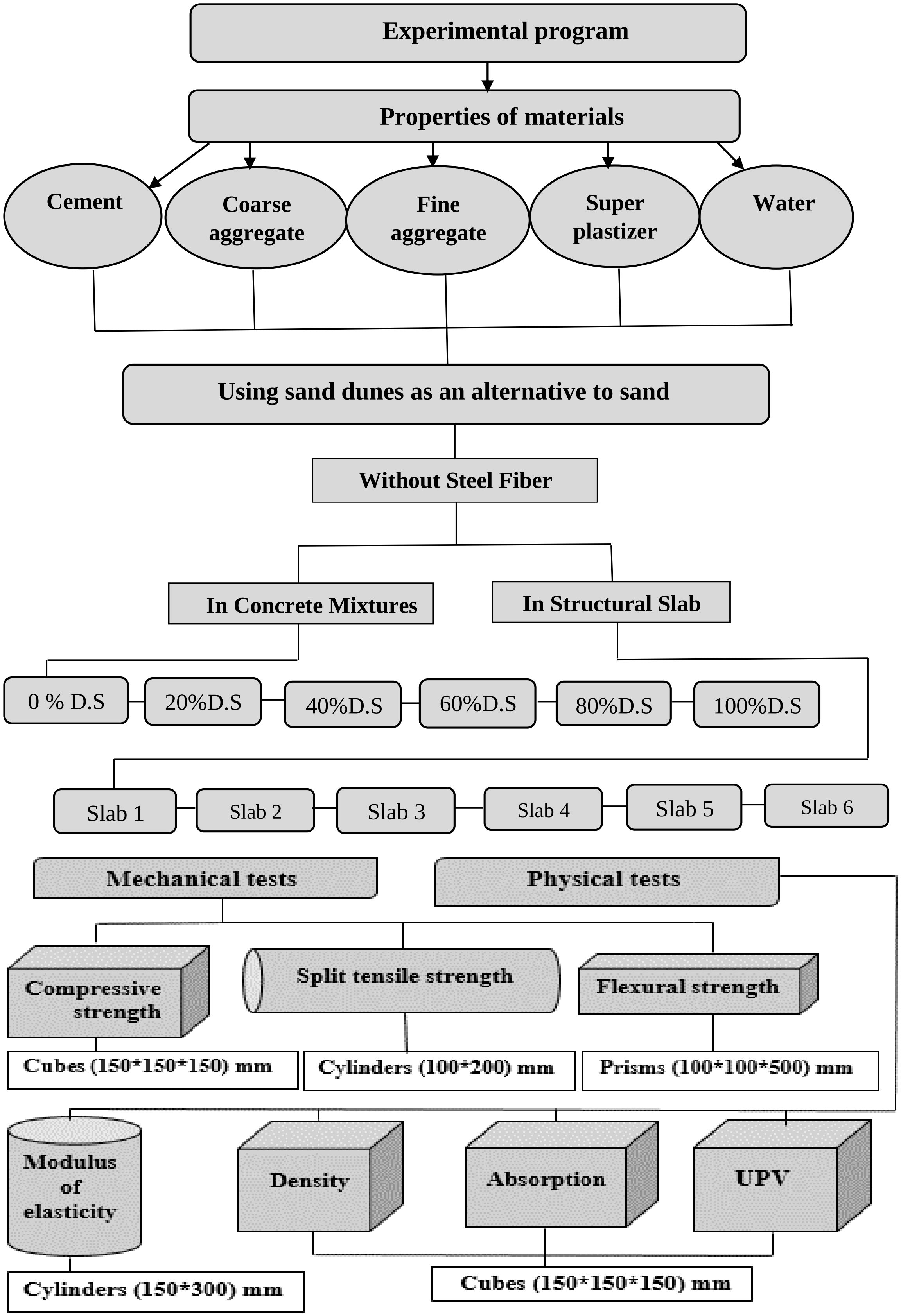


Figure 3.1 Flowchart of the experimental program without steel fiber.

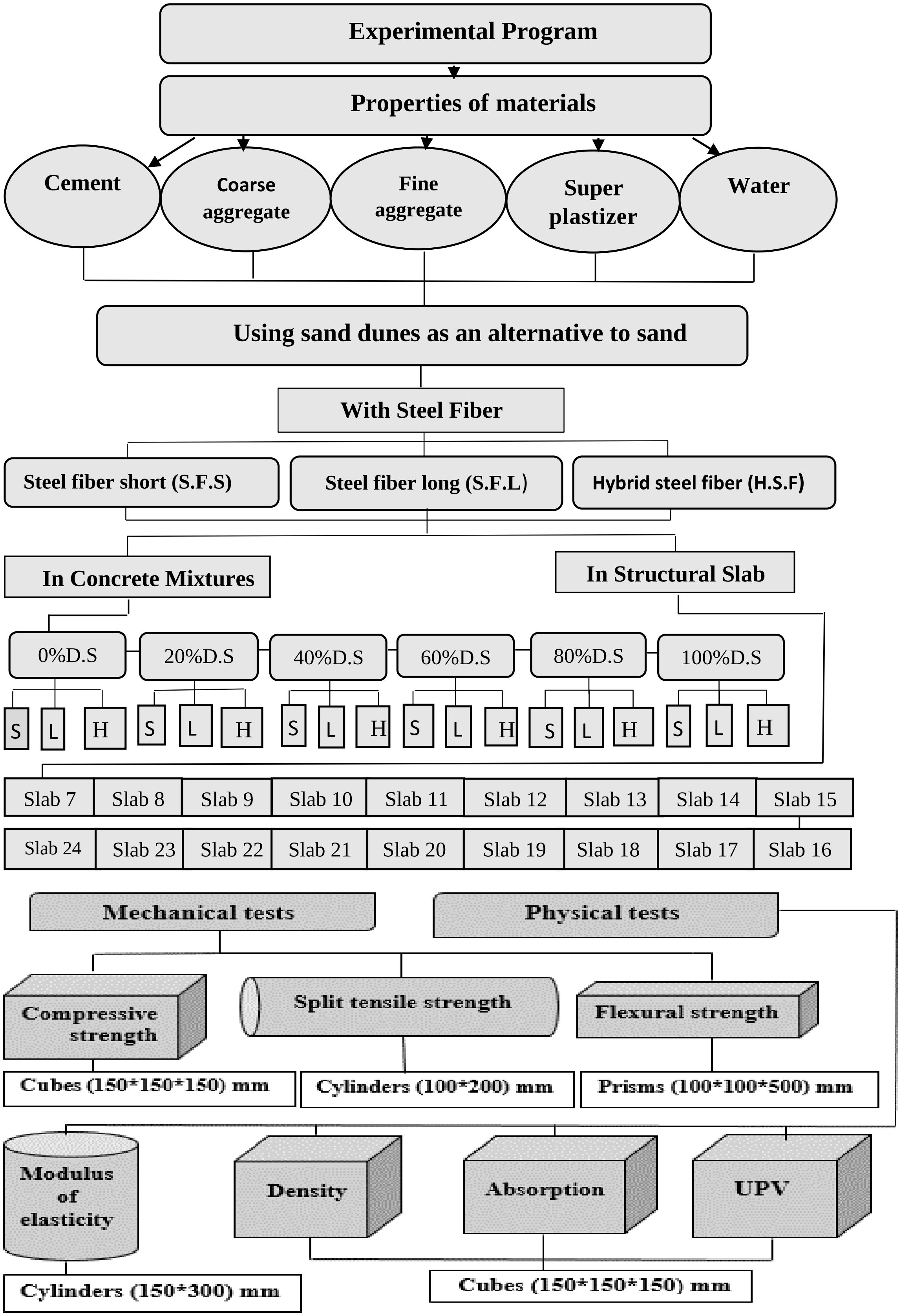


Figure 3.2 Flowchart of the experimental program with steel fiber.

Table 3.1 Physical tests of cement according to the Iraqi standard specification No. 5/1984 [36]

Cement type		Ordinary Portland cement
Physical properties	Test results	The limits of the Iraqi standard No. 5/1984[36]
Fineness (kg/m^2)	381	≥ 230
Freezing time (using victa's method) Initial Cohesion time(hrs:min) Final Cohesion time (hrs:min)	2: 09 4 : 20	≥ 0.45 min. ≤ 10 hrs.
The compressive strength of mortar		
3 Day , MPa 7 Day, MPa	19.8 32.1	≥ 15 ≥ 23

Table 3.2 Chemical tests of cement according to the Iraqi standard specification No. 5/2019 [35]

Chemical properties (%)	Test result (%) by weight	The limits of the Iraqi standard No. 5/2019[35]	
Silica sio_2	21.42	______	
Alumina AL_2O_3	4.17	______	
Lime cao	62.56	______	
Iron oxide Fe_2o_3	4.38	______	
Tri calcium Aluminates C3A	3.66	______	
Sulphate SO_3	2.23	SO_3 (%) content is not more than when the proportion of	
		Ordinary cement	C3A
		≤ 2.5%	C3A< (3.5%)
		≤ 2.8%	C3A> (3.5%)
Insoluble substances I.S	0.62	≤ 1.5%	
Loss on ignition L.O.I	1.87	≤ 4%	
Magnesia Mgo	3.65	≤ 5%	

3.3.2 Coarse Aggregate

Coarse aggregate gradation (5-20) mm was used as one of the concrete components. It is naturally available in the chilat region, east of Al-Amarah, southern Iraq. Before using it in concrete, washed with water to get rid of the clay materials and salts suspended in the granules. The gradation of aggregates was examined in the concrete laboratory of the College of Engineering / the University of Misan , and the result was under the Iraqi Standard specification No. (45) / 1984 [37]. Table 3.3 and Figure 3.3, include the results of the gradation test of coarse aggregates and the gradation curve, respectively.

Table 3.3 Grading of coarse Aggregate

Sieve size (mm)	Passing (%) Coarse Aggregate	Iraqi specification No.(45)/1984 [37]
75mm	____	____
37.5 mm	100	100
20mm	98	95 ___ 100
10mm	38.4	30 ___ 60
5mm	2.5	0 ___ 10
2.36mm	____	_____

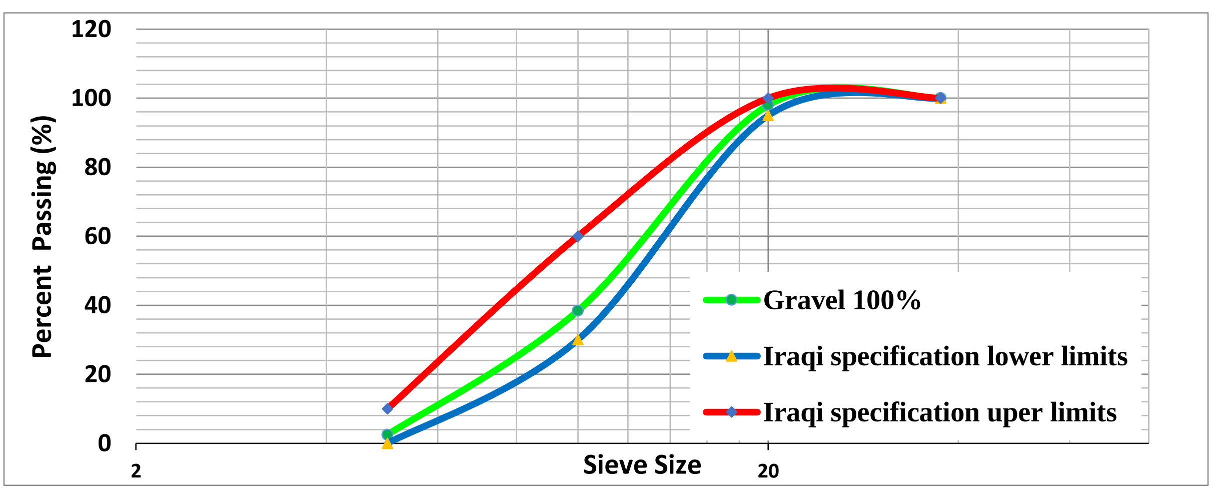


Figure 3.3 The gradation curve for gravel (5-20) mm. According to the Iraqi standard specification No. 45/1984 [37].

3.3.3 Fine Aggregate

Two types of natural sand were used in this study, the sand dunes and the natural graded sand used in construction.

3.3.3.1 Graded natural sand

The fine aggregate represented by natural sand in partial and total proportions was used as one of the components of fibrous concrete. These materials were brought from sand quarries in Basra Governorate, southern Iraq .Table 3.4, Table 3.5, and Figure 3.4 show the physical and chemical properties of sand, which include the gradient test of sand، specific gravity، absorption as well as the gradient curve of sand، respectively. The results conformed with the Iraqi Standard No. (45) / 1984 [37] for fine aggregates within the gradient zone No. (2), as well as the American specification ASTM C33 [38].

Table 3.4 Sand gradation test results

Sieve size (mm)	Passing % (sand)	Limits of the specification (Gradient region No. 2) According to the Iraqi standard specification No. (45) / 1984[37]
10 mm	100	100
4.75 mm	97	90 __ 100
2.36mm	89	75 __ 100
1.18 mm	75	55 __ 90
0.60 mm	39	35 __ 59
0.30 mm	9	8 __ 30
0.15 mm	3	0 __ 10

Table 3.5 The results of the properties of graded sand

	Test	Test result	Limits of Iraqi standard [37]
Harmful and fine materials	Material passing through a 75 micron sieve%	0.6	≤ 5
	Sulfate content %	0.297	≤ 0.5
Specific gravity		2.56	___
Absorption %		0.76	___
Fineness		2.61	___

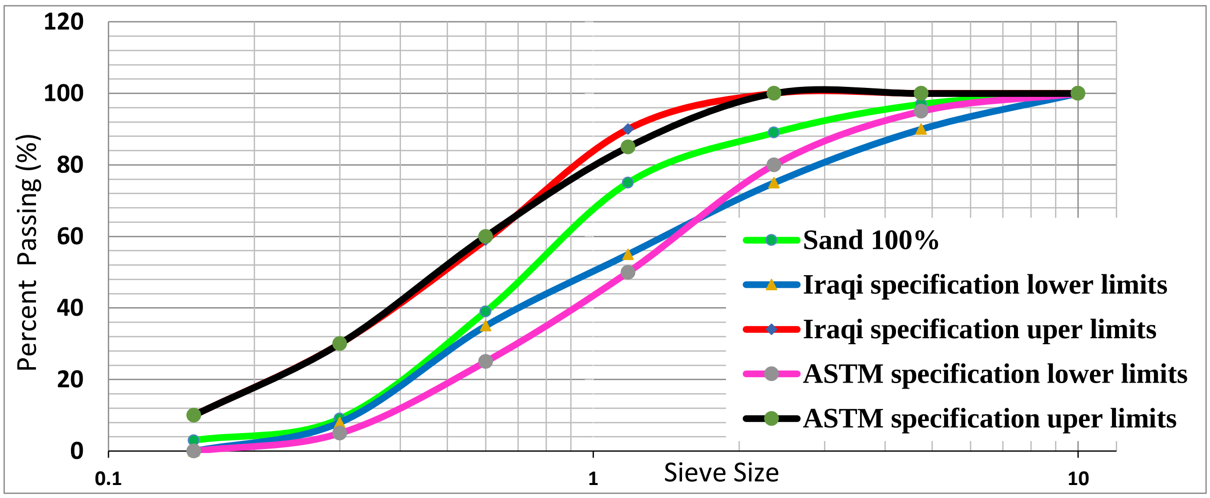


Figure 3.4 Gradation curve of natural sand within a gradation region (2) of Iraqi standard [37] and ASTM C33 [38].

3.3.3.2 Sand Dunes

Natural sand dunes used as a fine aggregate for fibrous concrete in different proportions. Where the focus will be on replacing the natural sand with sand dunes as a replacement for one of the components of the concrete.

This material was brought from the Al-Batera region, west of Misan Governorate, 65 km from the city center. They are crescent-shaped dunes and are single, with their head in the direction of wind movement. This sand dunes is characterized by its finer and finer grains than the natural graded sand grains used in construction through grading tests conducted on it. According to the tests, these sands are mostly composed of quartz crystals and are free of clay and organic compounds to some extent .These sands are homogeneous in nature, and their color tends to be almost brown (Al-Batera sand). It grains are circular because the grains transported by air due to their lightweight are subjected to intense collision and the sand dunes particles become spherical where the spherical grains move easier than the grains of angular shape. This fine sand is also characterized by the absence of grain gradation, and the average size of these sand grains ranges from 0.2 - 0.02 mm by calculating the fineness coefficient (1.9) according to standard sieves. There are no known standards or special specifications or limitations covering the use of sand dunes in concrete, although sand dunes do not meet the requirements for gradation limits of Iraqi standard No. (45)/1984 for fine aggregates [37], as well as the American specification ASTM C33 [38] .

However, this sand can be used correctly in concrete mixes without negative effects, according to the results of tests on concrete containing sand dunes. Mixed it with natural sand graded in different proportions to obtain a fine aggregate as one of the components of concrete with acceptable specifications [17], [18]. Therefore, the use of sand dunes in concrete is one of the successful solutions to address environmental problems to expand these dunes and limit their increase. Figure 3.5 and Table 3.6 show bring dunes sand material and chemical analysis, respectively, for the specimen taken from the Al-Batera region in Misan Governorate, where the tests were carried out in the laboratory of the national center for laboratories and construction research in Misan, to identify the components of this material, and the tests of the sand specimen showed that it contains several elements and in different proportions.

Figure 3.5 The sand dunes of the Al-Batera site, west of Misan Governorate.

Table 3.6 Chemical analysis of the sand dunes (Al-Batera)

compounds	Test results of sand dunes % Misan region /specimens From AL-Batera
Quartz	54.1
Oxides compounds	
Sio_2	54.51
Mgo	1.58
Al_2o_3	6.2
Cao	16.93
Fe_2o_3	3.24
K_2O	1.21
So_3	0.01
Muo	0.06
Others	16.04

3.3.4 Steel Fiber

In order to obtain sustainable concrete with high durability, steel fiber was used in this study. Steel fiber is the most available fiber type in the market because it has multiple dimensions, forms, and suitable characteristics. Its aim to increase the efficiency and quality of concrete, reduce contraction and improve its mechanical properties such as tension resistance, and compression. Also steel fiber reinforced concrete reduces the brittle of concrete, and the ductility of concrete is an important property that can be increased using steel fiber. In this study, two types of steel fibers were used: Micro straight steel fiber high strength and Macro steel fiber (hook-end).

3.3.4.1 Micro straight steel Fiber high strength

The purpose of using this type of fiber in this study is to increase the maximum strength of concrete and reduce initial cracks. This type of fiber has a high tensile strength of 2600 MPa and is more rigid with a diameter of (0.2) mm and a length of (13) mm. It has a large modulus of elasticity of about (210 GPa). Its shape is rounded, and surface treatment is copper-plated, it has an aspect ratio of 65, and was taked advantage of its properties when adding to concrete that contains replacement ratios of dunes sand as an alternative to sand to improve its mechanical properties, efficiency, and durability. Figure 3.6 shows the shape of the micro straight steel fibers with a length of 13 mm used in this research and Table 3.7 includes the properties of micro straight steel fibers.

Figure 3.6 The shape of the micro straight steel fiber.

Table 3.7 Properties of steel fiber straight *

Description	Steel fiber
Shape	Straight
Length (L)	13mm
Diameter (D)	0.2mm
Tensile strength	2850 MPa
Density	7800 kg/m^3
Color	Golden
Cross section	Round
Aspect ratio (L /D)	65
Modulus of Elasticity	210 Gpa

*The above data is from the bag technical leaflet.

3.3.4.2 Macro Steel Fiber (Hooked end)

Long steel fibers of the type hooked-end with a diameter (0.75 mm) and a length of (50 mm) were used to be added to the concrete containing the replacement ratios of sand dunes. These fibers have a high modulus of elasticity (200 GPa) and high tensile strength (1100MPa).Table 3.8 and Figure 3.7 show the properties of long steel fibers (hook-end) and the shape of these fibers, respectively.

Table 3.8 Properties of steel fiber type hooked-end *

Properties	Steel fiber
Shape	Hooked –end
Length (L)	50mm
Diameter (D)	0.75mm
Tensile strength	1100 MPa
Density	7800 kg/m^3
Aspect ratio (L / D)	67
Young’s modulus	200 GPa

*The above data is from the bag technical leaflet.

Figure 3.7 The shape of the macro steel fiber (hooked-end).

3.3.5 Water

In order to obtain salt-free concrete, pure drinking water (RO) was used in the preparation of mixtures and all pouring works in this study. The same pure water was used in the treatment of all concrete specimens during the concrete maturation period until the final hardening stage after the age of 28 days. Figure 3.8 shows the curing of concrete specimens in water basins in the laboratory of the College of Engineering / University of Misan.

Figure 3.8 Curing concrete models with pure water.

3.3.6 Admixture

Concrete that contains dunes sand as an alternative to sand as one of the components of the concrete mix needs to add some improvers materials to get acceptable workability and reduce water, and porosity. The improvers give good properties to the concrete in the fresh and hard state. One of these plasticizers is the superplasticizer (Hyperplast PC 260), which was used in this study as an additive for fibrous concrete containing sand dunes. Figure 3.9 shows the shape of the package of the superplasticizer hyperplast PC 260, with 25 liters capacity .This material complies with the American Standard ASTM C494 Type A, G [39]. Table 3.9 shows the technical specifications of hyperplast PC 260 material (according to its technical bulletin).

Figure 3.9 The package of a material (Superplasticizer Hyperplast PC 260).

Table 3.9 Technical properties of the material hyperplast PC 260*

Properties	Hyperplast pc 260
Chemical Base polymer	Modified polycarxylates Based
Colors liquid	Light yellowish to brownish
Freezing point	≈ -7 c°
Specific gravity @25 c°	0.02 ± 1.1
Air content	Less than 2% The increase in air content in the concrete mixture compared to the architectural mixture
Dosage	0.5 to 3.0 Liter per100kg of binder

* The data above are from the Technical Bulletin for Superplasticizer Hyperplast pc.

3.4 Sand dunes as sand replacement

The sand dunes used in this study as a partial and total alternative for graded sand in concrete are sands of the type whose grains are very fine and the diameters are very small and all of these grains of sand dunes (without merging with the grains of natural graded sand) pass through Sieve No. 16 .This explains that the maximum size of the sand dunes particles is less than 1.18 mm, as shown in Figure 3.10 . This material was brought from the Al-Batera region, west of Misan Governorate, and they are placed in closed bags.

Figure 3.10 Sand dune specimen shape.

Gradation testing of sand dunes was conducted to determine its suitability as fine aggregate in concrete using listed natural sand specifications and applied to sand dunes. Standard sieves were utilized according to Iraqi Standard Specification No. 45/1984[37]and ASTM C33 [38] for fine aggregate and its application in the sand dunes sieving process. The tests were conducted in the laboratory of the College of the Engineering / University of Misan. Figure 3.11 shows the gradation test of sand dunes. The sieve analysis of sand dunes showed that the maximum limits of the gradation specification for fine aggregates (sand) were achieved for gradation zone

No. (4) of the Iraqi Standard specification No. 45/1984 [37]. Except for the fine sieve (300 microns), where differences were recorded in the transient percentages, which are outside the limits of the specification, and this is due to the small size of the sand dunes grains, as shown in Table 3.10, Figure 3.12 and Figure 3.13 show a gradation of sand dunes, gradation curve for sand dunes, and dune gradation curve when compared with the (natural sand) gradation class used in this study respectively.

Figure 3.11 Gradation test for sand dunes in a laboratory.

Table 3.10 Sand dunes gradation test results

Sieve size (mm)	Passing % (D.S)	Limits (Gradation Class- D) Iraqi standard No. (45) / 1984[37]
10 mm	100	100
4.75 mm	100	95 __ 100
2.36mm	100	95 __ 100
1.18 mm	100	90 __ 100
0.60 mm	99.942	80 __ 100
0.30 mm	99.88	15 __ 50
0.15 mm	9.71	0 __ 15

The coefficient of fineness of the sand dunes used is (1.9) which indicates that its grains tend to be fine within the B range of sand fineness calibrations [40]. Table 3.11 shows the ranges of fineness calibrator for sand. The average size of these sand grains (Maximum aggregate size) is (0.2) mm according to the standard sieves (4.75, 2.36, 1.18, 0.6, 0.3, 0.15) mm. Although there is no granular gradation of sand dunes, it can be well used in concrete as an alternative to natural sand, which gives this sand great economic importance due to its presence in large quantities and availability easily. Therefore, its exploitation and use in concrete as fine aggregate is one of the successful solutions to address the problem of sand dune expansion and reduce the environmental problems resulting from it.

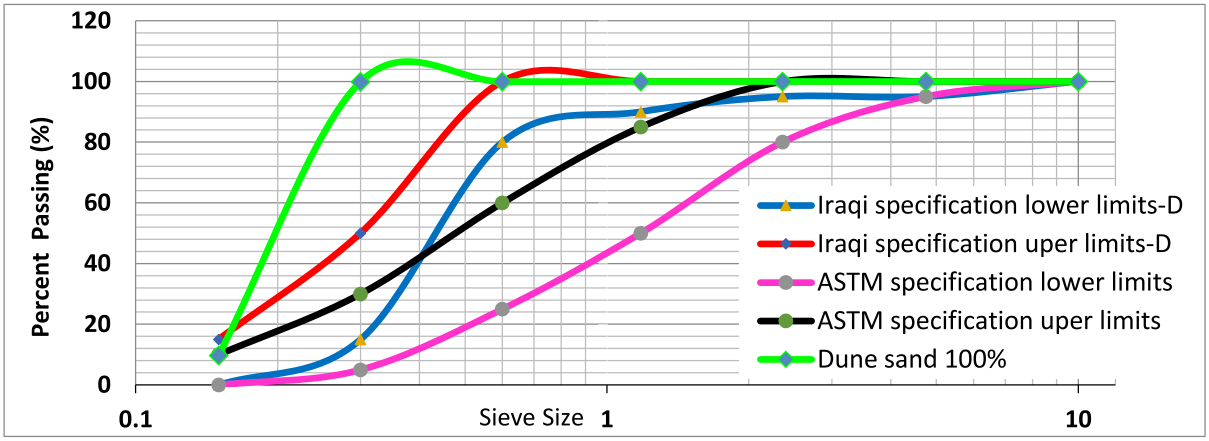


Figure 3.12 Gradation curve for sand dunes vs class (D) to the Iraqi standard [37] and ASTM C33 [38].

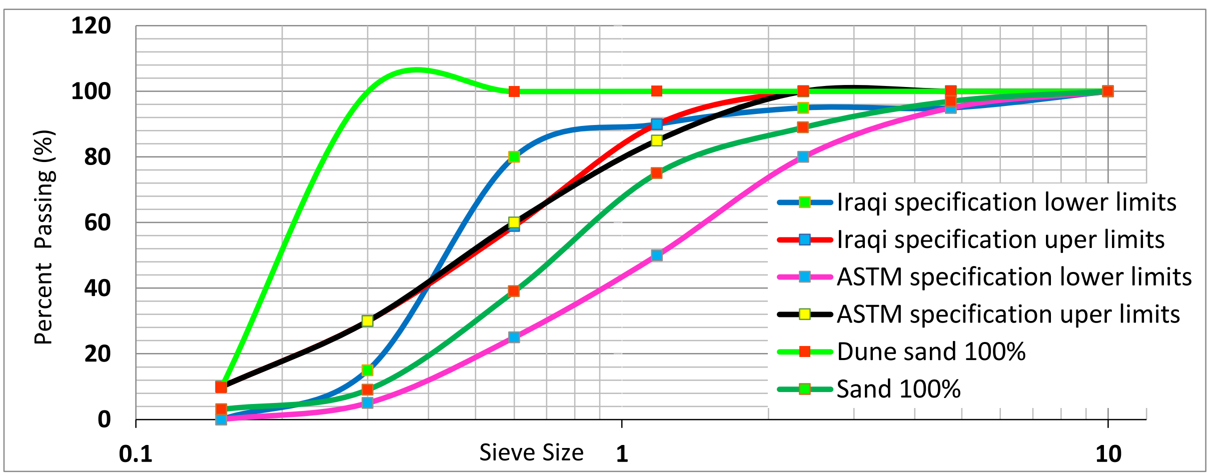


Figure 3.13 Gradation curve for dunes sand vs class (B) of Iraqi standard [37] and ASTM C33 [38].

Table 3.11Domains of fineness standards for sand [40]

Domain	fineness modulus limits	Description
A	2.2-2.8	Best used in concrete or mortar
B	1.8-2.2	Sand whose grains tend to be finer
C	2.8-3.2	Sand whose grains tend to be coarser

3.5 Selection of sand dunes percentages

In this research, several concrete mixtures containing sand dunes have been studied as an alternative to sand in order to obtain good and structurally acceptable results for the use of dune sand as one of the concrete components. Different ratios of dune sand were used to know the optimal ratios for replacement.

3.5.1 Sand dunes as a partial and complete alternative to sand

Despite the fact that the bulk of the dunes sand grains pass through standard fine sieves, and from the observation of the results of sifting this sand and its fineness coefficient, noted that the grains of this material are very fine. This fineness of aggregate may negatively affect the properties of concrete and at the same time, it fills the spaces between coarse sand and gravel. Therefore, for obtaining good performance from sand dunes as fine aggregate in concrete, experimental concrete mixtures were used in which dunes sand mixed with sand in different ratios was used by making a granular correction of the fineness of this material, ratios were used (20%, 40%, 60%, 80%, 100%) in addition to 0% without sand dunes (reference mixture) where it designed according to the American Code ACI 211.1-91[41]. The purpose of these ratios is to obtain an acceptable indication of the replacement ratios of fine aggregates in concrete through tests for the purpose of using them in the practical program of this study, and as shown in Figure 3.14 preparing a reference mix and mixes containing sand dunes.

The gradation test was performed for the fine aggregate mixture which includes the replacement ratios which will be explained later in this chapter, as well as casting (36) cubes with dimensions (150 × 150 × 150) mm, six cubes for each percentage weight, three cubes of (7) days age and three cubes of (28) days age were examined to obtain the compressive strength and density of concrete for the purpose of checking these ratios and indicating their suitability as constant mixtures in this study and as shown in Figure 3.15.

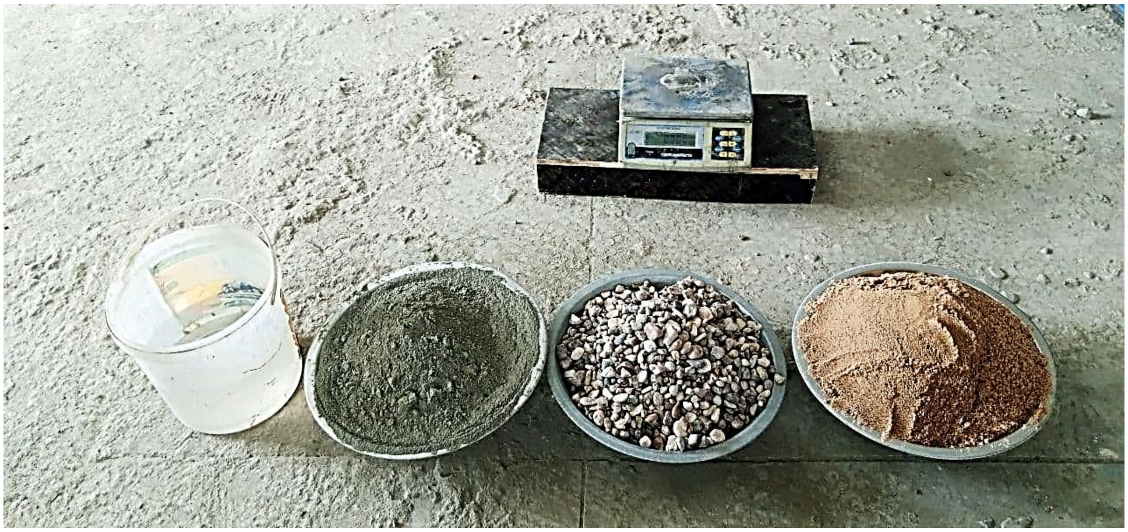


Figure 3.14 preparing a reference mixture.

The water to cement ratio is 0.41 with the use of (superplasticizer hyperplast pc 260 by ratio of 0.5% from ordinary portland cement weight), as well as the use of coarse aggregate in mixtures.

Figure 3.15 Specimens for mixtures containing sand dunes in different ratios.

The compressive strength and density test results of the cubes were shown in Table 3.12, Figure 3.16 and Figure 3.17.

Table 3.12 Compressive strength and density for experimental cubes

Dune sand % percentage	Age (7) days		Age (28) days	
	Compression (MPa)	Density (kg/m^3)	Compression (MPa)	Density (kg/m^3)
0% R	34.3	2445.9	44.9	2457.48
20%	41.09	2367.7	50.7	2375.4
40%	41.06	2390.22	55.1	2424.8
60%	37.20	2381.62	49.19	2390.81
80%	28.63	2344.59	38.24	2351.11
100%	25.2	2342.1	30.1	2349.3

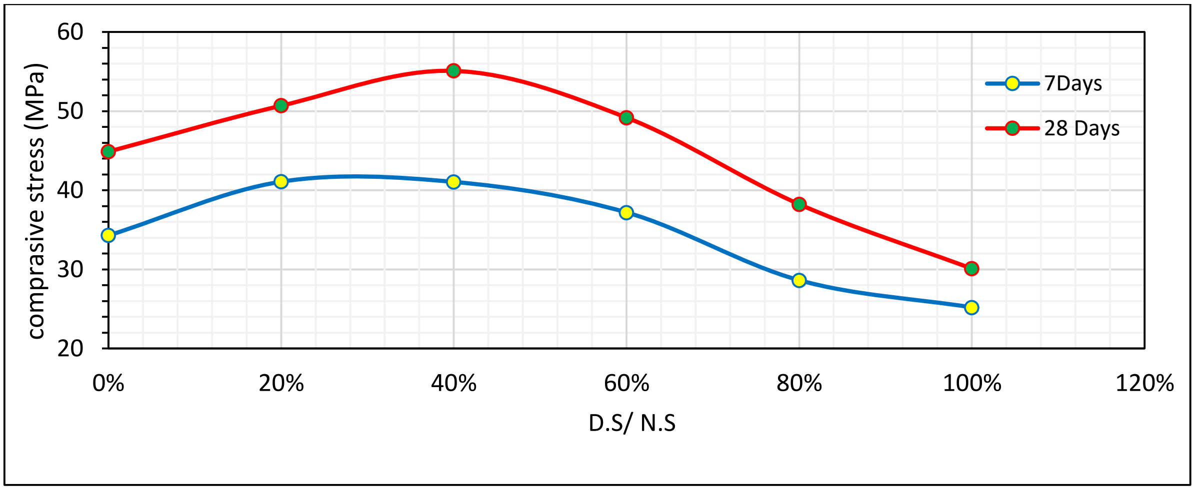


Figure 3.16 The compressive strength curves for concrete mixes.

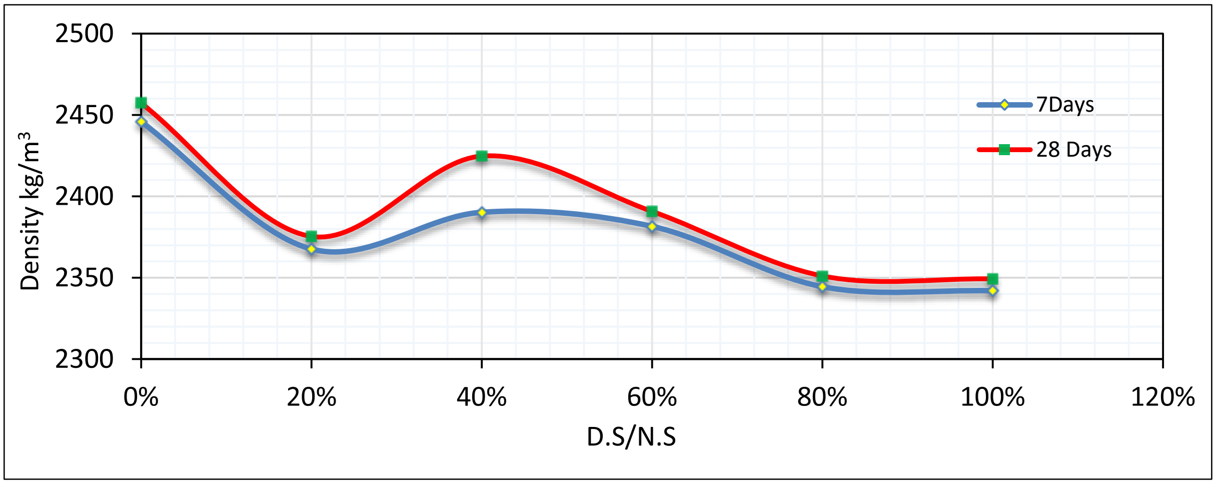


Figure 3.17 The dry density curves for concrete mixes.

From the Figures (3.16 and 3.17) of the experimental tests, noted that the compressive resistance of concrete specimens at 28 days age increases by increasing the percentage replacement of sand with sand dunes until the ratio of 60% .Where the compressive strength was (49.19) MPa. The highest compressive strength of the replacement ratio (40%), recorded (55.1) MPa. which is considered the optimal replacement ratio in this study. The compressive strength and density decrease with the increase of the sand dunes content for the replacement ratios of 80% and 100%, where the replacement ratio (100%) recorded a decrease in the compressive strength and density by about 33% and 4.4%, respectively compared to the reference specimen. Based on the good results of testing the compressive strength of experimental cubes containing sand dunes in concrete, therefore, 20% was determined as the lowest ratio of replacement in this study.

3.5.2 Sieve analysis of the fine aggregate consisting of sand dunes

For the purpose of classifying the fine aggregate mixture according to the size of its granules, an experiment was conducted for the sieve analysis of fine aggregate (sand) and sand dunes with a percentage of 100%, each type separately, as mentioned previously. The sieve analysis was also conducted for the rest of the mixed proportions of fine aggregates (sand + sand dunes) in different proportions. When the fine aggregate mixture consisted of a ratio (20% dunes sand (D.S) + 80% natural sand (N.S)), the sifting process of the aggregate was carried out using standard sieves according to the Iraqi Standard No. (45)/1984 [37]for fine aggregates and ASTM C33 [38]. We note that the granules of this mixture are fine to medium fineness, and the granules of this mixture contain a good granular gradation and have fulfilled the requirements of class (C) of the Iraqi standard, fineness modulus of this mixture (2.58) as in Table 3.13 and Figure 3.18.

Table 3.13 Sieve analysis of fine aggregate mixture (20%D.S+80%N.S)

Sieve size (mm)	Passing %	Limits (Gradation Class C) Iraqi standard No. (45) / 1984[37]
10 mm	100	100
4.75 mm	100	90 __ 100
2.36mm	99.773	85 __ 100
1.18 mm	88.798	75 __ 100
0.60 mm	68.038	60 __ 79
0.30 mm	33.098	12 __ 40
0.15 mm	9.389	0 __ 10

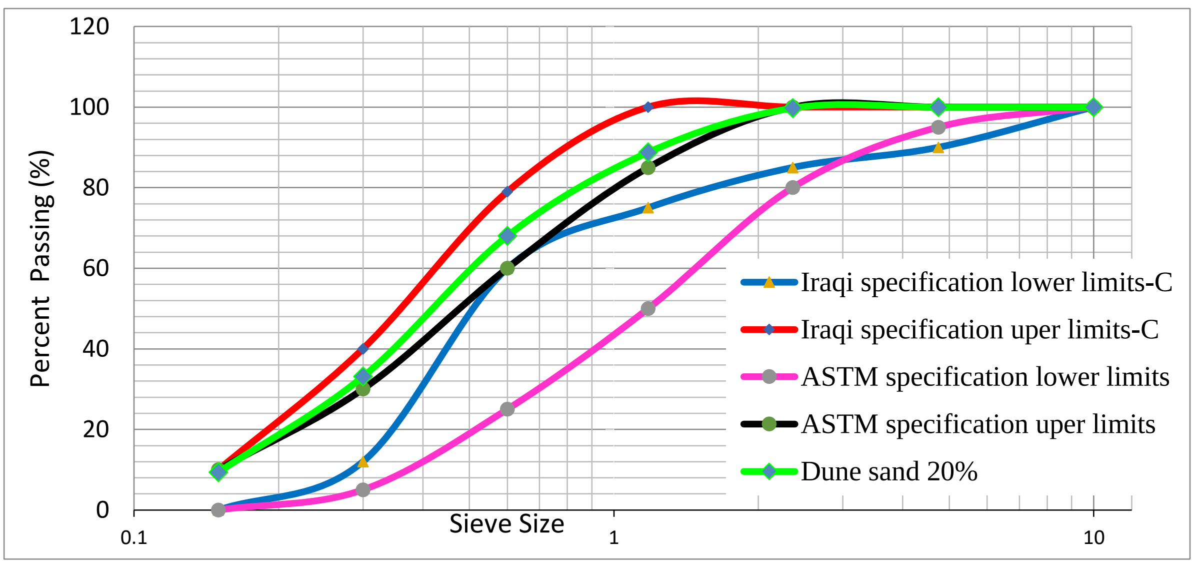


Figure 3.18 Gradation curve for fine aggregate (20%D.S+80%N.S) [37, 38].

At the proportion of fine aggregate mixture (40% D.S + 60% N.S), it was observed from the sieve analysis that this sand is close to the gradation class (C) of the Iraqi standard, which means that its grains tend to fineness except some deviations in the fine sieves (0.15 mm and 0.30 mm) as in Table 3.14 and Figure 3.19 .The coefficient of fineness for this ratio is (2.5).

Table 3.14 Sieve analysis of fine aggregate mixture (40%D.S+60%N.S)

Sieve size (mm)	Passing %	Limits (Gradation Class C) Iraqi standard No. (45) / 1984[37]
10 mm	100	100
4.75 mm	100	90 __ 100
2.36mm	99.118	85 __ 100
1.18 mm	92.412	75 __ 100
0.60 mm	78.778	60 __ 79
0.30 mm	54.943	12 __ 40
0.15 mm	21.001	0 __ 10

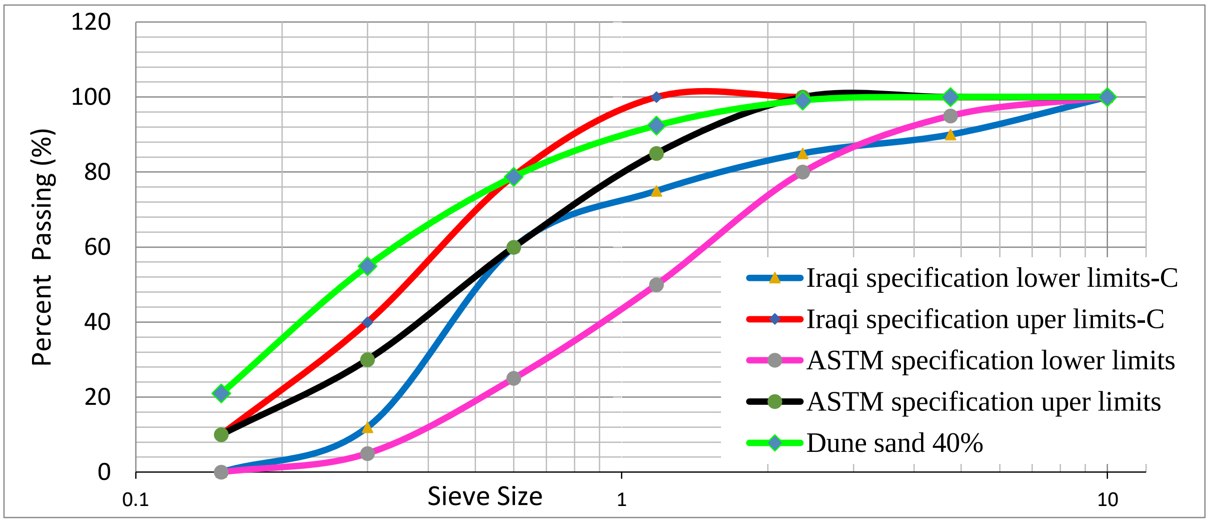


Figure 3.19 Gradation curve for fine aggregate (40%D.S+60%N.S) [37, 38].

When mixing fine aggregates (60%D.S+40%N.S), noticed that the gradation of the granules of this mixture approaches the gradation of class (D) of the Iraqi standard except for some deviations in the fine sieves (0.15 and 0.3) mm, as shown in Table 3.15 and Figure 3.20, the coefficient of fineness for this mixture is (2.3).

Table 3.15 Sieve analysis of fine aggregate mixture (60% D.S + 40% N.S)

Sieve size (mm)	Passing %	Limits (Gradation Class D) Iraqi standard No. (45) / 1984[37]
10 mm	100	100
4.75 mm	100	95 __ 100
2.36mm	100	95 __ 100
1.18 mm	95.321	90 __ 100
0.60 mm	85.48	80 __ 100
0.30 mm	67.188	15 __ 50
0.15 mm	12.991	0 __ 15

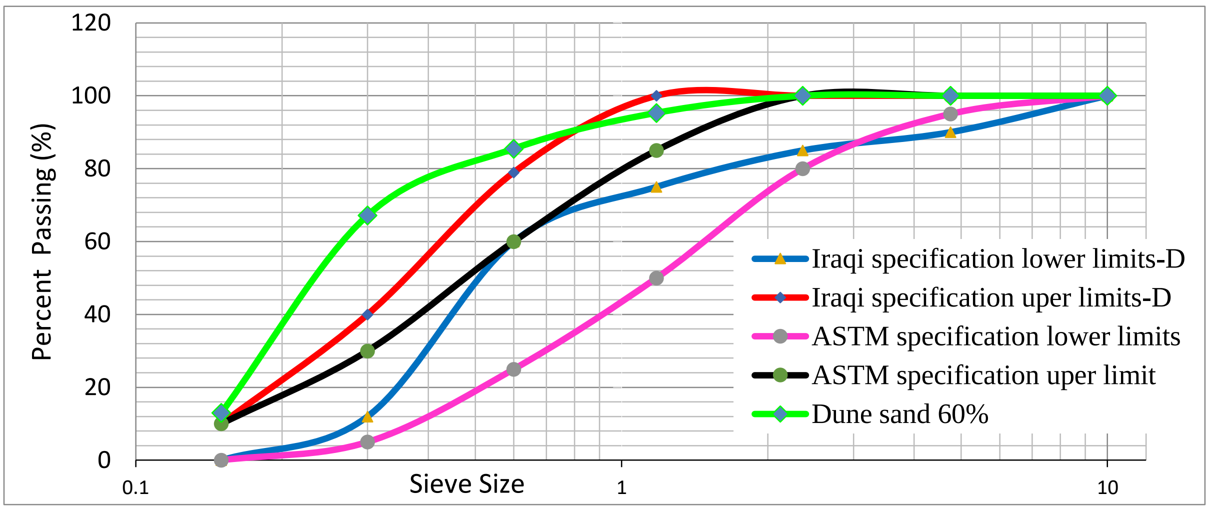


Figure 3.20 Gradation curve for fine aggregate (60%D.S+40%N.S) [37, 38].

When mixing fine aggregates (80%D.S+20%N.S) from the sieve analysis of this ratio, noticed that the gradation of the grains of this mixture approaches the gradation region of class (D) of the Iraqi standard and the coefficient of fineness of this mixture is 2 meaning that the granules of this mixture tend to be fine (very fine granules) except for one deviation in sieve (150) micron as shown in Table 3.16 and Figure 3.21.

Table 3.16 Sieve analysis of fine aggregate mixture (80%D.S + 20% N.S)

Sieve size (mm)	Passing %	Limits (Gradation Class D) Iraqi standard No. (45) / 1984 [37]
10 mm	100	100
4.75 mm	100	95 __ 100
2.36mm	100	95 __ 100
1.18 mm	97.425	90 __ 100
0.60 mm	92.688	80 __ 100
0.30 mm	84.547	15 __ 50
0.15 mm	22.680	0 __ 15

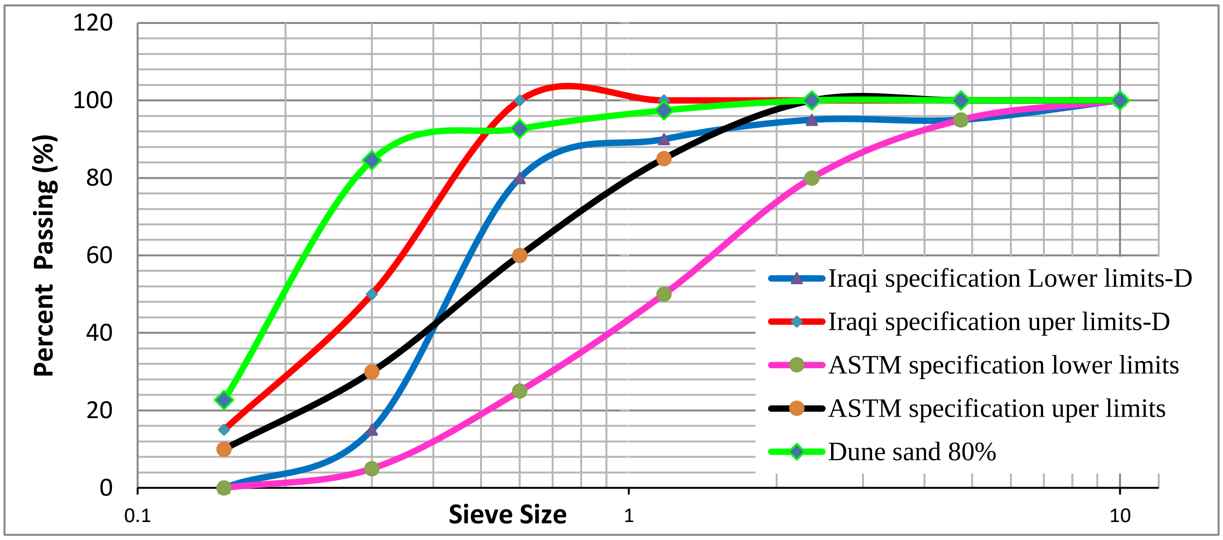


Figure 3.21 Gradation curve for fine aggregate (80%D.S+20%N.S) [37, 38].

It can be said through the results of the sieves analysis of the mixture of fine aggregates (sand dunes with sand) in different proportions that these mixtures meet the requirements of varieties (B), (C), (D) with some deviations in the fine sieves, meaning that the size of the grains of these mixtures is between the average fineness and fine into very fine. Figure 3.22 shows the gradation curves for the ratios from (20%D.S to 100%D.S) and their comparison with the gradation of the sand (0%D.S) of class (B) from the Iraqi standard [37] and ASTM C33-03.

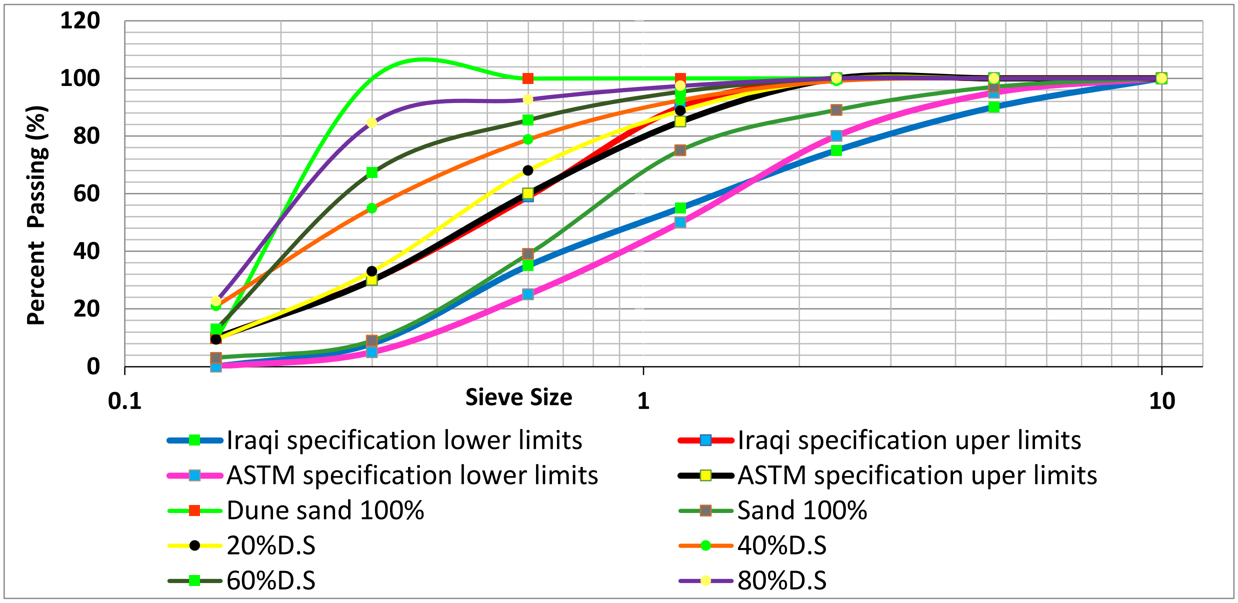


Figure 3.22 Gradation curves for different mixing ratios of sand dunes and natural sand versus Iraqi standard class (B) limits.

3.5.3 Sand dunes as a partial and complete alternative to sand with the addition of steel fiber

To increase the efficiency and quality of concrete containing sand dunes as a partial and total alternative to sand in this study, steel fibers of different shapes were used to be added to the concrete mix. This addition of fibers was adopted based on some results of research, experiments, and studies whose content was reviewed in the second chapter [16], [20], [34]of this study, which gave the positive role to use. Most of these studies have shown that the best ratio for using steel fibers in concrete is 1% added to concrete components depending on the aspect ratio[24], [29]. If this percentage is more than 1%, this may lead to many problems, including poor workability, the irregular distribution of the fibers, and poor spreading, separating, and bleeding concrete. Based on the results of these studies [24], [26], [29], [31], [34], a total and optimal volumetric ratio was adopted to add steel fibers to concrete in this study, which is 1% calculated from the total volume of concrete. Two types of steel fibers were used, they are micro-straight steel fibers with a length of (13 mm) and macro steel fibers with hook-ends with a length of (50mm) as well as hybrid fibers (long + short) added to the concrete mixture. For the purpose of studying the effect and role of each addition separately and knowing the extent of its contribution to strengthening and reducing cracks in concrete containing sand dunes. Therefore, the first ratio of 1% of short straight fibers was used to be added to concrete containing sand dunes as a fine aggregate for the ratios (0%, 20%, 40%, 60%, 80%, and 100%).The second percentage is 1% of the long steel fibers (hook end)are also added to the mentioned percentages, also used a third percentage of fibers, which is to use 1% of hybrid fibers (0.35% short + 0.65% long) added to the concrete mix for the purpose of studying its effect on concrete that contains sand dunes as an alternative to sand as-mentioned ratios, where this ratio of hybrid fibers is an optimal ratio and close to the ratios of previous studies reviewed [31]. Therefore, in this study, the focus was on using a short single (microfiber), long single (macro fiber), and hybrid fibers, separately, as shown in Figure 3.23.

Figure 3.23 Single and hybrid steel fiber.

3.5.3.1 Sand dunes mixing ratios as an alternative to sand without fibers

Five mixing ratios of sand dunes were used as an alternative to sand in addition to the ratio of the without dune (0% D.S, 20% D.S, 40% D.S, 60% D.S, 80% D.S, 100% D.S), and these ratios without adding steel fibers to her. With casting one slab per proportion and casting (6) cubes (150×150×150) mm, (6) prisms (500×100×100) mm, (6) cylinders (200×100) mm, (1) cylinder (300 × 150) mm for each ratio, and a study of the mechanical and physical properties of these ratios, which will be clarified later.

3.5.3.2 Sand dunes mixing ratios with the addition of single micro straight steel fibers

Six mixing ratios containing 1% of single straight steel fibers with a length of 13 mm and a diameter of 0.2 mm were used for the mixture consisting of mixing ratios:0%D.S+1%S.F.S,20%D.S+1%S.F.S,40%D.S+1%S.F.S,60%D.S+1%S.F.S, 80%D.S+1%S.F.S, 100%D.S+1%S.F.S. For each ratio, six cubes of dimensions (150 × 150 × 150) mm were cast, six cylinders (100 × 200) mm, six prisms with dimensions (500 × 100 × 100) mm, one cylinder (300 × 150 mm) with slab casting for each mixture, for the purpose study the physical and mechanical properties of these mixtures, which will be clarified later.

3.5.3.3 Sand dunes mixing ratios with the addition of single macro steel fibers (hook-end)

Six mixing ratios containing 1% of the long steel fiber hooked-end type 50 mm long and 0.75 mm in diameter were used for the mixture consisting of mixing ratios of sand dunes with sand, as shown: 0%D.S+1%S.F.L, 20%D.S+1%S.F.L,40% D.S+1%S.F.L, 60%D.S+1%S.F.L, 80%D.S+1%S.F.L, 100%D.S+1%S.F.L. For each ratio, six cubes of dimensions (150 × 150 × 150) mm were cast, six cylinders (100 × 200) mm, six prisms with dimensions (500 × 100 × 100) mm, one cylinder

(300 × 150 mm) with slab casting for each mixture, to study the physical and mechanical properties of these mixtures.

3.5.3.4 Sand dunes mixing ratios as an alternative to sand with the addition of hybrid steel fibers

Six mixing ratios were used containing on 1% percentage of the hybrid steel fibers of the concrete volume. These hybrid fibers consist of 65% of the long fibers and 35% of the short fibers. They are added as a single percentage to the concrete mixtures containing mixing ratios of dunes sand as an alternative to sand as shown: 0%D.S+1%H.S.F, 20%D.S+1%H.S.F, 40%D.S+1%H.S.F, 60%D.S+1%H.S.F, 80%D.S+1%H.S.F, 100%D.S+1%H.S.F. For each ratio casting of specimens as the previous with slab casting for each mixture, to study the physical and mechanical properties of these mixtures and their effect on concrete and the role of hybridization.

3.6 Design of concrete mix

In this work, all the requirements for mixing concrete were prepared from the mixing machine and equipment, as well as the raw materials from cement, fine aggregate consisting of a mixture of sand dunes and natural sand, gravel, pure water with a plasticizer additive and steel fibers. A reference concrete mixture was prepared according to American code ACI.211.1-91 [41] and audited by pouring and testing trial concrete cubes, in addition to a slump test of fresh concrete for proper workability of concrete.

Specific compressive strength at 28 days age ($f`c$) = 25 MPa

Determining the required design resistance ($f`cr$) from the Table (A1.5.3.4-ACI .211.1.92 Code) [41].

$f`cr = f`c + 8.3\ MPa$ When $34.5 \leq f`c \geq 20.7$

$f`cr = 25 + 8.3\ MPa = 33.3$ MPa

From Table (A1.5.3.1- code) the slump is estimated for concrete slabs (10) cm.

The maximum size of the coarse aggregate used in this study is 20 mm.

The water content of the mixing is estimated in (kg) and the air content as a percentage from the Table (A1.5.3.3- ACI 211 code) depending on the slump value and the maximum size of the aggregate.

Use Water content =198 kg/m^3

Air content =2%

From compressive strength =33.3MPa and Table (A1.5.3.4 - ACI code):

The ratio of water to cement by weight (W/C) = 0.41, with adding a superplasticizer of 0.5% by weight of cement to the mixture to improve workability, (according to the technical bulletin of the material).

The amount of cement calculate from the following relationship:

Cement content = $\frac{\text{water content}}{\text{W/C}}$

Cement content = $\frac{198}{0.41}$ =482.93kg/m^3

The sand fineness coefficient = 2.6 (from gradation calculation)

From Table (A1.5.3.6 - ACI code), the intersection of the maximum size of the coarse aggregate with the coefficient of sand fineness in the table. The volume of coarse aggregate is determined per cubic meter of the mixture.

The volume of coarse aggregate = 0.64 m^3

Dry density of coarse aggregate =1600 kg/m^3

Weight of coarse aggregate = 0.64 × 1600 = 1024 kg/m^3

From Table (A1.5.3.7.1 - ACI code) and the maximum size of the coarse aggregate, the density of fresh concrete is determined:

The density of fresh concrete (γ_c) =3255 kg/m^3

Weight of fine aggregate = 2355 – 482.93 – 1024 – 198 = 650.07 kg/m^3

Therefore, weights of cement, sand and gravel are respectively (482.93, 650.07, and 1024) per cubic meter as in Table 3.17.

Table 3.17 Reference mix ratios per cubic meter of concrete

Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3	Water kg/m^3	W/C	S.P (260) %
482.92	650.07	1024	198	0.41	0.5

Five main proportions of sand dunes (weight ratios) as a partial and total alternative to sand in this study in addition to the reference mixture without sand dunes (0%D.S, 20%D.S, 40%D.S, 60%D.S, 80%D.S, and 100% D.S), eighteen concrete mixes contain different proportions of dune sand with the addition of steel fibers to it .Table 3.18 and Table 3.19 show mixing ratios per cubic meter for six mixtures without steel fibers. Mixing ratios per cubic meter for eighteen mixtures with a single steel fibers and hybrids, respectively.

Table 3.18 Mixing ratios per cubic meter without steel fiber

Sand dunes replacement level%	Cement kg/m^3	Water Kg/m^3	Super plasticizer kg/m^3	Coarse aggregate kg/m^3	Fine aggregate kg/m^3	sand dunes kg/m^3	Water to cement ratio(w/c)
0%	482.93	198	0.5 %	1024	650.07	0	0.41
20%	482.93	198	0.5 %	1024	520.06	130.01	0.41
40%	482.93	198	0.5 %	1024	390.04	260.03	0.41
60%	482.93	198	0.5 %	1024	260.03	390.04	0.41
80%	482.93	198	0.5 %	1024	130.01	520.06	0.41
100%	482.93	198	0.5 %	1024	0	650.07	0.41

Table 3.19 Mixing ratios per cubic meter with the steel fibers

Sand dunes replacement level%	Description of steel fiber	Cement Kg/m^3	Steel Fiber (Long) Kg/m^3	Steel Fiber (Short) Kg/m^3	Water Kg/m^3	Super Plasticizer Kg/m^3	Coarse aggregate Kg/m^3	Fine aggregate Kg/m^3	Sand dunes Kg/m^3	W/C
% 0	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	650.07	0	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	650.07	0	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	650.07	0	0.41
% 20	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	520.06	130.01	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	520.06	130.01	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	520.06	130.01	0.41
% 40	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	390.04	260.03	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	390.04	260.03	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	390.04	260.03	0.41
% 60	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	260.03	390.04	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	260.03	390.04	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	260.03	390.04	0.41
% 80	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	130.01	520.06	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	130.01	520.06	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	130.01	520.06	0.41
% 100	Mono (50mm)	482.93	78.5	0	198	0.5%	1024	0	650.07	0.41
	Mono (13mm)	482.93	0	78.5	198	0.5%	1024	0	650.07	0.41
	0.65 long +0.35 short	482.93	51.025	27.475	198	0.5%	1024	0	650.07	0.41

3.7 Slab Molds

Square wooden molds were used consisting of a wooden base with side ribs connected to each other and to the wooden base by means of fixing screws that can be opened. The thickness of the wood used is 18 mm, also the concrete slab is a square-shaped slab with dimensions of length (l) = 800 mm, width (w) = 800 mm, and thickness (t) = 80 mm. these dimensions are used in all fiber-reinforced and non-reinforced concrete slabs that contain sand dunes. (24) Wooden molds were manufactured in this study, the internal dimensions of the wooden mold are (800 * 800) mm and the height from the inside is 80 mm. All concrete slabs are poured into these wooden molds with the same dimensions and as shown in Figure 3.24 the internal dimensions of the wooden mold. The same dimensions were used for all concrete slabs to be suitable for the test conditions available in the laboratory in terms of the test machine and the width of the axes of the device. The method of support and loading is a simulation approximate to previous studies [26], all slabs are tested as simply supported slabs under one concentrated bearing point in the middle of the concrete slab.

Figure 3.24 The internal dimensions of the wooden mold.

The support points on which the slab sits are connected to an iron frame that was specially manufactured for testing these slabs in the testing machine. This iron structure consists of four ribs of heavy type iron, and the external dimensions of this iron structure are the same as the dimensions of the concrete slab. The steel support points are the column points at the edges (D = 40mm) ,(t = 50mm), and the distance from the center of the support point to the edge of the steel structure is 50 mm in all directions of the four corners of the steel structure. Clear span Length is 700 mm for all slabs in this study. These concrete slabs are supported in such a way as to prevent the punching shear of the slabs in the middle. As well as shearing at the edges of the slab, so that Five-point load was used, meaning a central point load in the middle and four steel support points at the edges on which the concrete slab sits. These support points are covered by rubber in the form of a hollow cylinder at the bottom and from the top, it ends with a vertical cap with a thickness of 30 mm, as shown in Figure 3.25. In order to absorb shocks and increase the resistance of punching shear and vibration, thus preventing the occurrence of punching shear of the concrete slab in the middle and shearing at the ends.

Figure 3.25 Fabrication of the steel structure and the support points and cover.

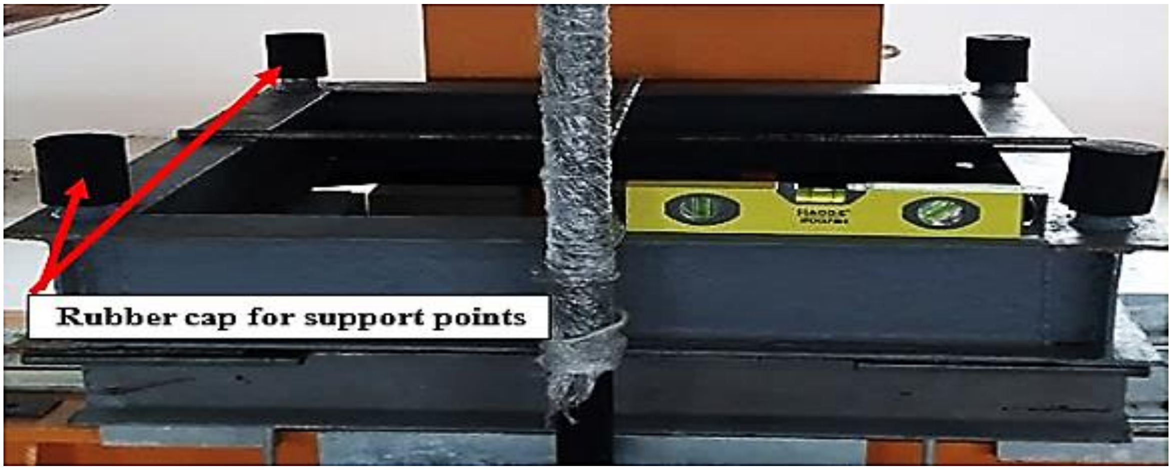


Figure 3.25 Continued.

3.8 Concrete Mixing

An electric mixer with capacity of (0.128) m^3 was used for mixing all concrete mixtures, and each mixture was prepared separately in the laboratory of the Faculty of Engineering / University of Misan, according to the following steps:

1- All raw materials included in the composition of each mixture were brought from materials of sand, gravel, sand dunes, cement, superplasticizer, and steel fibers of two types, short and long.

2- The gravel material was washed with pure water to removing dust and dirt, then dried by leaving them for several days under the sun until it was completely dried.

3- preparing the mixing machine and cleaning it, along with preparing all the casting equipment from pots and vibrator to expel air from the concrete, as well as workers and others, while taking all safety and prevention measures.

4- Preparation of laboratory standard steel molds, cleaning and lubricating them to prevent adhesion between the concrete and the inner surface of the mold, these molds are used for casting concrete models. They are standard molds for cubes with dimensions (150 × 150 × 150) mm, prisms (500 × 100 ×100) mm, cylinders (150 × 300) mm, and cylinders (200 × 100) mm. With the preparation of the wooden molds for casting concrete slabs with dimensions (80 × 800 × 800) mm. They are placed on flat ground.

5- All components of concrete mixtures are weighed in advance, for each mixture separately, and placed in bags with an identification sheet containing the name and weight of the specimen in each bag.

6- Coarse aggregate and fine aggregate consisting of mixing ratios of sand dunes and natural sand are added and placed in the bowl of the electric mixer, then the mixer is running for 2 minutes. Then the cement is added to the mixer and the ingredients are mixed for another 2 minutes for the purpose of homogeneity of the dry mixture components well. The water is gradually added with the addition of the superplasticizer to the mixing bowl, the ingredients are mixed for 3 minutes. The mixer is restarted for a period of 2 minutes in order to ensure good homogeneity in the concrete components. Then the steel fiber material is added to the concrete mix, where the fiber is added manually and slowly to the mixer bowl while the mixer bowl continues to rotate in order to avoid its gathering in one block, as shown in Figure 3.26, then mix the concrete components inside the mixer for 5 minutes to disperse the fibers and spread well throughout the concrete mix.

Figure 3.26 Manually adding fibers to the mixer.

7- After the mixing process is completed, then a specimen of the fresh concrete is taken and a slump test is conducted on it for each mixture, the concrete is poured into the modeling molds, and the vibrator is operated on it, and left for (24) hours after casting to harden.

3.9 Casting and curing operations

Concrete is poured into three layers in the mold, each layer with a thickness of 5 cm for specimens with the use of a standard steel rod with dimensions (2.5 × 2.5 × 38) cm to compacting small specimens and a vibrator for large molds. After the casting is completed, the specimens are left for 24 hours, then the molds are opened the next day, and the concrete specimens are transferred to water basins for the purpose of concrete maturation for a period of 28 days, with the water changed every 5 days. After the concrete curing period with water is over, it is taken out and prepared for testing. As for the large specimens represented by the concrete slabs, they are covered with pieces of cloth that are characterized by their retention of moisture. These pieces of fabric are soaked with water and placed on the concrete specimens and sprayed with water every day. Lubrication of molds, pouring concrete slabs, and small specimens, stacking them, and curing them with water, as shown in Figure 3.27.

3.10 Experimental program for Fiber-reinforced concrete slabs with sand dune

The experimental program includes the study of the physical and mechanical properties of sand dunes -containing concrete as an alternative to sand and reinforced with single and hybrid steel fiber as well as the concrete without fiber. And a study of the behavior of concrete slabs reinforced with steel fibers and that containing sand dunes as an alternative to sand (FRDC-S, L, HY). The experimental work was divided into two parts:

Figure 3.27 Lubrication of molds, casting concrete, and curing the slabs with water.

3.10.1 Physical and mechanical properties of fiber-reinforced concrete mixes with sand dunes

In this part of the thesis, the physical and mechanical properties of short, long, and hybrid steel fiber reinforced concrete that contain replacement ratios of sand dunes as an alternative to sand will be studied. Mechanical tests include compressive strength test, split tensile strength, and flexural strength, while physical tests include dry density test, absorption, ultrasonic pulse velocity test, static modulus of elasticity, and calculating the dynamic modulus of elasticity. Also, slump test for fresh concrete. 24 concrete mixtures containing different proportions of sand dunes are cast, six without fiber and 18 reinforced with steel fibers.

3.10.2 The concrete slabs with sand dunes

This part of the thesis is concerned with studying the effect of using sand dunes on the behavior of concrete slabs reinforced with single and hybrid steel fiber, where five square two-way slab concrete Simply supported were cast with dimensions (800 × 800 × 80) mm and containing different proportions of sand dunes. The ratio of length (l) to width (w) of these slabs (l/w) < 2. These slabs are without steel fibers, where one slab is cast for each replacement ratio, in addition to the sixth reference slab (without sand dunes). The results of the test of these slabs containing sand dunes are compared with the results of the test of the reference slab as well as with slabs reinforced with steel fibers. Also, 18 fiber-reinforced concrete slabs were cast, including three fiber-reinforced concrete slabs without sand dunes, the first reinforced with short steel fibers, the second reinforced with long steel fibers, and the third reinforced with hybrid steel fibers, as well as 15 fiber-reinforced concrete slabs containing sand dunes in different ratios as shown in Figure 3.28. These slabs specimens are tested under one concentrated loading point in the middle of the slab. From the concrete slabs test, we get the deflection of the slab, the absorption energy, strain, and the maximum failure load of the slab, ductility, stiffness, crack pattern and study the results, evaluating to get the best performance of concrete.

Figure 3.28 All concrete slabs in the laboratory of the College of Engineering.

3.11 Tests on concrete

3.11.1 Fresh concrete Test

3.11.1.1 Slump test

This test is important for concrete and is carried out on all types of concrete at the worksite before pouring it into the mold. It is used to identify changes that occur in the materials that enter into the production of concrete through it, obtained an indicator of the workability of the fresh concrete, also, guarantee obtaining a homogeneous concrete. For this test, a standard iron mold in the shape of a minus cone is used, with a height of 300 mm and a diameter of 100 mm from the top and 200 mm from the bottom with an iron base and a standard steel rod 600 mm in length and 15 mm in diameter as shown in Figure 3.29. The slump test is applied to fresh concrete according to ASTM C143 [42].

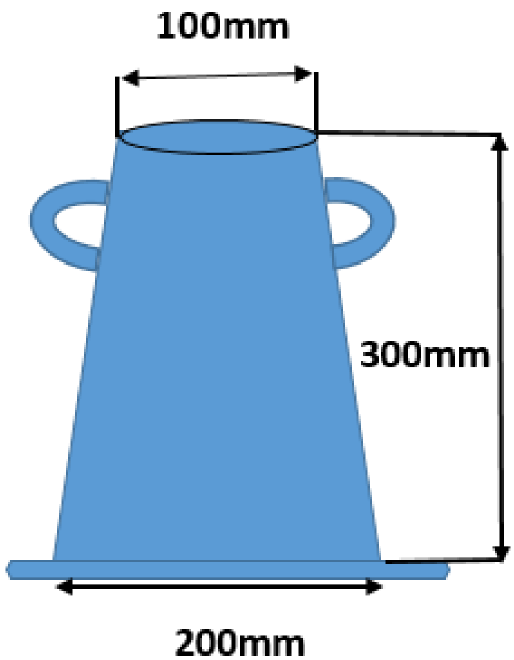


Figure 3.29 Slump test for concrete.

3.11.2 Mechanical tests on hardened concrete

3.11.2.1 Compressive resistance test

The compressive strength test of concrete was carried out by using standard cubic iron molds and casting concrete cube specimens with standard dimensions (150×150×150) mm and according to the British Standard BS1881 part 116-89[43]. Where the cubes were cast with a thickness of 15 cm in the form of layers and each layer was 5 cm thick and the layers were tamped using a steel rod with dimensions (2.5 × 2.5 × 38) cm or by using a mechanical vibrating device to expel the trapped air inside the concrete, and the compression testing machine for concrete with a capacity of 2000 kN is used. The benefit of this test on cubes is to know the concrete resistance to the compressive applied to it, all specimens were tested in the laboratory of the College of Engineering / University of Misan as shown in Figure 3.30.

Figure 3.30 Compression testing machine for concrete cubes.

3.11.2.2 Flexural resistance test

For this test, concrete prisms specimens with dimensions of (500 × 100 × 100) mm are used to test the flexural strength of concrete according to ASTM - C78 [44]. By applying a linear load in the middle of the beam according to the type of testing machine available in the laboratory. The capacity of the flexural testing device is (5000 kN), as shown in Figure 3.31.

Figure 3.31 Flexural strength testing machine for concrete prisms.

By used the following equation to calculate the modulus of rupture [44]:

Where:

Modulus of rupture (Fr) = $\frac{3PL}{2b.d.d}$ Eq. 3.1

Modulus of rupture (Fr) in (MPa)

P: Maximum Load applied to the beam (N)

L: Span Length (mm) from center to center support.

b: average width of the specimen (mm).

d: average depth of specimen (mm), as shown in Figure 3.32.

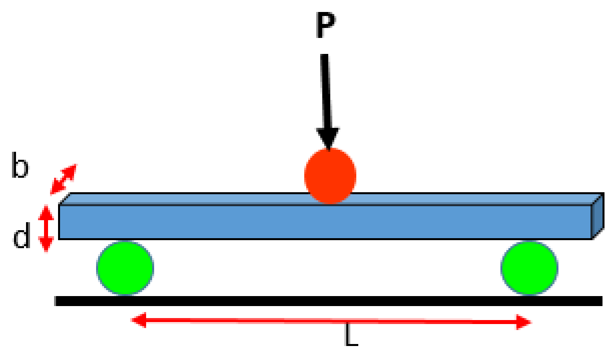


Figure 3.32 Illustration of a prism test (3-point load).

3.11.2.3 Splitting Tensile Strength Test

To extract the tensile strength of concrete, we used the splitting tensile strength test. To conduct this test, and used concrete cylindrical specimens with dimensions (200 × 100) mm, and tested (3) specimens with an age of (7) days and (3) specimens with an age of (28) for each concrete mixture, this test is applied according to the American Standard ASTM-C496 [45], and the test is carried out in the same compression test device with a capacity (2000kN), to determine the splitting tensile strength of a concrete cylinder when it is compressed, causing an indirect (secondary) tensile stress that divides the cylinder into two pieces depending on the kind of concrete mixture as shown in Figure 3.33.

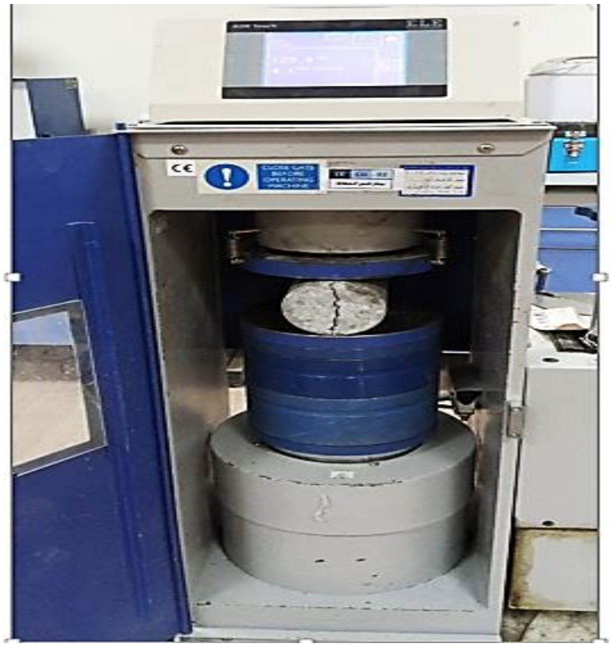


Figure 3.33 Splitting tensile test for concrete cylinders.

To calculate the splitting tensile strength (Horizontal tensile stress) of concrete specimens, we use the following equation [45]:

$$Ft = \frac{2p}{\pi DL} \qquad \text{Eq. 3.2}$$

Where:

Ft: splitting Tensile strength (MPa).

D: Diameter of specimen (mm).

P: Maximum applied Load on specimen concrete (N),

as shown in Figure 3.34.

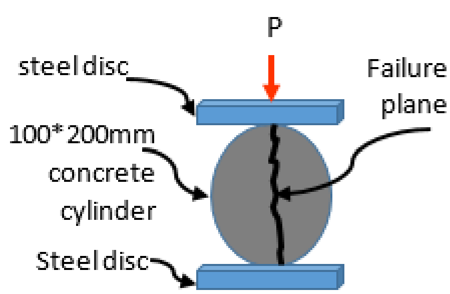


Figure 3.34 Failure pattern.

3.11.3 Physical tests on hardened concrete

3.11.3.1 Dry density test

The weight of concrete cubes (150) mm is taken before a compressive test is performed on them for each specimen of the cubes to calculate the dry density of the concrete as shown in Figure 3.35. The test as per ASTM C642 [46].

Figure 3.35 Dry density test of the concrete cubes.

3.11.3.2 Absorption water test

The absorption water test was carried out by using concrete cubes with dimensions (150 ×150 × 150) mm for all concrete mixtures and according to the American specification ASTM C642 [46]. Where the cubed specimens are placed in the drying oven for 72 hours at a temperature of 100˚C, then the specimens are weighed while they are dry to obtain the dry weight. The specimens are immersed in water for 24 hours, and taken the weight of the specimens after immersion again. The test was carried out in the laboratory of the Technical Institute in Misan, as shown in Figure 3.36 .The percentage of absorption concrete for water is calculated from the following relationship [46]:

$$W.A=\left[\frac{\text{weight of specimen after submerged in water } (w_2) - \text{Dry weight } (w_1)}{\text{weight before submerged (Dry weight) } (w_1)}\right] * 100 \qquad \text{Eq. 3.3}$$

Where:

W.A: Water Absorption rate %.

Figure 3.36 Water absorption test of concrete cubes specimens.

3.11.3.3 Ultrasonic pulse velocity (UPV)

This non-destructive test is performed on concrete cubes with dimensions (150 × 150 × 150) mm at the age of 28 days and before crushing by testing the compression, three cubes for each concrete mix. The test is carried out according to BS 1881 Part 116 [47], a (bundlt Lab) device with an accuracy of 0.1 microseconds is used to do the test. And the path length of the specimen is set between transducers for the device, then a light layer of gel liquid is placed on the face of the test area of the concrete cube .Then the test is done on all the axes of the cube, this test is used to determine the quality of the concrete, as shown in Figure 3.37.

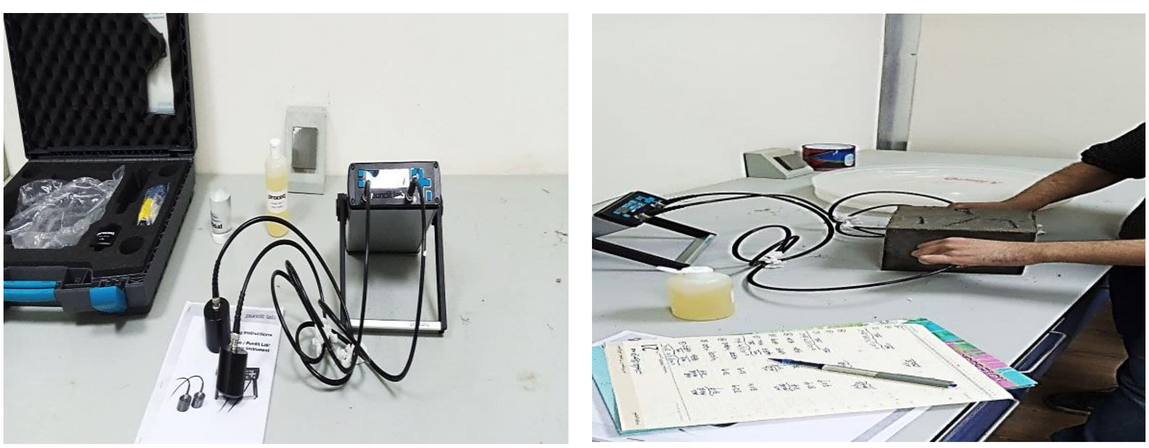


Figure 3.37 Ultrasonic pulse velocity (UPV) test for concrete cubes.

3.11.3.4 Dynamic Modulus of Elasticity

The dynamic modulus of elasticity depends on the concrete density and the Poisson's ratio, as per IS 13311.part1:1992[48], it is calculated from the measurement of Ultrasonic pulse velocity of the used concrete cubes (150 × 150 ×150) mm, with an age of 28 days. We can calculate the dynamic modulus of elasticity from the following relationship [48]:

$$\text{Dynamic Modulus of Elasticity (Ed)} = \left[\frac{V^2 \rho (1+\mu)(1-2\mu)}{(1-\mu)}\right] \quad \text{Eq. 3.4}$$

Where: ρ = concrete density in (kg/m^3) at age 28- days, v = velocity (km/s), μ= Poisson's ratio.

3.11.3.5 Static modulus of elasticity

The 24 concrete cylinders with dimensions (150 × 300) mm were cast for testing the static modulus of elasticity according to the American specification ASTM C-469 [49]by using an electronic compressmeter with a length of 120 mm، and the sensitivity of the scale is 0.01 mm. After installing the compressometer on the cylindrical specimen, it is placed inside the compression device with a capacity of 2000 kN and the specimen is loaded up to 40% of the cylinder’s compressive strength, with deflection readings recorded until 40% of the load is reached, then the testing process stops. These steps are repeated 3 times on one specimen, then the average results are taken as shown in Figure 3.38. The static modulus of elasticity can be calculated from the calculation of strain and stress as in the following relationship [49]:

$$E = \frac{S_2 - S_1}{\varepsilon_2 - 0.000050} \quad \text{Eq. 3.5}$$

Where:

E= Static Modulus of Elasticity, (MPa).

S_2 = stress corresponding to 40% of ultimate load.

S_1= stress corresponding to a longitudinal, strain ε_1, of 50 millionths, MPa.

ε_2= Longitudinal strain produced by stress s_2.

Figure 3.38 Modulus of elasticity test for cylindrical specimens.

3.12 Testing of concrete slabs

3.12.1 Strain Gauge

Two strain gauges with a length of 30 mm were used for each concrete slab, it is placed in the compression zone before the test for the purpose of measuring the compressive strain of the upper surface of the slab, and their locations are set on the axes (x, y) with a distance of d/2 from the center of the slab as shown in Figure 3.39.

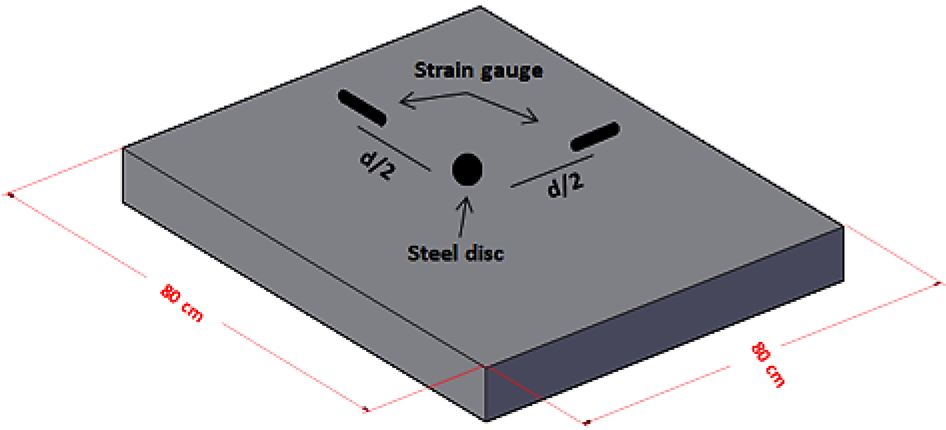


Figure 3.39 The strain gauge location for all slabs.

The concrete area on which the strain gauge is placed is cleaned, then a base layer is placed for leveling the surface and left for 24 hours. Then the strain gauge is fixed to the concrete surface with a special adhesive, and then the strain gauge wires are connected to the Data Logger device, as shown in Figure 3.40.

Figure 3.40 Paste strain gauges on the concrete slabs.

3.12.2 Testing Machine

Concrete slabs are tested by a flexural testing machine (ALFA) in the laboratory of the College of the Engineering / University of Misan. The capacity of the device is 6000 kN with dimensions (5 meters long × 0.8 meters wide) and the device contains a hydraulic jack with an electronic control panel. The frame of these slabs is mounted on this machine, Linear Variable Displacement Transformer (LVDT) is placed in the middle of the slab from the bottom to measure the deflection. The test is carried out under one concentrated load point in the middle of the slab under the action of flexural until the maximum load is reached and the final failure of the slab occurs as shown in Figure 3.41.

Figure 3.41 LVDT device with the electronic testing machine for concrete slabs.

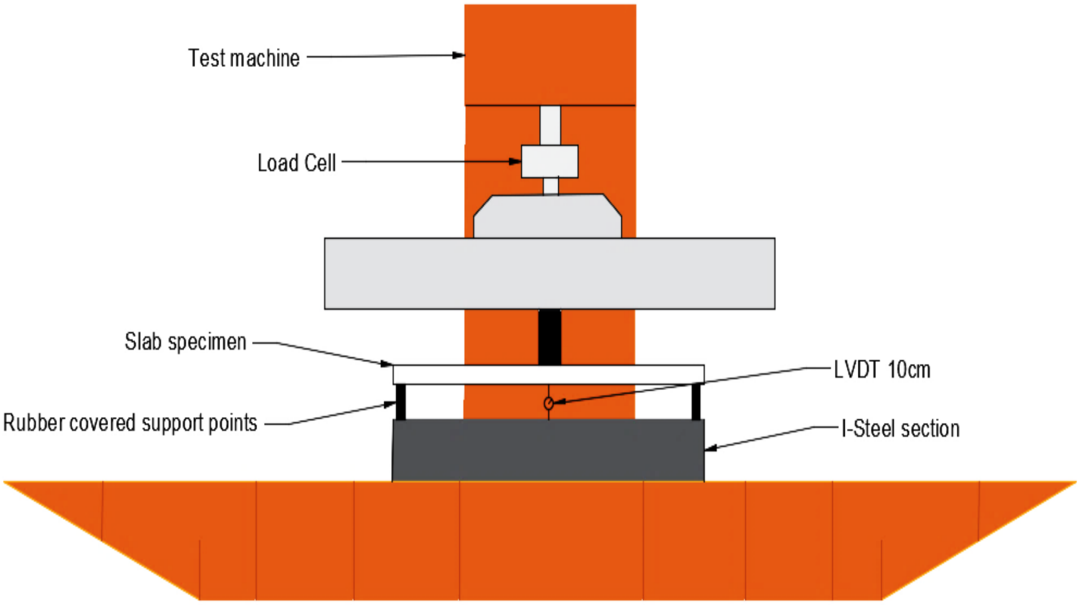


Figure. 3.41 Continued.

3.12.3 Slab Test Method

The Simply supported slab with point reactions is placed on the iron base with dimensions (800×800) mm installed on the hydraulic testing machine, the slab sits on four iron support points at the corners and is covered by a hollow cylindrical rubber cap and as shown in Figure 3.42.

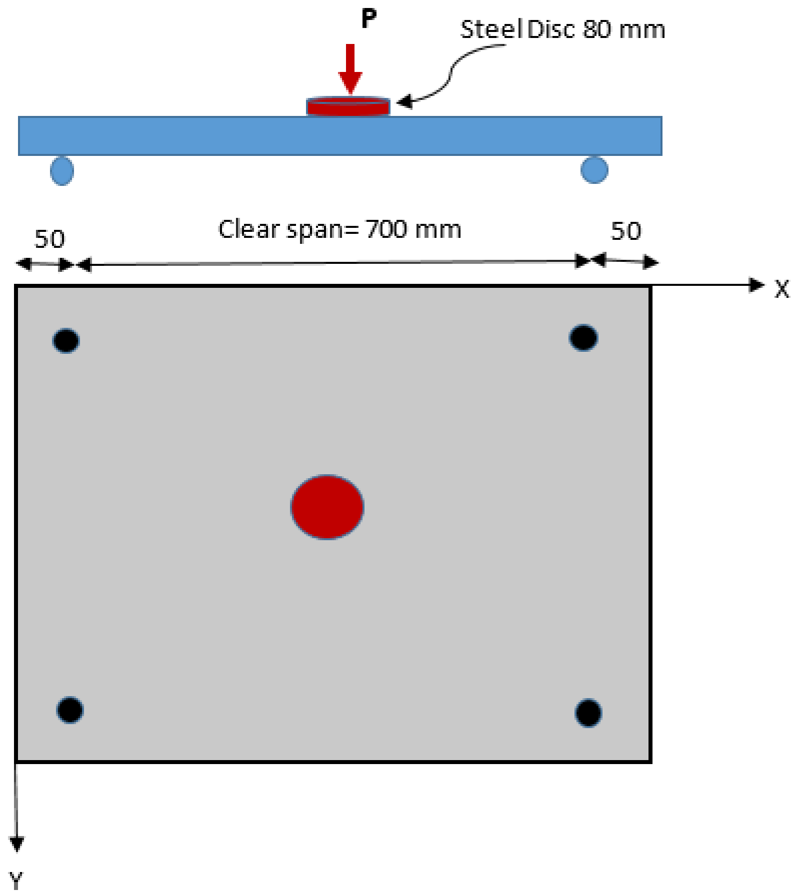


Figure 3.42 Location of the four points supports at the edges of the steel structure.

Then the strain gauge wires installed on the slab surface are connected by a Data Logger device. Then the device (LVDT) is installed in the middle of the slab from the bottom to measure the deflection, the load is a steel disc with a diameter of 80 mm that is placed at the center of the slab. After completing the adjustment procedures, the hydraulic device is operated and the load is applied in, successive increments under one concentrated load point in the middle of the slab from the top under the influence of flexion until the final failure load is reached.

The procedure of loading and supporting the concrete slab on four points of support, which was adopted in this study, is appropriate when the concrete slabs are reinforced with fibers, the reason is that the reinforced fibers are scattered in the concrete block. As a result, the effect of fiber reinforcement on the resistance of concrete slabs against internally applied loads can be clearly seen in all directions when the concrete slab is supported by four support points. In addition, the dependence of loads of the central point of the concrete slab and the support of the concrete slab on four points may ensure the start of cracks and their spread towards the limits of the concrete slab.

The laptop records and saves the readings of deflection, load, and strain at each applied phase, the loading rate of all slabs are 1 kN per second, and maximum load, deflection, and strain are achieved, as well as is observe the failure and cracking pattern for the slab, once the final failure of the slab, is reached, the device stops loading as shown in Figure 3.43.

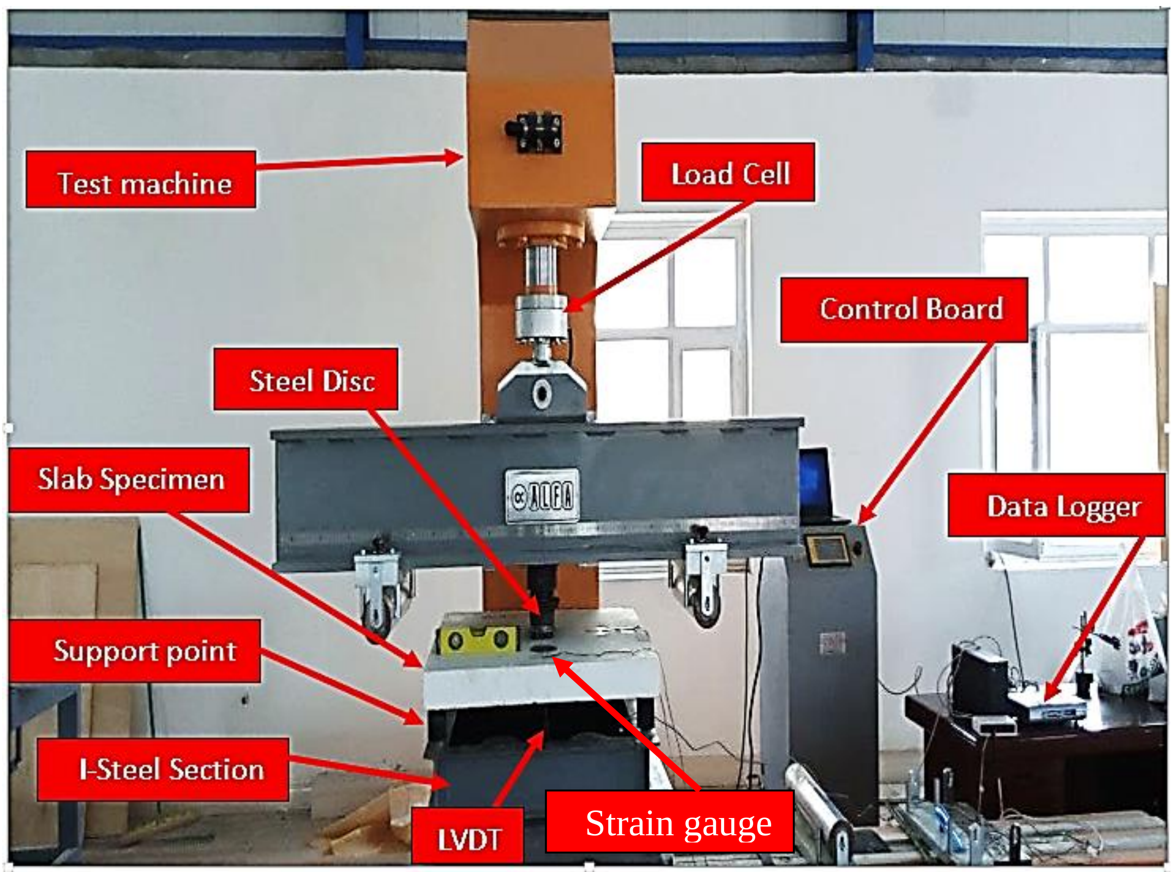


Figure 3.43 Details of concrete slab test on the electronic testing machine.

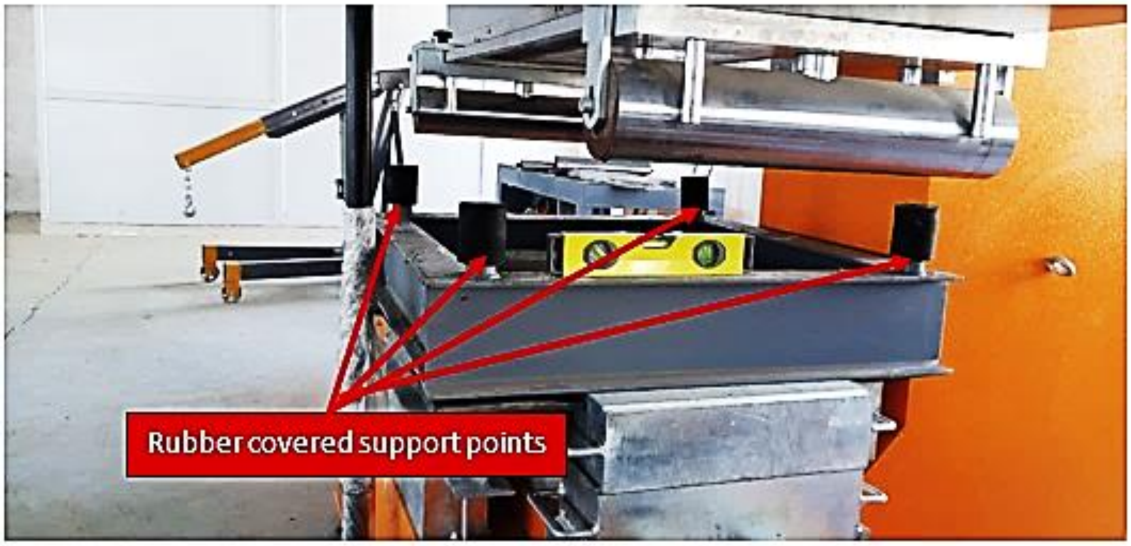


Figure. 3.43 Continued.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 General

The results of the tests are presented and discussed for fresh and hardened concrete in this chapter. For fresh concrete, the results of the slump test will be shown for each casting meal. For the hardened concrete, all their results will be presented in this chapter, which are the tests of compressive, flexural, tensile, dry density, absorption, ultrasonic pulse velocity for concrete, static modulus of elasticity and calculating the dynamic modulus of elasticity for concrete specimens. Five specimens without steel fibers and containing sand dunes as an alternative to sand for ratios (20%,40%,60%,80%,100%) in addition to the reference specimen without sand dunes and fibers (0%). (18) specimens contain sand dunes as an alternative to sand for the mentioned ratios and reinforced with short, long, and hybrid steel fibers. Also, the results of the concrete slabs test are presented and the results of the structural behavior of these slabs are evaluated for each replacement ratio of sand dunes and fibers. And compared with the results of the test of concrete slabs without fibers. 24 concrete slabs, six slabs without fibers and containing different proportions of dunes sand as an alternative to sand, and 18 slabs containing single and hybrid steel fibers with different proportions of dunes sand. The results of the tests on the slab include the knowledge of the slab's ultimate failure load, ultimate deflection, strain, failure pattern, stiffness, ductility, and absorption energy with graphs for each group and evaluation of their results for each replacement ratio.

4.2 Tested Specimens' Results

The results of the tests for the concrete specimens used in this study are divided into two parts. The first part includes presenting the results of mechanical and physical tests on concrete specimens that contain sand dunes as a partial and total alternative for sand ,also reinforced with or without steel fibers. The second part includes a study of the structural behavior of simply supported concrete slabs under the influence of flexural under one concentrated load point in the middle of the slab. 462 specimens of concrete were used for all concrete mixtures for the purpose of testing the mechanical and physical properties of the concrete used in this study. These concrete specimens consist of 150 standard cubes with dimensions (150×150×150) mm, 144 concrete prisms with dimensions (100×100×500) mm, 144 cylinders with dimensions (200×100) mm, and 24 cylinders with dimensions (300×150) mm . (24) square two-way concrete slabs with dimensions (80 × 800 × 800) mm, containing sand dunes as an alternative for sand in different proportions and reinforced with short, long, and hybrid steel fibers, (6) slabs without fibers, and (18) slabs containing steel fibers.

4.2.1 Part (1): Results of tests of mechanical and physical of concrete specimens

This part is concerned with presenting and discussing the results of tests on specimens of fresh and hardened concrete that contain different ratios of sand dunes as a partial and complete alternative for sand and reinforced with steel fibers or without fibers. The mechanical properties of the hardened concrete specimens are tested at the age of 7 and 28 days and for each replacement ratio, these tests include:

1- Slump test (workability of fresh concrete)

2- Mechanical properties tests for hardened concrete

   2 -1 Compressive resistance

   2 -2 Flexural resistance

   2 -3 Split tensile resistance

3- physical properties tests for hardened concrete

   3-1 Dry Density

3-2 Absorption

3-3 Ultrasonic pulse velocity test

3-4 Static modulus of elasticity

3-5 Dynamic modulus of elasticity

4.2.1.1 Workability of fresh concrete (slump test)

Slump test results for soft concrete mixtures containing sand dunes as an alternative to sand for the ratios (0%,20%,40%,60%,80%,100%) and reinforced with short, long, and hybrid steel fibers, as well as for mixtures without fibers, are listed in Table 4.1.

The results of the test indicate that the reference specimen (0%D.S without fibers) achieved the highest workability while maintaining a constant W/C ratio in all mixtures, the workability decreases with the increase of the sand dunes content as an alternative to sand for the ratios (20%,40%,60%,80%,100%) without fibers in the specimens with a decrease of about 15%,13%,21%,26% and 30%, respectively less than the reference specimen, these specimens are classified as having medium workability according to limit of EN 206 [50].

Slump decrease as shown in Figure 4.1 is due to the particle size distribution produced when natural sand is replaced by sand dunes, and whenever the finer the fine aggregate, the less workability the concrete will be. Also, the very fine sand absorbs a larger amount of the mixing water, due to the increased activity of the specific surface area of the fine aggregate, and the fine aggregate particles intertwine and reduce the freedom of movement of the particles in the fresh concrete.

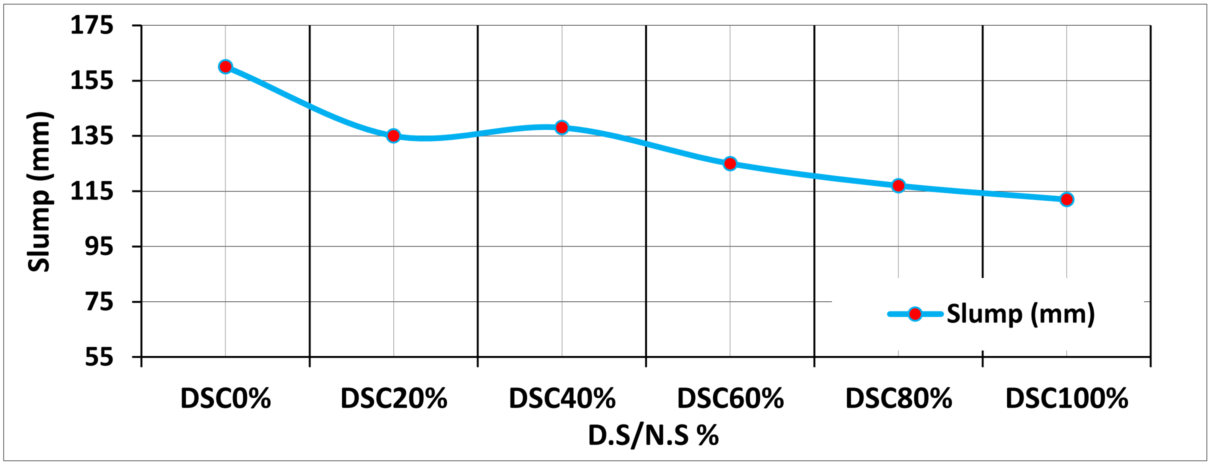


Figure 4.1 The slump curve for mixtures containing sand dune without fibers.

Table 4.1 Results of a slump test for concrete specimens containing sand dunes

D.S/Sand Percentage %	Slump test (mm)	Workability classification according to European standard ENV 206:1992	Limit of EN 206 :1992 [50]	Reduction in Slump (%)
0% D.S	160	High workability	≥160mm	-
20% D.S	135	Medium workability	100 –150 mm	-15
40% D.S	138	Medium workability	100 –150 mm	-13
60% D.S	125	Medium workability	100 –150 mm	-21
80% D.S	117	Medium workability	100 –150 mm	-26
100% D.S	112	Medium workability	100 –150 mm	-30
0%D.S+1%S.F.S	107	Medium workability	100 –150 mm	-33
0%D.S+1%S.F.L	102	Medium workability	100 –150 mm	-36
0%D.S+1%H.S.F	104	Medium workability	100 –150 mm	-35
20%D.S+1%S.F.S	98	Low workability	50-90 mm	-27
20%D.S+1%S.F.L	90	Low workability	50-90 mm	-33
20%D.S+1%H.S.F	93	Low workability	50-90 mm	-31
40%D.S+1%S.F.S	88	Low workability	50-90 mm	-36
40%D.S+1%S.F.L	83	Low workability	50-90 mm	-39
40%D.S+1%H.S.F	85	Low workability	50-90 mm	-38
60%D.S+1%S.F.S	80	Low workability	50-90 mm	-36
60%D.S+1%S.F.L	70	Low workability	50-90 mm	-44
60%D.S+1%H.S.F	75	Low workability	50-90 mm	-40
80%D.S+1%S.F.S	75	Low workability	50-90 mm	-35
80%D.S+1%S.F.L	70	Low workability	50-90 mm	-40
80%D.S+1%H.S.F	73	Low workability	50-90 mm	-37
100%D.S+1%S.F.S	70	Low workability	50-90 mm	-37
100%D.S+1%S.F.L	65	Low workability	50-90 mm	-41
100%D.S+1%H.S.F	68	Low workability	50-90 mm	-39

The results of the mixtures reinforced with short steel fibers and the replacement ratios (0%-100%), showed that the mix without sand dunes (0%D.S + 1%S.F.S) achieved the highest workability with an increase of about (9.2%,21.6%, 33.7%, 42.6%, 52.8%) compared to the mixtures reinforced with short steel fibers and the replacement ratios (20%, 40%, 60%, 80%, 100%), respectively (the decrease is gradual) , as shown in Figure 4.2.

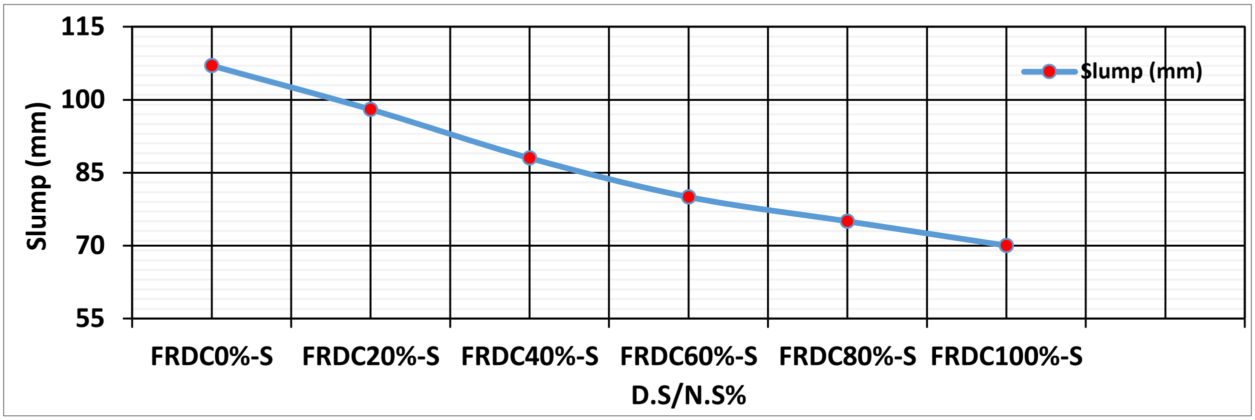


Figure 4.2 The slump curve for mixtures containing sand dunes with S.F.S.

The results of the mixtures reinforced with long steel fibers and replacement ratios (0% - 100%), showed that the mixture without sand dunes (0% D.S + 1% S.F.L) achieved the highest workability compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (13.3%, 22.8%, 45.7%, 45.7%, 56.9%), respectively (the decrease is gradual) , as shown in Figure 4.3.

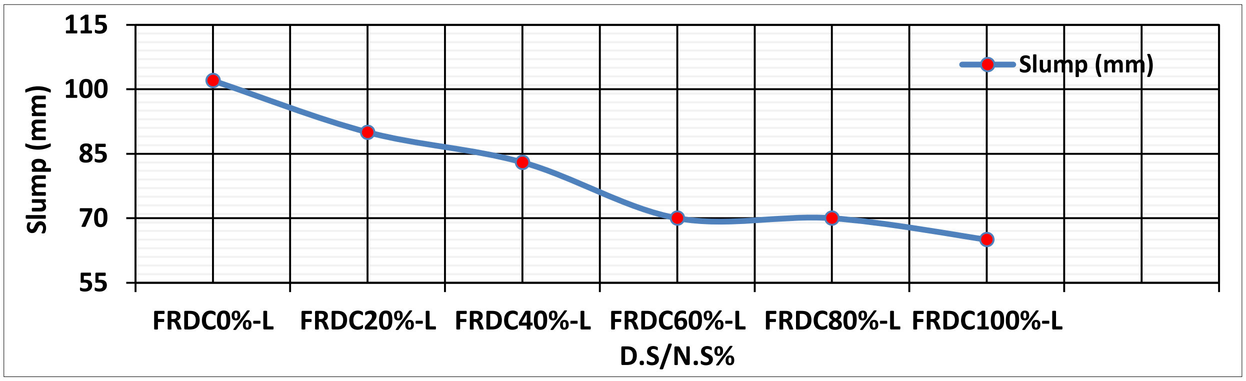


Figure 4.3 The slump curve for mixtures containing sand dunes with S.F.L.

The results of the mixtures reinforced with hybrid steel fibers and replacement ratios (0%-100%), showed that the hybrid mixture without sand dunes (0%D.S + 1%H.S.F) achieved the highest workability compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (11.8%, 22.3%, 38.6%, 42.4%, 52.9%), respectively (the decrease is gradual) , as shown in Figure 4.4.

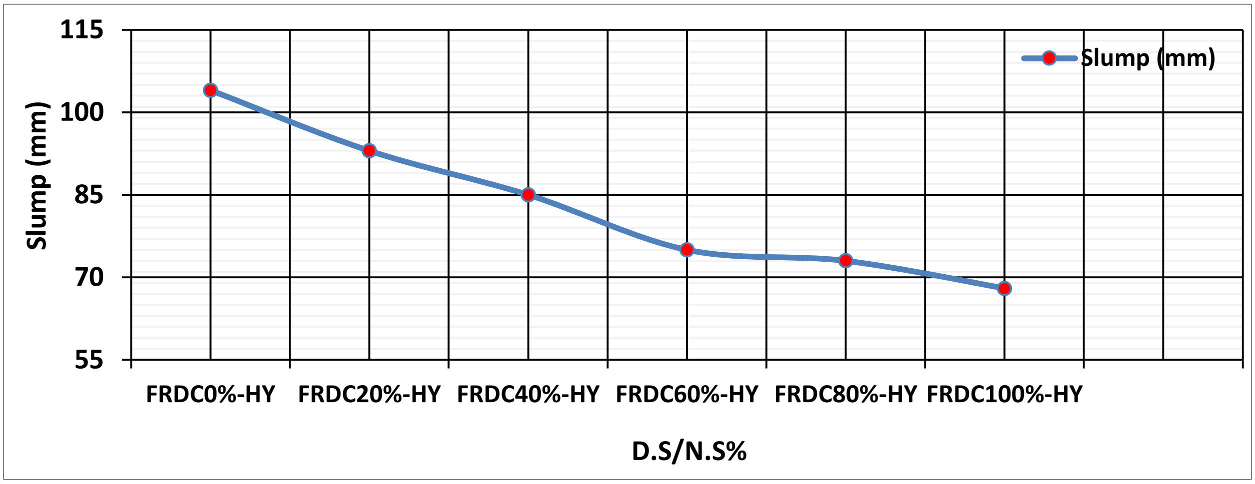


Figure 4.4 The slump curve for mixtures containing sand dunes with H.S.F.

The slump measurement results for concrete specimens containing short, long, and hybrid steel fibers at 1% show that the workability decreases with the addition of steel fibers to the mixtures. Where the specimens without sand dunes (0%D.S+1%S.F.S), (0%D.S+1%S.F.L) and (0%D.S+1%H.S.F) achieved medium workability according to EN 206 classification [50] with a decrease of about 33%, 36%, 35% less than the reference specimen. Also, the measured slump for the specimen (0%D.S+1%S.F.S) is higher than the slump for the specimens (0%D.S+1%S.F.L) and (0%D.S+1%H.S.F) by about 4.9%, 2.8%, as shown in Figure 4.5.

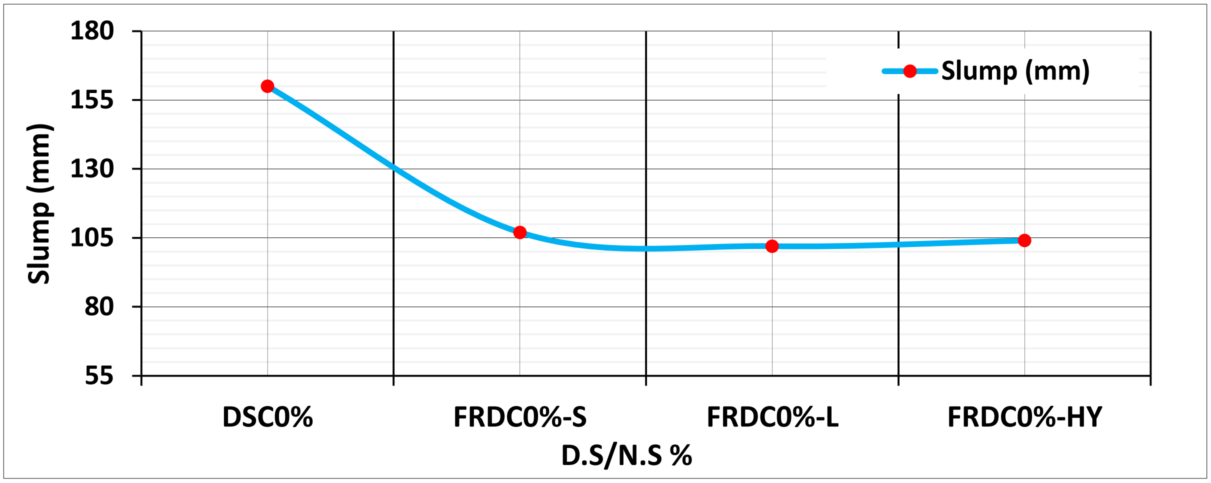


Figure 4.5 The curve of a slump for mixtures containing sand dunes (0%).

Workability decreases gradually with increasing sand dunes content as an alternative to the sand of ratios (20%, 40%, 60%, 80%, 100%) reinforced with short, long, and hybrid steel fibers. Whereas the specimens (20%D.S+1%S.F.S), (20%D.S+1%S.F.L), and (20%D.S+1%H.S.F) achieved low workability according to EN 206 [50], with a decrease of about 27%, 33%, and 31% compared to the specimen (20%D.S without fibers). Also, the measurement of a slump for the specimen containing short steel fibers (20%D.S + 1%S.F.S) is higher than the slump for specimens (20% D.S + 1%S.F.L) and (20%D.S + 1%H.S.F) by about 8.8 % and 5.4%, respectively, as shown in Figure 4.6.

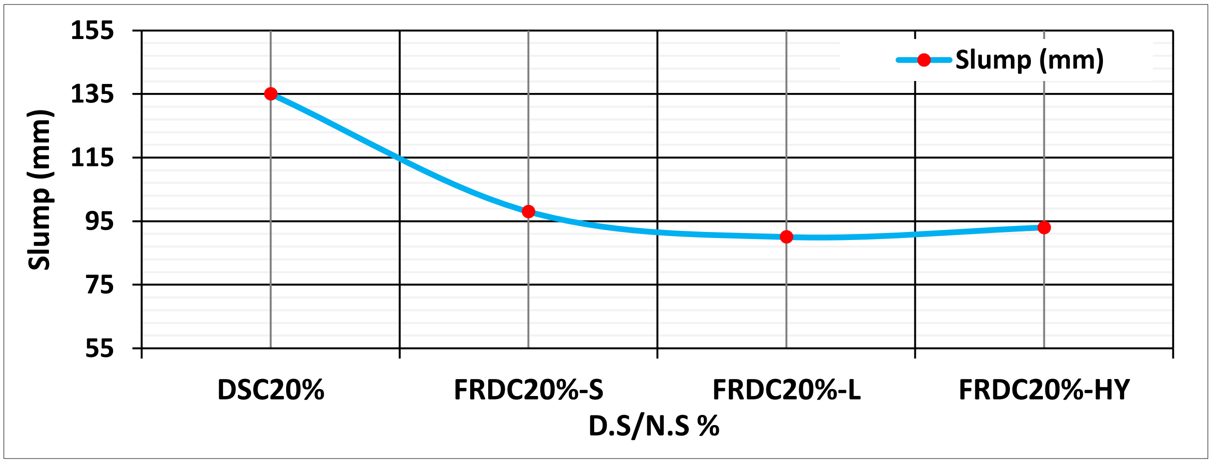


Figure 4.6 The curve of a slump for mixtures containing sand dunes (20%).

When sand dunes is used as an alternative for sand for a ratio of 40%, the workability of specimens (40%D.S+1%S.F.S), (40%D.S+1%S.F.L), and (40%D.S+1%H.S.F) decreases by approximately 36%,39%, and 38% respectively compared to the specimen (40%D.S without fibers) and the concrete for the specimens is classified as having low workability according to EN 206 [50].Also, the measurement of slump for the specimen (40% D.S + 1% S.F.S) is higher than the slump for specimens (40% D.S + 1% S.F.L) and (40% D.S + 1% H.S.F) by about 6% and 3.5% respectively, as shown in Figure 4.7.

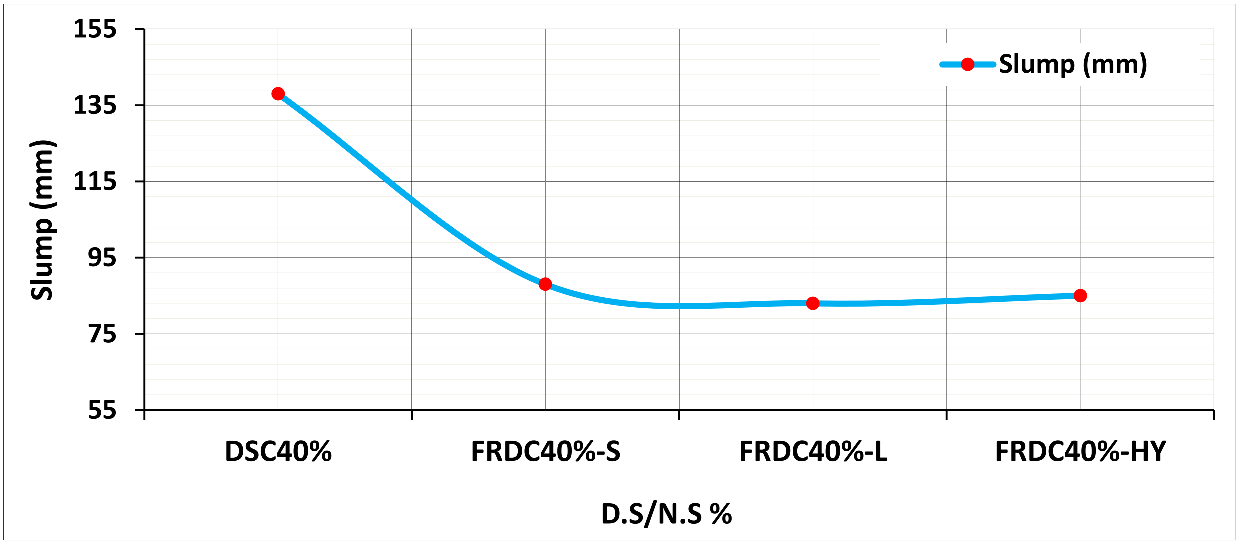


Figure 4.7 The curve of a slump for mixtures containing sand dunes (40%).

Workability decreases when sand dunes is alternative for the sand of ratio 60%, where the specimens (60%D.S+1%S.F.S), (60%D.S+1%S.F.L) and (60%D.S+1%H.S.F) achieved Low workability according to EN 206 [50], with a decrease of about 36%, 44%, 40%, respectively, compared to the specimen (60%D.S without fibers), also, the measure of slump for the specimen (60% D.S + 1% S.F.S) is higher than the slump for the specimens (60% D.S + 1% S.F.L) and (60% D.S + 1% H.S.F) by about 14.3% and 6.7%,respectively, as shown in Figure 4.8 .

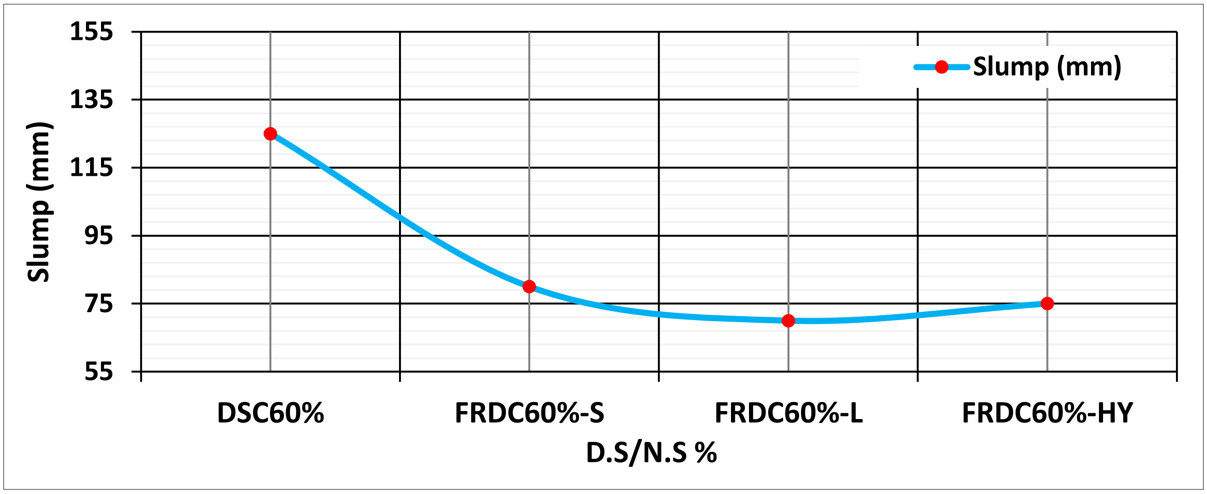


Figure 4.8 The curve of a slump for mixtures containing sand dunes (60%).

When the sand dunes content is increased as an alternative for the sand of ratio 80% in the mixtures, the workability decreases, where the specimens (80%D.S+1%S.F.S), (80%D.S+1%S.F.L) and (80%D.S+1%H.S.F)achieved low workability according to EN 206 [50], with a decrease of about 37%,40%, and 35%, respectively, compared to the specimen (80%D.S without fibers).Also, the measurement of a slump for the specimen (80%D.S+1%S.F.S) is higher than the slump for the specimens (80%D.S+1%S.F.L) and (80%D.S+1%H.S.F) by about 7.1% and 2.7%, respectively, as shown in Figure 4.9 .

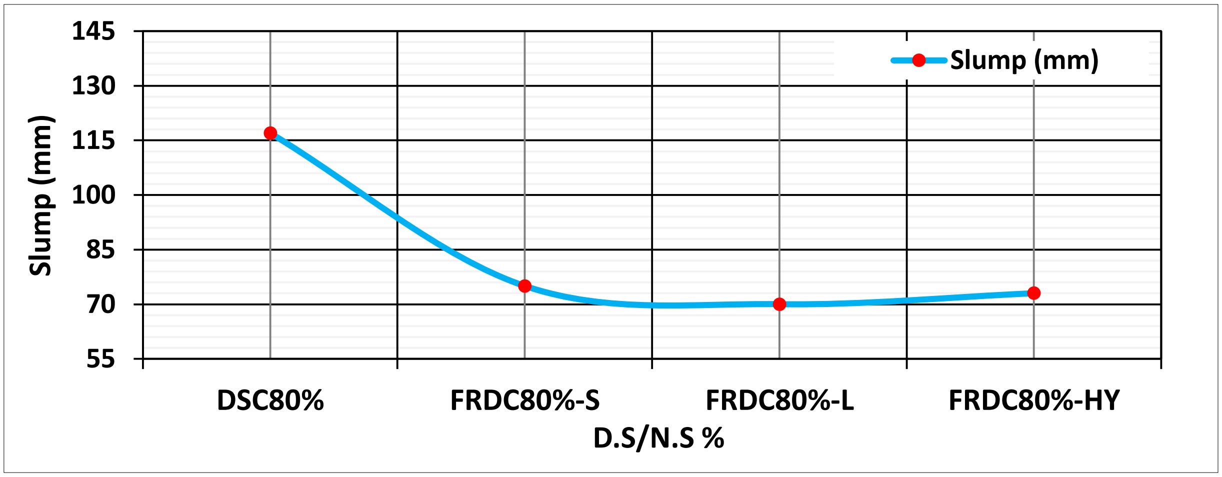


Figure 4.9 The curve of a slump for mixtures containing sand dunes (80%).

When sand dunes is used as an alternative for the sand of ratio 100%, the workability decreases, where the lowest workability is recorded for the specimen containing long steel fibers (100%D.S + 1%S.F.L) with a decrease of about 41% compared with the specimen (100% D.S without fibers). Followed by the hybrid specimen (100% D.S + 1% H.S.F) with a decrease of about 39% compared with the specimen (100% D.S without fibers), while the measured slump for the specimen(100%D.S+1%S.F.S) is higher than the specimens (100%D.S without fibers) (100%D.S+1%S.F.L) and (100%D.S+1%H.S.F) by about 37%, 7.6%, and 2.9%, respectively, as shown in Figure 4.10.

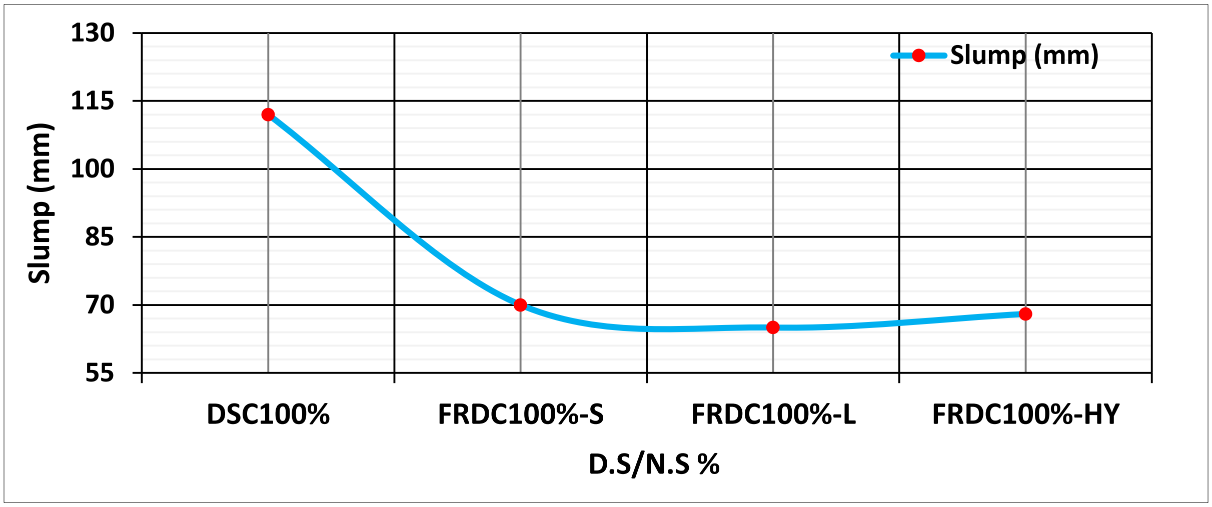


Figure 4.10 The curve of a slump for mixtures containing sand dunes (100%).

Whereas, the short steel fibers are better than the long and hybrid fibers in obtaining the workability of the fresh concrete. Followed by the hybrid fibers. While the long fibers give less workability to concrete. This decrease in workability is due to the increase in the strength of cohesion and adhesion between the concrete components that contain steel fibers, so it does not make the fresh concrete fall easily during the test. Also, the length and diameter of the fiber play a role in decreasing the workability, where the workability decreases whenever the length of the fiber increases. By adding a plasticizer to mixtures containing sand dunes and steel fibers, found an improvement in the level of workability. Also, the diameter of the sand dunes grains is very fine and is less than 1.18 mm, so the specific surface is larger, which makes the concrete mixture less workability, so it requires adding a larger amount of water, but in this study, the ratio of W/C is constant. Therefore, it becomes necessary to add a plasticizer to mixtures containing sand dunes and reinforced with steel fibers to improve workability.

4.2.1.2 Results of Mechanical Properties

4.2.1.2.1 Compression strength results

The compressive strength test results at the age of 7 and 28 days for concrete specimens containing sand dunes as an alternative to sand and reinforced with steel fiber as well as for specimens without fibers were listed in Table 4.2, where noted that all concrete specimens and reinforced with long steel fibers or hybrid at 1% of the concrete volume, showed a positive effect better than short fibers in terms of compressive resistance, especially with sand dunes of ratios (0% - 60%) and it can be clarified as follows:

At age 7 days: The results of the compressive strength test at the 7-day age for concrete cubes that contain sand dunes indicate for ratios (20%,40%,60%, 80%, 100%) without steel fibers, in addition to the reference specimen (0%) without sand dunes and fibers. Noted that the specimen (0%D.S) achieved the highest value of compressive strength of 43.05MPa, as shown in Table 4.2, followed by the specimen that contains sand dunes for a ratio of 40%D.S, which achieved a compressive strength of 41.06 MPa, but it is less than the reference specimen by about 4.6%. When sand dunes are replaced with sand without fibers, the compressive strength of the specimens (20%,60%,80%,100%) decreases about (12.6%, 20.5%, 32.8%, and 40.1%) respectively compared to the reference specimen(0% D.S),(ripening stage).

Table 4.2 Results test of compressive strength for specimens containing D.S ratios

D.S/Sand Percentage %	Average compressive strength (f_{cu}) MPa	Average compressive strength (f_{cu}) MPa	%change in compressive strength at 28 days
	7days	28days	
0% D.S	43.05	51.02	------
20% D.S	37.6	51.44	+0.82
40% D.S	41.06	56.30	+10.34
60% D.S	34.20	51.6	+1.13
80% D.S	28.9	39.51	-22.55
100% D.S	25.8	31.2	-38.84
0%D.S+1%S.F.S	47.93	65.80	+28.96
0%D.S+1%S.F.L	61.12	74.93	+46.86
0%D.S+1%H.S.F	48.40	64.90	+27.20
20%D.S+1%S.F.S	41.8	58.7	+14.11
20%D.S+1%S.F.L	48	62.8	+22.08
20%D.S+1%H.S.F	50.7	65.2	+26.74
40%D.S+1%S.F.S	46.16	59.72	+6.07
40%D.S+1%S.F.L	48.83	63.3	+12.43
40%D.S+1%H.S.F	49.6	71.3	+26.64
60%D.S+1%S.F.S	37.14	53.2	+3.10
60%D.S+1%S.F.L	38.63	54.5	+5.62
60%D.S+1%H.S.F	47.5	54.04	+4.72
80%D.S+1%S.F.S	29.7	41.8	+5.79
80%D.S+1%S.F.L	37.8	46.8	+18.45
80%D.S+1%H.S.F	30.2	43.7	+10.60
100%D.S+1%S.F.S	32.5	34.6	+10.89
100%D.S+1%S.F.L	30.6	39.1	+25.32
100%D.S+1%H.S.F	30.1	36.4	+16.66

The results of the compressive strength at the age of 7- days for concrete specimens containing single and hybrid steel fibers show an increase in the compressive strength in varying proportions and according to the type of added fibers, where the specimen (0%D.S + 1%S.F.L) recorded the highest compressive strength of 61.1 MPa with an increase by about 41.9% higher than the reference specimen without fibers. It is also higher than the specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) by about 27.5% and 26.3%, respectively. Followed by the specimen (20% D.S + 1% H.S.F) containing hybrid fibers for the ratio (0.35%S + 0.65%L), which achieved a compressive strength of 50.7MPa, an increase of 34.8%

higher than the specimen (20%D.S without fibers), and also, higher than the specimens (20%D.S+1%S.F.S) and (20%D.S+1%S.F.L) by about 21.3% and 5.6%, respectively. Recorded the concrete specimens containing sand dunes of the ratios (60% and 80%) and reinforced with single and hybrid fiber compressive strength ranging from (29.7 - 47.5 MPa) with an increase ranging between (2.8% - 38.9%) higher than the specimens for the same proportions of sand dunes without fibers. When sand dunes for the ratio (100%), the compressive strength decreases compared to other replacement ratios that contain steel fibers. Where the hybrid specimen (100%D.S+1%H.S.F) recorded the lowest compressive strength by about (37.8%) compared to the hybrid specimen (0%D.S+1%H.S.F). Figure 4.11 shows the failure patterns of all concrete cubes.

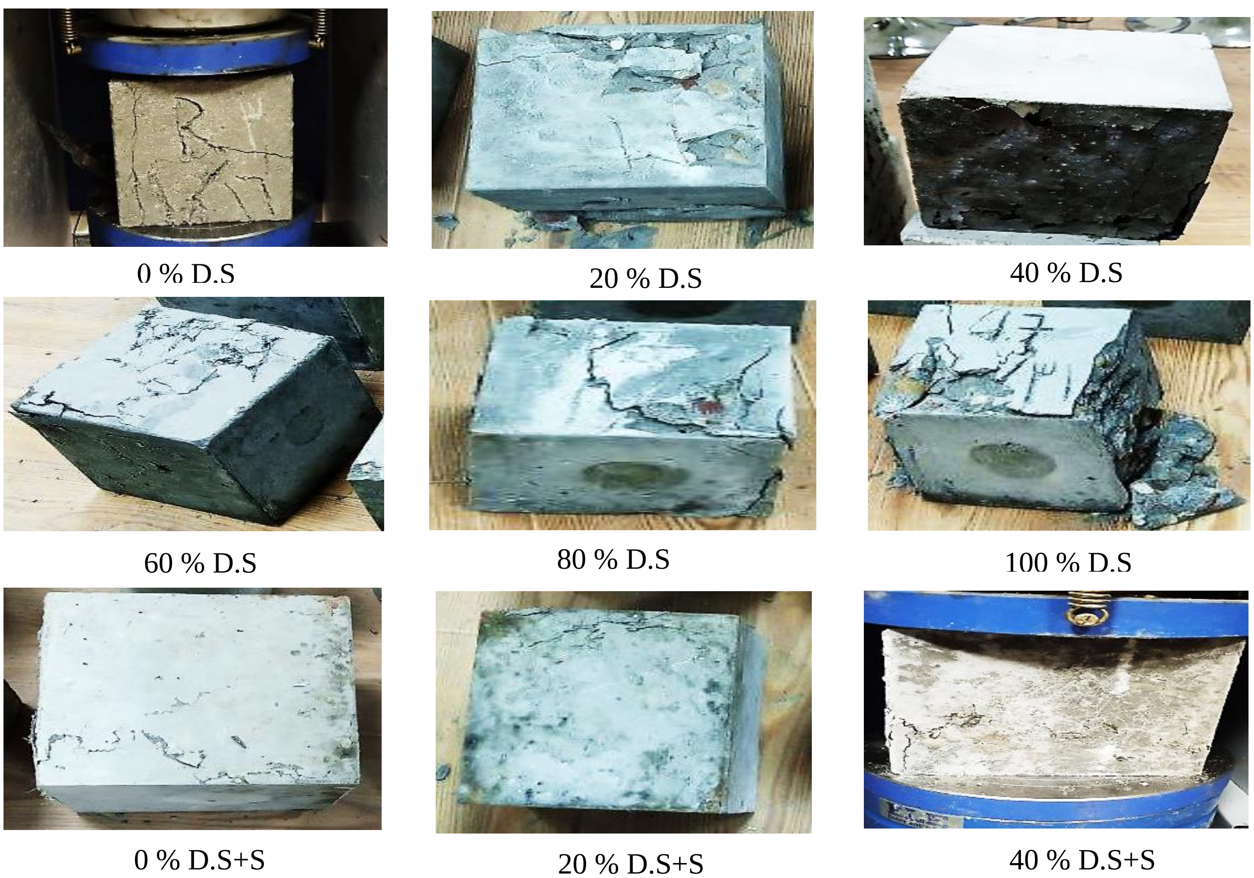


Figure 4.11 Failure modes of concrete specimens.

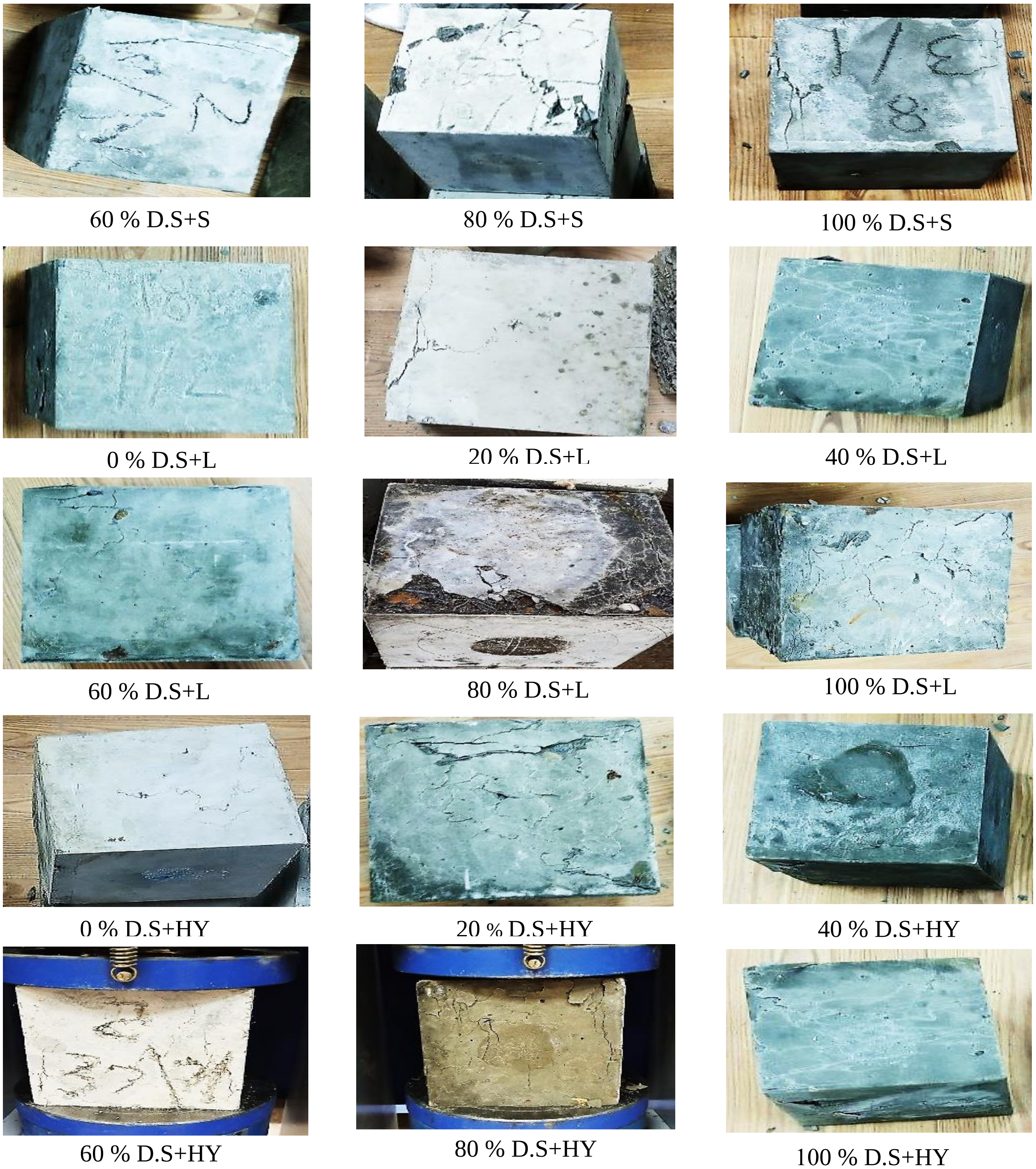


Figure 4.11 Continued.

At age 28 days: The results of the compressive strength test at the age of 28 days for concrete specimens without fibers indicate an increase in the compressive strength, as the reference specimen (0%D.S) achieved a compressive strength of

51.02MPa. After using sand dunes for the ratios (20%,40%,60%), the specimens achieved a compressive strength of (51.44, 56.3, 51.6) MPa with an increase of about (0.82%,10.34%,1.13%) respectively. higher than the reference specimen (0%D.S). The compressive strength decreases with the increase of the sand dunes content in the specimens, where the specimen (80% D.S) achieved a compressive strength of 39.51 MPa, with a decrease of 22.5% compared to the reference specimen. Also, when the natural sand is replaced with dunes sand for 100%, the compressive strength decreases by about 38.8% less than the reference specimen without fibers, and as shown in Figure 4.12. The reason for the decrease in the resistance is due to the increase in the surface area of the fine aggregate, as the increase in the amount of fine materials in the concrete mix weakens the resistance.

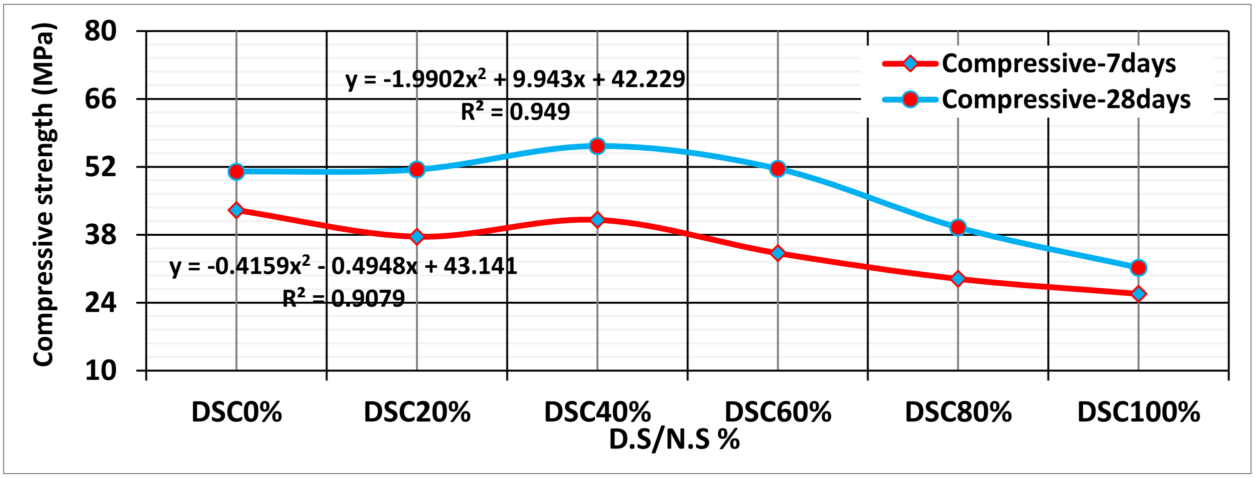


Figure 4.12 The compressive strength curves for specimens containing D.S without fibers.

The results of the mixtures reinforced with short fibers and replacement ratios (0% - 100%), showed that the mixture without sand dunes (0%D.S + 1%S.F.S) achieved the highest compressive strength compared to all the mixtures reinforced with short fibers and replacement ratios (20%, 40%,60%,80%,100%), with an increase of about (12.1%, 10.2%, 23.6%, 57.4%, and 90.1%), respectively, as shown in Figure 4.13.

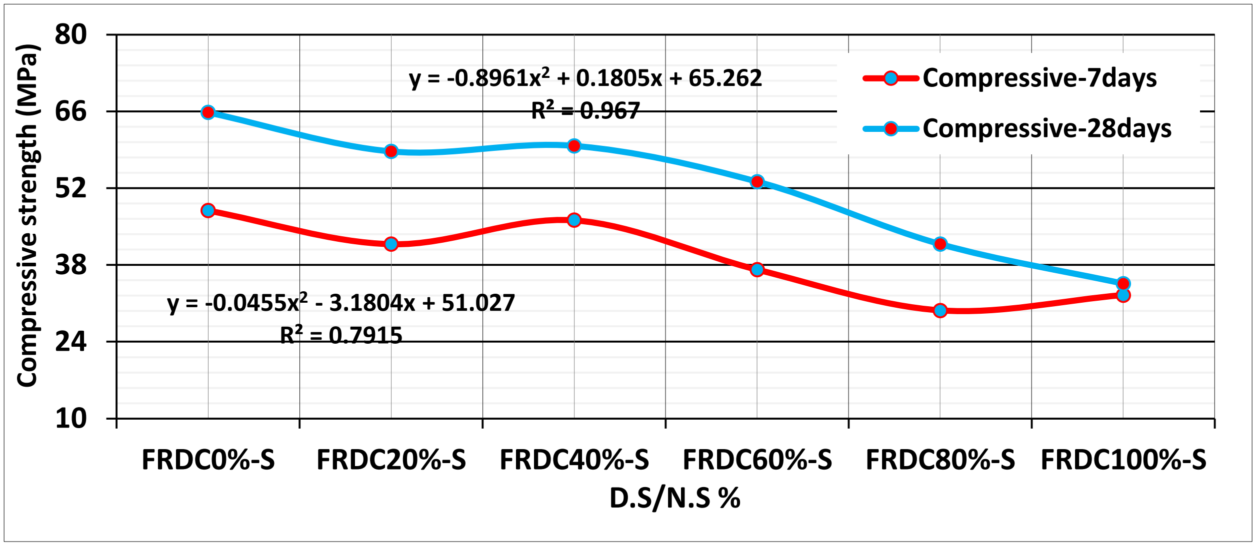


Figure 4.13 The compressive strength curves for mixtures containing S.F.S.

The results of the mixtures reinforced with long steel fibers and replacement ratios (0%-100%), showed that the mixture without sand dunes (0%D.S+1%S.F.L) achieved the highest compressive strength compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (19.3%, 18.3%, 37.4%, 60.1%, and 91.6%) respectively, as shown in Figure 4.14.

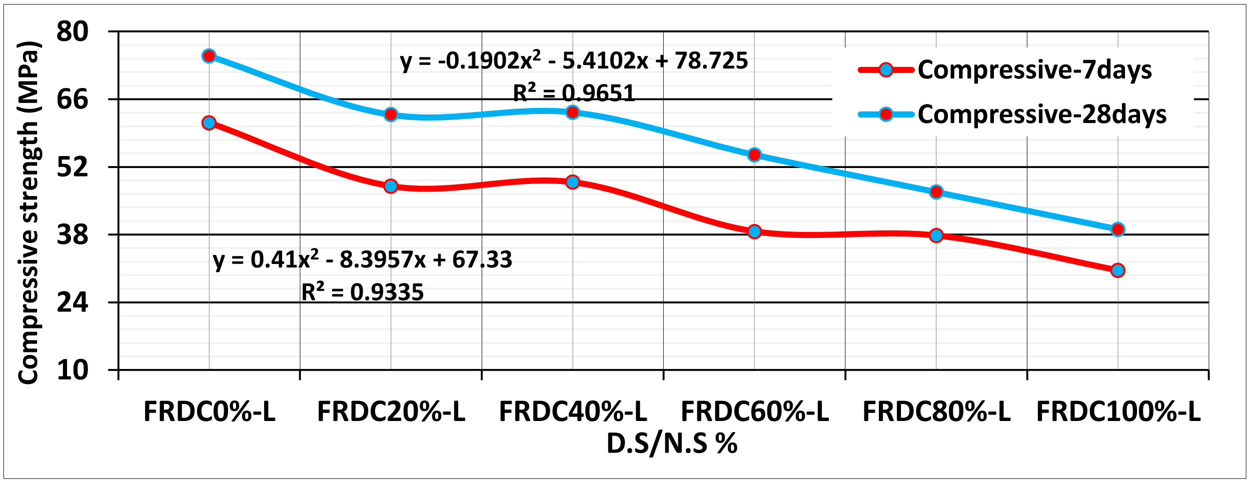


Figure 4.14 The compressive strength curves for mixtures containing S.F.L.

The results of the mixtures reinforced with hybrid steel fibers and replacement ratios (0% - 100%), showed that the hybrid mixture (0% D.S + 1% H.S.F) achieved the highest compressive strength compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (9.8%, 9.35%, 31.9%, 63.1%, and 95.8%), respectively, as shown in Figure 4.15.

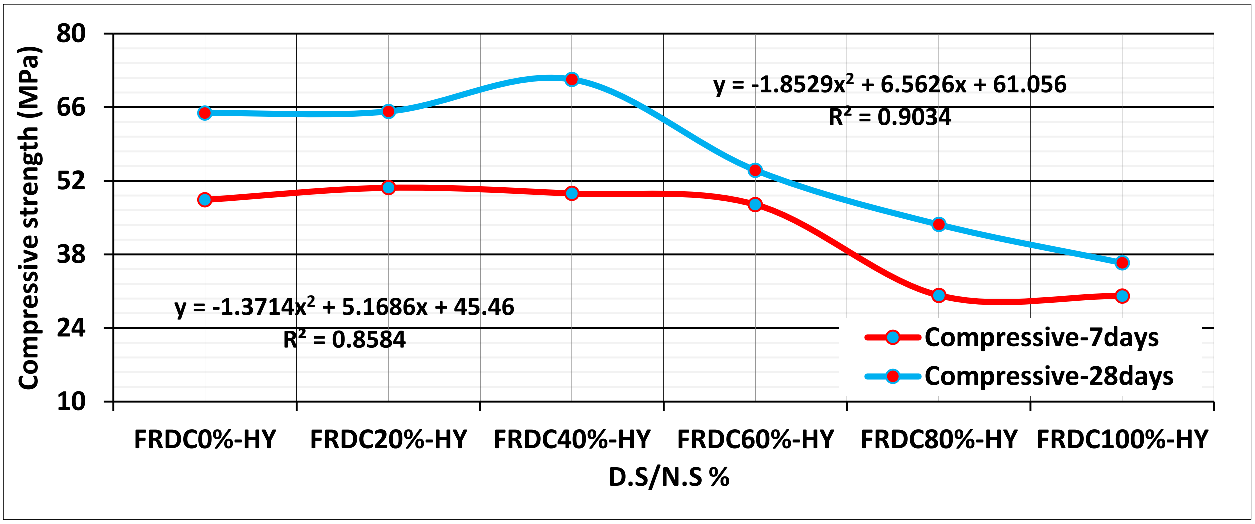


Figure 4.15 The compressive strength curves for mixtures containing H.S.F.

The results of the compressive strength test at 28 days of age for specimens containing short, long, and hybrid fibers show an increase in compressive strength, where the concrete specimen without sand dunes and reinforced with short steel fibers (0%D.S+1%S.F.S) achieved an increase in compressive strength of 65.8 MPa (i.e. 28.9% higher than the reference specimen). While the specimen containing hybrid steel fibers (0%D.S + 1%H.S.F) achieved a compressive strength of 64.9MPa, an increase of 27.2% compared to the reference specimen. While the specimen containing long steel fibers (0%D.S + 1%S.F.L) achieved the highest compressive strength of 74.9MPa (i.e. 46.8% higher than the reference specimen without fibers. Also, higher than the specimens (0%D.S + 1% S.F.S) and (0% D.S + 1% H.S.F) by about 15.4% and 13.8%, respectively, as shown in Figure 4.16.

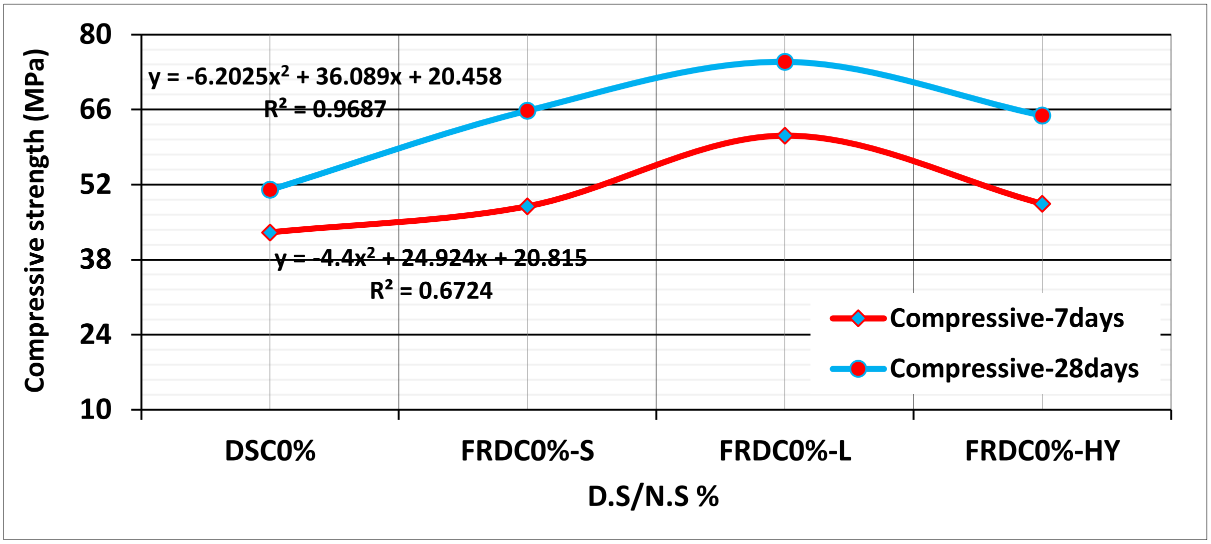


Figure 4.16 The curves of compressive strength for specimens containing sand dunes (0%) and reinforced with fiber.

When sand dunes is replaced by 20% as an alternative to sand, the compressive strength increases, as the specimens (20%D.S + 1%S.F.S) and (20%D.S + 1%S.F.L) achieved a compressive strength of 58.7and 62.8 MPa (an increase by about 14.1% and 22.08% compared to the specimen(20%D.S without fibers),also, the hybrid specimen (20%D.S + 1%H.S.F) achieved an increase in compressive strength of 65.2MPa (i.e. 26.7%, 11.07%, and 3.82%) higher than the specimens (20%D.S without fibers), (20%D.S+1%S.F.S) and (20%D.S+1%S.F.L) respectively, as shown in Figure 4.17.

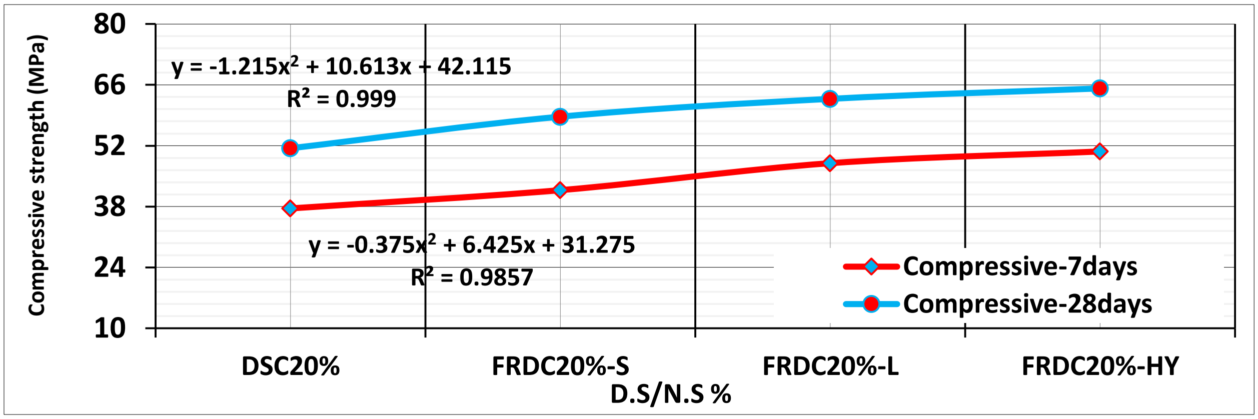


Figure 4.17 The curves of compressive strength for specimens containing sand dunes (20%) and reinforced with fiber.

The compressive strength increases with the increase in the sand dunes content in the specimens, where the specimen containing sand dunes of 40% and reinforced with short fibers (40%D.S + 1%S.F.S) achieved an increase in the compressive strength of 59.72MPa with an increase of about 6.07% higher than the specimen (40%D.S without fibers). Also, the specimen (40%D.S + 1%S.F.L) achieved a compressive strength of 63.3MPa higher than the specimen (40%D.S without fibers) by about 12.4%. While the compressive strength increases with specimens reinforced with hybrid fibers, where the hybrid specimen (40% D.S + 1%H.S.F) achieved a compressive strength of 71.3MPa, with an increase of about 26.6% higher than the specimen (40% D.S without fibers), as well as higher than the specimens (40 %D.S+1%S.F.S) and (40%D.S+1%S.F.L) by about 19.4% and 12.6%, respectively, as shown in Figure 4.18. This increase in the compressive strength of hybrid concrete is attributed to the positive effect of the mixed fibers on the compressive strength, where the short type of (straight) fibers added by 0.35% to concrete has high tensile strength and is more rigid. While the second long type (hook end) added by 0.65% to concrete has high strength. Also, the fineness of the sand dunes is able to fill all the spaces between the crushed gravel and the graded sand particles, thus making the concrete more cohesive and without gaps.

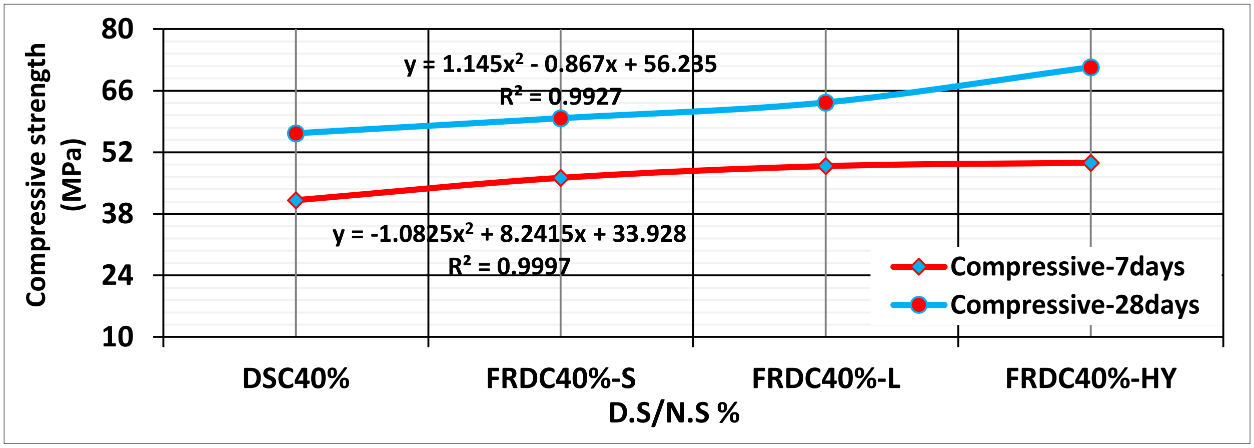


Figure 4.18 The curves of compressive strength for specimens containing sand dunes (40%) and reinforced with fiber.

The compressive strength decreases with the increase in the content sand dunes in the specimens of ratios(60%,80%,100%) and reinforced with single and hybrid fibers, but it remains higher than the specimens without fibers, where the specimens (60%D.S+1%S.F.S) and (60%D.S+1%H.S.F) achieved a compressive strength of 53.2 and 54.04 MPa (i.e. 3.1% and 4.72%), respectively, higher than the specimen (60% D.S without fibers). While the specimen (60%D.S + 1%S.F.L) achieved a compressive strength of 54.5 MPa with an increase of about 5.62%, 2.44%, and 0.85% higher than the specimens (60%D.S without fibers), (60%D.S +1%S.F.S) and (60% D.S + 1% H.S.F), respectively, as shown in Figure 4.19.

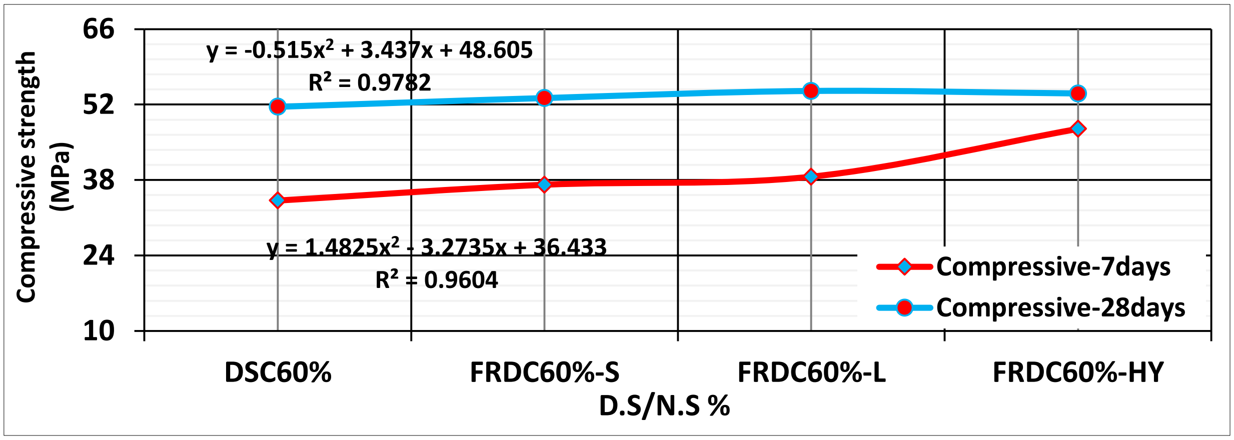


Figure 4.19 The curves of compressive strength for specimens containing sand dunes (60%) and reinforced with fiber.

The compressive strength decreases with the increase of the sand dunes content, where the specimens (80%D.S+1%S.F.S), (80%D.S+1%S.F.L) and (80%D.S+1%H.S.F) achieved compressive strength 41.8, 46.8 and 43.7 MPa, but it is higher by about (5.8%, 18.4%, 10.6%) respectively, compared to the specimen (80%D.S without fibers). Also, the compressive strength of the specimen (80%D.S+1%S.F.L) is higher than the specimens (80%D.S+1%S.F.S) and (80%D.S+1%H.S.F) by about 11.9% and 7.09%, respectively, as shown in Figure 4.20.

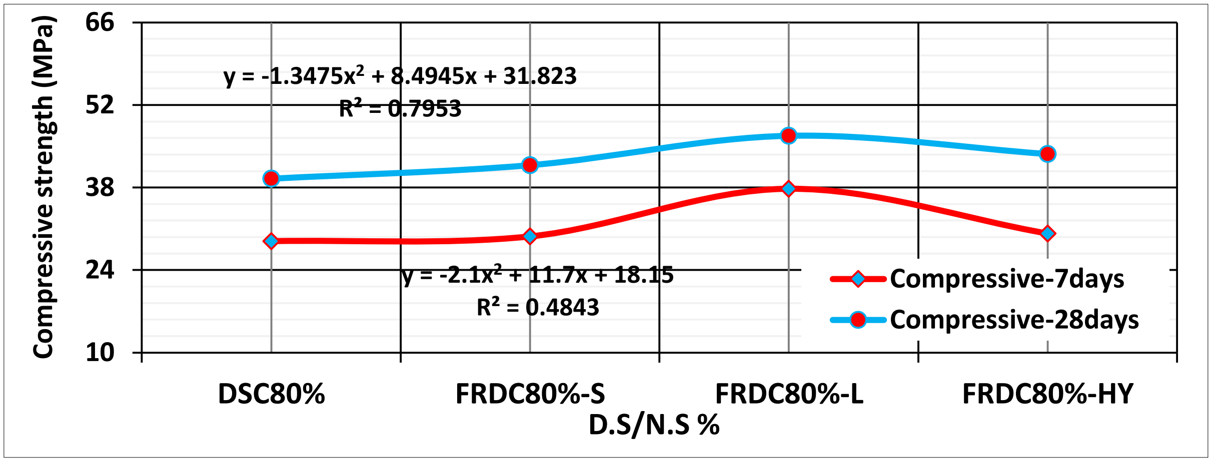


Figure 4.20 The curves of compressive strength for specimens containing sand dunes (80%) and reinforced with fiber.

Compressive strength decreases when using sand dunes of ratio 100%, where the specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L), and (100%D.S+1%H.S.F) achieved a compressive strength of 34.6 , 39.1 , and 36.4 MPa, but it is higher than the specimen (100%D.S without fibers) by about 10.89% , 25.3% , and 16.7%, respectively, also, the compressive strength of the specimen (100%D.S+1%S.F.L) was higher than the specimens (100%D.S+1%S.F.S) and (100%D.S+1%H.S.F) by about 13% and 7.4%, respectively ,as shown in Figure 4.21. The reason for the decrease in the strength is due to the increase in the fineness of the fine aggregate, which lowers the strength of the concrete.

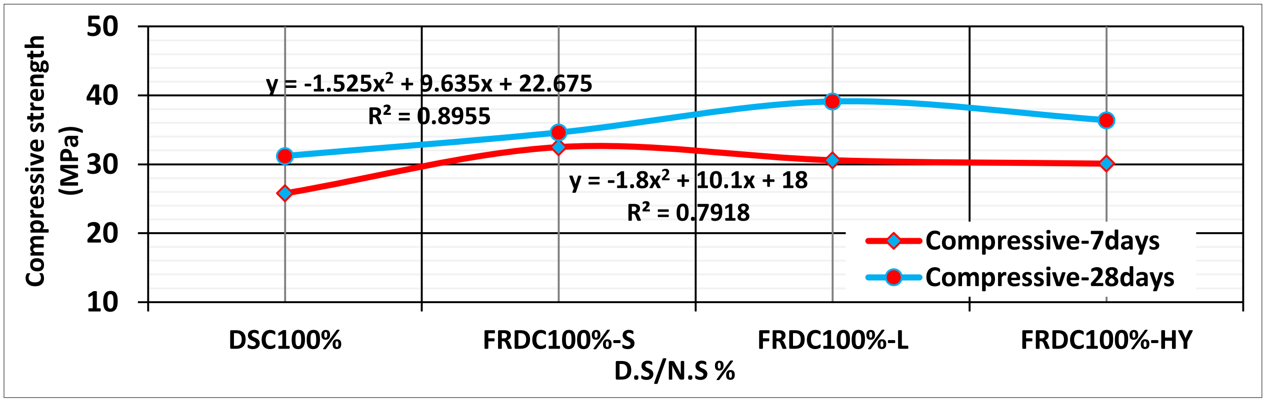


Figure 4.21 The curves of compressive strength for specimens containing sand dunes (100%) and reinforced with fiber.

4.2.1.2.2 Flexural strength results

The results of the flexural strength test at the age of 7 and 28 days for concrete specimens (prisms) containing sand dunes and reinforced with steel fiber as well as for specimens without fibers are listed in Table 4.3, where noted that all concrete specimens reinforced with long steel fibers or hybrid at 1% of the concrete volume showed a positive effect better than short fibers in terms of flexural resistance, especially with sand dunes for the ratios (0% - 60%) and it can be clarified as follows:

At age 7 days: The results of the flexural resistance test indicate at the 7 -day age for concrete specimens containing the previous replacement ratios without steel fibers. The flexural strength increases with the increase in the sand dunes content for the ratios (20%,40,60%,80%), where the specimens achieved flexural strength 6.11MPa,6.24 MPa, 6.21MPa,and 6 MPa with an increase of about 2.17%,4.3%, 3.8%, 0.33%, respectively highest than the reference specimen . The flexural strength of the specimen (100%D.S) decreases by 13.7% less than the reference specimen, and as in Table 4.3.

The results of flexural strength for concrete specimens reinforced with single and hybrid steel fibers show an increase in flexural strength. Where the highest flexural strength of 8.58MPa was recorded for the specimen (20%D.S + 1%S.F.L), namely 15.2% higher than the specimen (0%D.S +1%S.F.L), it is also higher than the specimens (20%D.S+1%S.F.S) and (20%D.S+1%H.S.F) by about 23.6% and 18%, respectively. Flexural strength decreases when sand dunes is used as an alternative to the sand of ratio 100%, where the specimen (100%D.S+1%S.F.S) recorded the lowest flexural strength of 5.31MPa, a decrease of about 15.1% ,6.67% and 8.7% less than the specimens (0%D.S+1%S.F.S), (100%D.S+1%H.S.F) and (100%D.S+1%S.F.L), respectively. Figure 4.22 shows the failure patterns of concrete prisms (100×100×500) mm after flexural testing.

Table 4.3 Results test of flexural strength for the concrete specimens

D.S/Sand Percentage %	Average Flexural strength (fr) MPa 7days	Average Flexural strength (fr) MPa 28days	%change in Flexural strength at 28 days
0% D.S	5.98	6.80	----
20% D.S	6.11	6.93	+1.91
40% D.S	6.24	7.47	+9.85
60% D.S	6.21	6.75	-0.73
80% D.S	6.00	6.36	-6.47
100% D.S	5.16	5.35	-21.32
0%D.S+1%S.F.S	6.26	7.60	+11.76
0%D.S+1%S.F.L	7.45	8.73	+28.38
0%D.S+1%H.S.F	7.38	8.56	+25.88
20%D.S+1%S.F.S	6.94	7.79	+12.40
20%D.S+1%S.F.L	8.58	10.07	+45.31
20%D.S+1%H.S.F	7.27	8.37	+20.77
40%D.S+1%S.F.S	6.96	7.98	+6.82
40%D.S+1%S.F.L	7.86	8.39	+12.31
40%D.S+1%H.S.F	7.81	8.08	+8.16
60%D.S+1%S.F.S	6.45	7.15	+5.92
60%D.S+1%S.F.L	7.61	7.92	+17.33
60%D.S+1%H.S.F	7.56	7.83	+16.00
80%D.S+1%S.F.S	6.58	7.29	+14.62
80%D.S+1%S.F.L	7.07	7.68	+20.75
80%D.S+1%H.S.F	6.90	7.50	+17.92
100%D.S+1%S.F.S	5.31	6.44	+20.37
100%D.S+1%S.F.L	5.82	6.71	+25.42
100%D.S+1%H.S.F	5.69	6.53	+22.05

At age 28 days : The results of the flexural strength test of concrete specimens without fibers indicate to increase in flexural strength, where the reference specimen (0%D.S) achieved a flexural strength of 6.8MPa . When sand dunes is used as an alternative to sand for a ratio of 20%, an increase in flexural strength, the specimen (20%D.S) achieved a flexural strength of 6.93MPa, an increase of about 1.9% higher than the specimen (0%D.S without fibers). But the content of dunes sand in the concrete increases, the flexural strength increases, where the specimen (40% D.S without fibers) achieved the highest flexural strength of 7.47 MPa (i.e. 9.85% higher than the reference specimen).

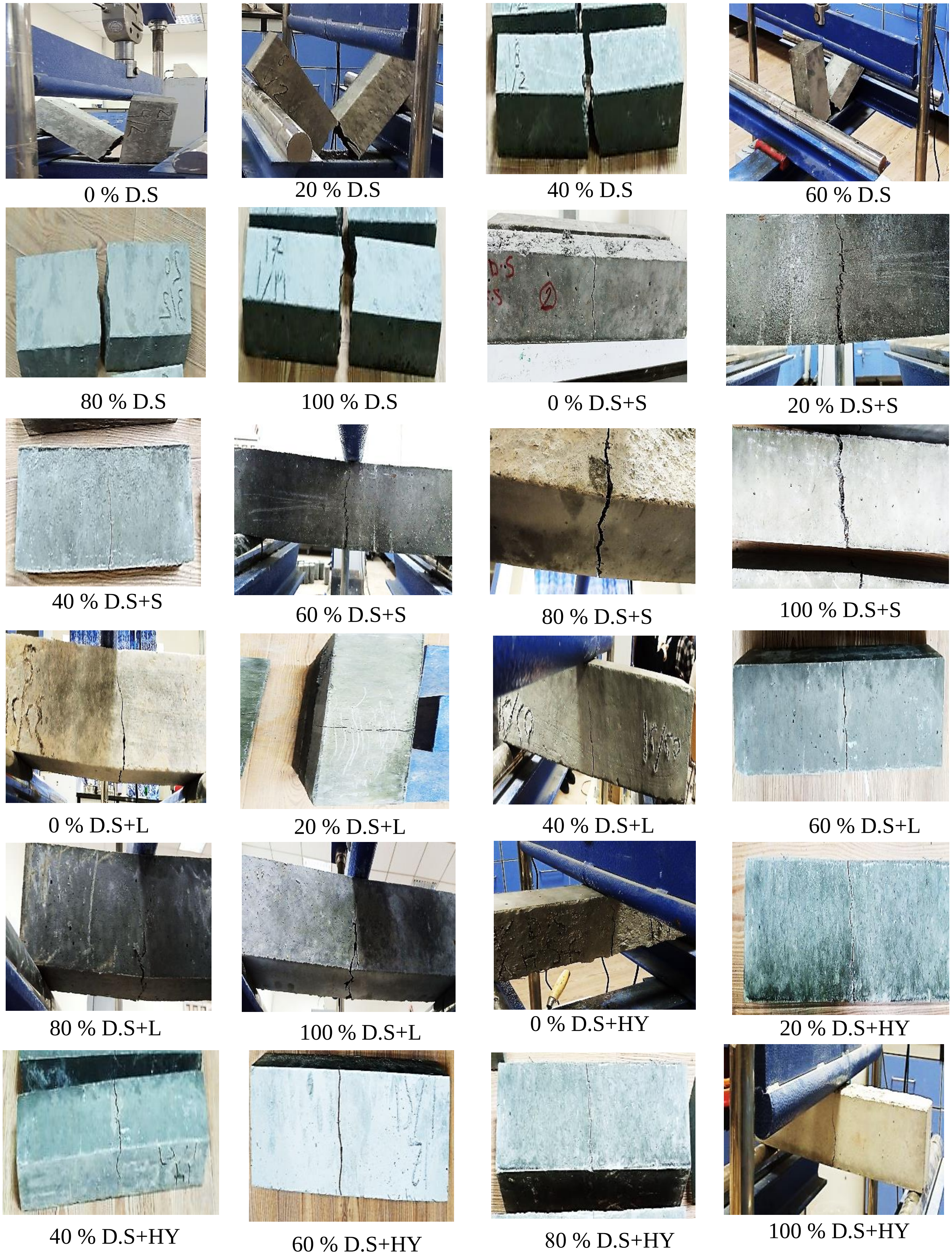


Figure 4.22 Failure modes of concrete specimens (100×100×500) mm.

The flexural strength decreases with the increase of the sand dunes content for the ratios (60%, 80%, 100%), where the flexural strength was recorded of 6.75MPa, 6.36MPa, 5.35MPa, with a decrease of about 10.73%, 6.47%, 21.32%, respectively compared to the reference specimen, as shown in Figure 4.23. The reason for the decrease in the resistance is due to the increase in the fineness of the fine aggregate grains, which affected the bearing of the prisms under the influence of flexural.

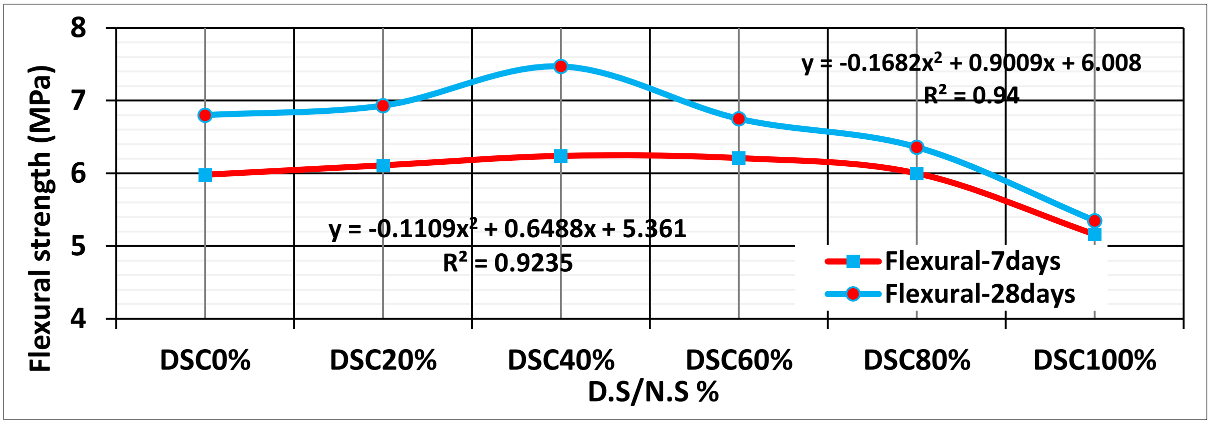


Figure 4.23 The flexural strength curves for specimens containing sand dunes without fibers.

The results of reinforced mixtures with short steel fibers and replacement ratios (0%-100%), showed that the mixture (40% D.S + 1%S.F.S) achieved the highest flexural resistance compared to all mixtures reinforced with short fibers and replacement ratios (20%, 40%, 60,80%, 100%) with an increase of about (5%, 2.4%, 11.6%, 9.46%, and 23.9%) respectively, as shown in Figure 4.24.

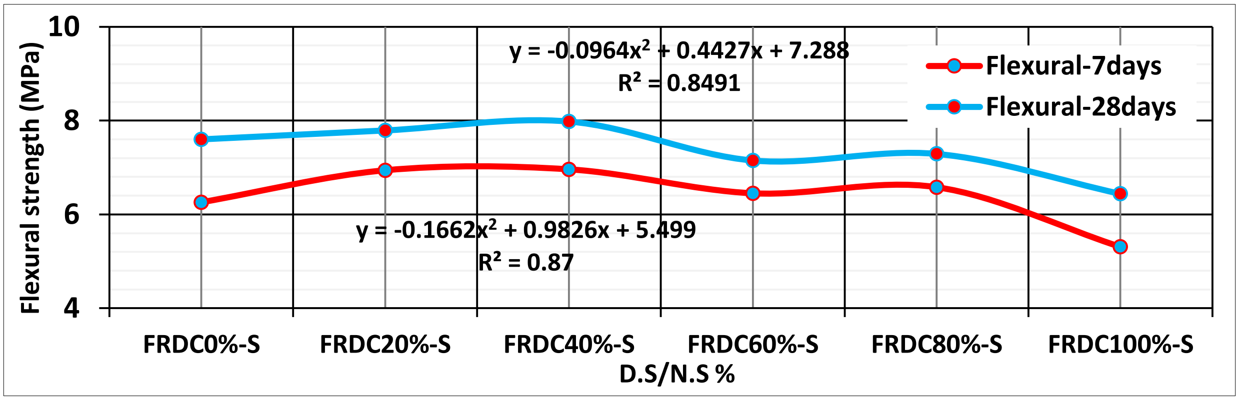


Figure 4.24 The flexural strength curves for mixtures containing S.F.S.

The results of the mixtures reinforced with long steel fibers and replacement ratios (0%-100%), showed that the mixture (20%D.S+1%S.F.L) achieved the highest flexural resistance compared to all mixtures reinforced with long steel fibers and replacement ratios (0%, 40%, 60%, 80%, 100%) with an increase of (15.3%, 20.02%, 27.14%, 31.1%, and 50.1%), respectively, as shown in Figure 4.25.

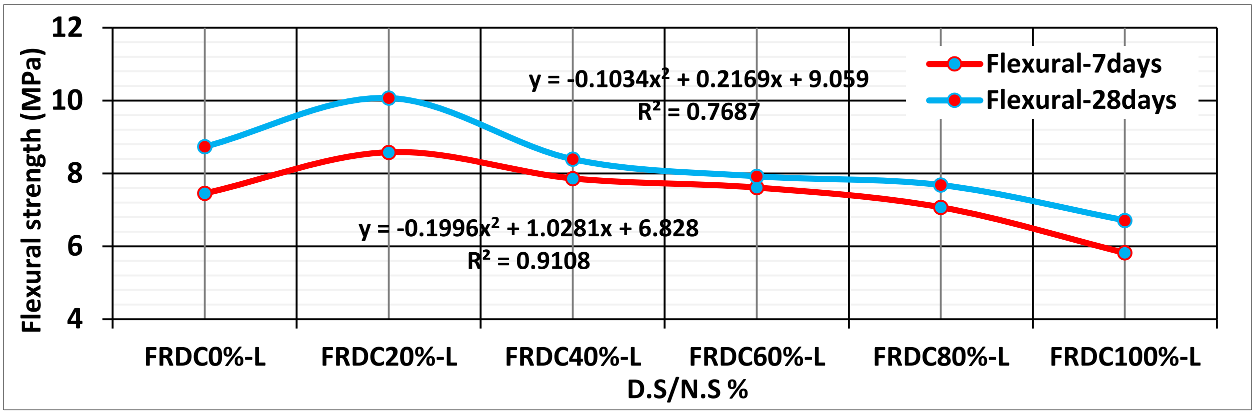


Figure 4.25 The flexural strength curves for mixtures containing S.F.L.

The results of the mixtures reinforced with hybrid steel fibers and replacement ratios (0%-100%), showed that the hybrid mixture without sand dunes (0% D.S + 1% H.S.F) achieved the highest flexural strength compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (2.27%, 5.94%, 9.32%, 14.13%, and 31.08%) respectively, as shown in the Figure 4.26.

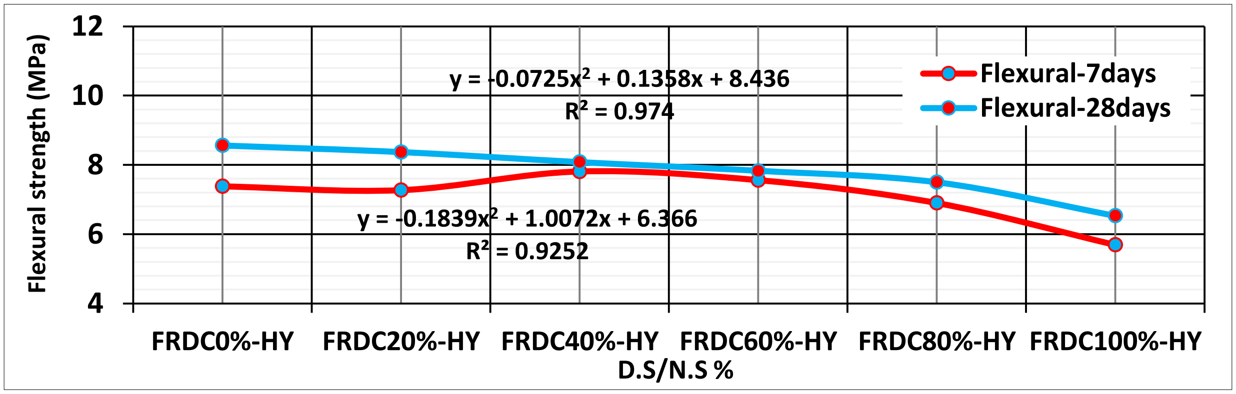


Figure 4.26 The flexural strength curves for mixtures containing H.S.F.

The concrete specimen without sand dunes and reinforced with short steel fibers (0%D.S+1%S.F.S) achieved an increase in flexural strength of 7.6 MPa (namely 11.76%higher than the reference specimen), while the specimen containing hybrid steel fibers (0%D.S + 1%H.S.F) achieved a flexural resistance of 8.56MPa (25.88% higher than the reference specimen), also, the specimen (0%D.S+1%S.F.L) achieved an increase in flexural strength of 8.73MPa, with an increase of about 28.38% higher than the reference specimen without fibers. It is also higher than the specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) by about 14.8% and 1.98%, respectively, and as shown in Figure 4.27.

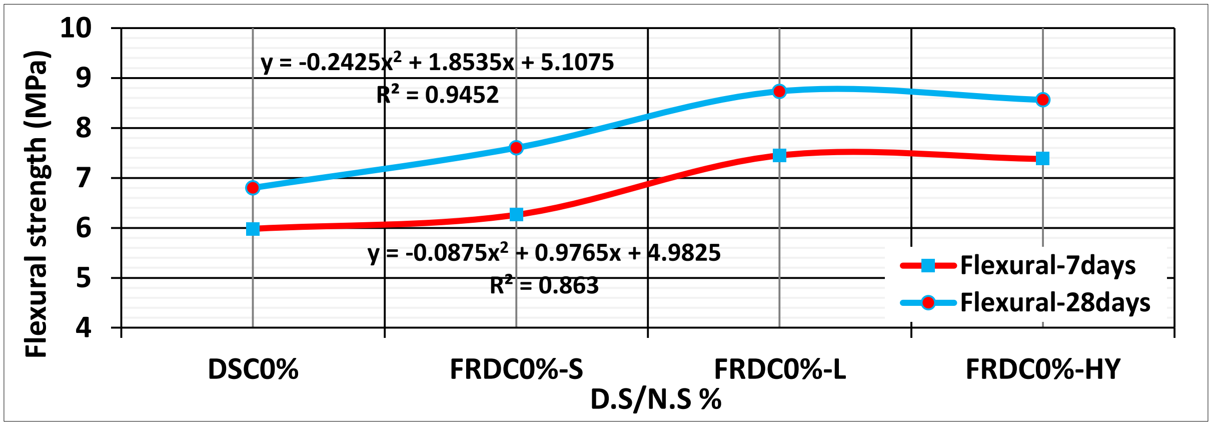


Figure 4.27 The curves of flexural strength for specimens containing sand dunes (0%) and reinforced with fiber.

The flexural strength gradually decreases at the age of 28 days for the hybrid concrete specimens with increasing sand dunes content as an alternative to the sand of ratios from (0% -100%). When sand dunes is used as an alternative to sand for a ratio of 20%, noticed an increase in flexural strength, where specimens (20%D.S + 1%S.F.S) and (20%D.S + 1%H.S.F) achieved flexural strength 7.79MPa and 8.37MPa with an increase of about 12.4% and 20.77%, respectively, higher than the specimen (20%D.S without fibers). While the specimen (20%D.S+1%S.F.L) achieved the highest flexural resistance of 10.07MPa, with an increase of about 45.3% higher than the specimen (20%D.S without fibers). It is also higher than the specimens (20%D.S+1%S.F.S) and (20%D.S+1%H.S.F), with an increase of about 29.3% and 20.3%, respectively, as shown in Figure 4.28.

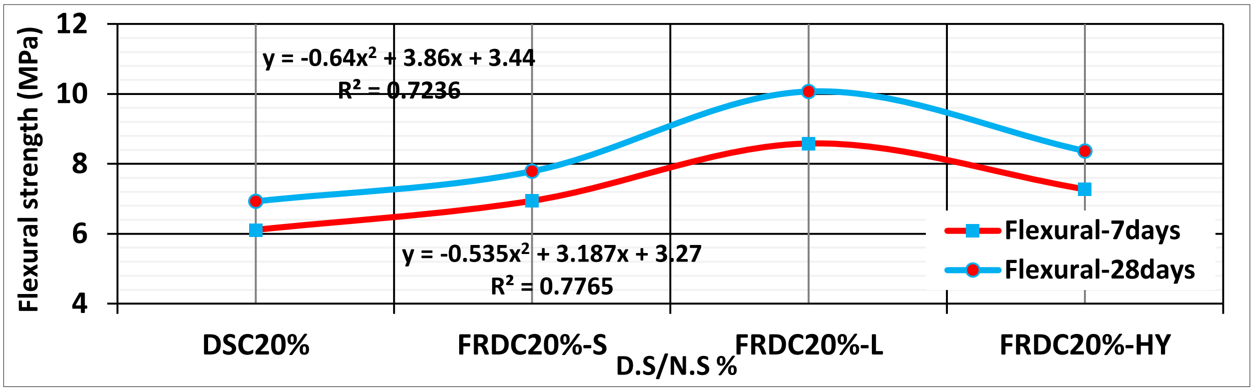


Figure 4.28 The curves of flexural strength for specimens containing sand dunes (20%) and reinforced with fiber.

The flexural strength decreases with the increase of the sand dunes content of ratio 40% for the specimens reinforced with long and hybrid steel fibers, and it increases with the short fibers compared to the other ratios, where The specimens (40%D.S+1%S.F.S), (40%D.S+1%S.F.L), and (40%D.S+1%H.S.F) achieved flexural strength of 7.98MPa, 8.39MPa, and 8.08MPa (namely, 6.82%, 12.3%, and 8.16%) respectively, higher than the specimen (40% D.S without fibers), also, the specimen (40% D.S + 1% S.F.L) achieved a higher flexural strength than the specimens (40% D.S + 1% S.F.S) and (40% D.S + 1% H.S.F), with an increase of about 5.13% and 3.83% respectively . As shown in Figure 4.29, where the flexural resistance improves with the addition of steel fibers compared to concrete does not contain fibers. Also, the role of fibers in concrete greatly helped delay the early failure of Prism. The specimens containing steel fibers, despite the increase in the content of sand dunes in the concrete, the examined specimens that contain steel fibers did not split into two parts during the test and as shown in the Figure 4.22. Except for the crack, which starts from the bottom and then to the middle of the specimen due to the cohesion of the fibers between the two ends of the crack, where we note that role fiber acts as a bridge for cracks between the two ends of the crack in the prism and transfers the stress of cracking from one of its sides to the other side, which helps reduce stress concentration on both sides of the crack and thus prevents the growth of the crack.

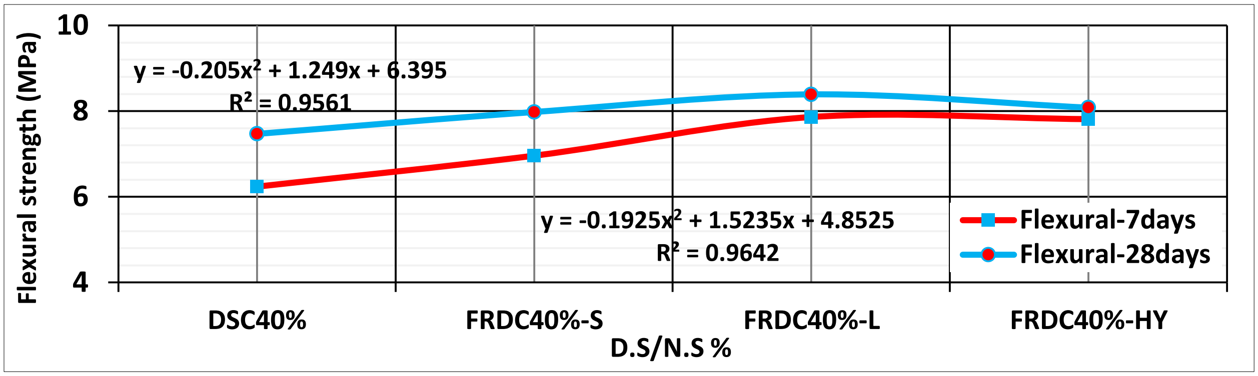


Figure 4.29 The curves of flexural strength for specimens containing sand dunes (40%) and reinforced with fiber.

Flexural strength decreases with increasing sand dunes content of ratios (60%, 80%, 100%) reinforced with single and hybrid steel fibers, where the specimens (60%D.S+1%S.F.S) and (60%D.S+1%H.S.F) achieved flexural strength of 7.15MPa and 7.83MPa (i.e. 5.92% and 16%) higher than the specimen (60%D.S without fibers). While the specimen (60%D.S+1%S.F.L) achieved flexural strength of 7.92MPa with an increase of about 17.3%, 10.7%, and 1.15% higher than the specimens (60%D.S without fibers), (60%D.S+1%S.F.S) and (60% D.S + 1% H.S.F), respectively, as shown in Figure 4.30.

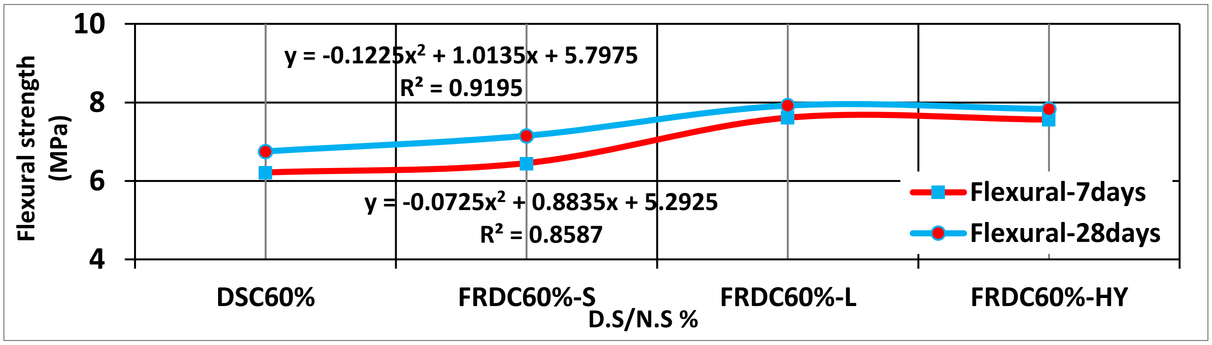


Figure 4.30 The curves of flexural strength for specimens containing sand dunes (60%) and reinforced with fiber.

The specimens achieved (80%D.S+1%S.F.S), (80%D.S+1%S.F.L), and (80%D.S+1%H.S.F) an increase in flexural strength by about 14.6%, 20.75%, and 17.9% respectively, higher than the specimen (80%D.S without fibers). also, the specimen (80%D.S + 1%S.F.L) achieved an increase in flexural strength by about 5.3% and 2.4% higher than the specimens (80%D.S +1%S.F.S) and (80%D.S +1%H.S.F), respectively, and as in Figure 4.31.

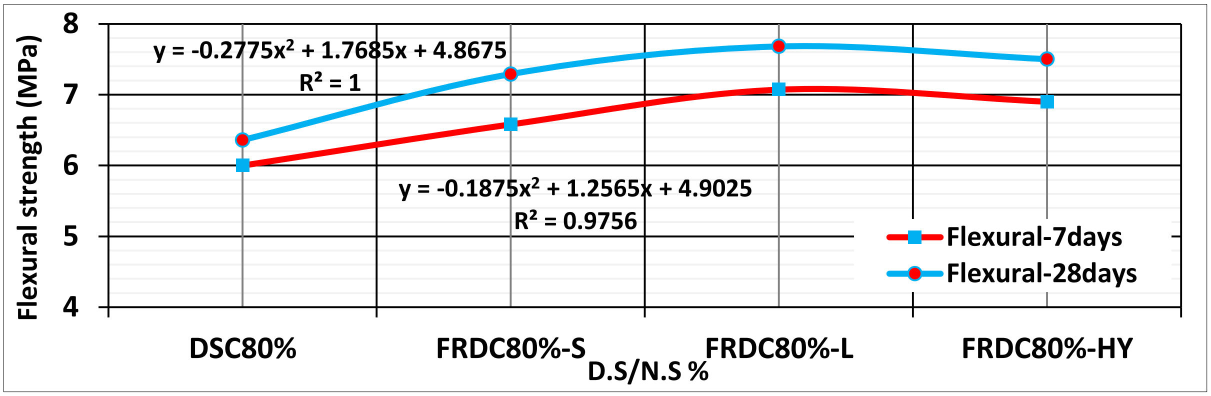


Figure 4.31 The curves of flexural strength for specimens containing sand dunes (80%) and reinforced with fiber.

When sand dunes is used as an alternative to sand for ratio100%, we notice a decrease in flexural strength, where the specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L), and (100%D.S+1 %H.S.F) achieved flexural resistance of 6.44MPa, 6.71MPa, and 6.53MPa, but it is higher than the specimen (100%D.S without fibers) by about 20.4%, 25.4%, 22.05%, respectively. Also, the flexural strength of the specimen (100%D.S+1%S.F.L) was higher than the flexural strength of the specimens (100%D.S+1%S.F.S) and (100%D.S+1%H.S.F) by about 4.195% and 2.75 %respectively, and as shown in Figure 4.32. Where note that the performance of long fibers was better than short and hybrid fibers on flexural resistance due to the role of long fibers by 1%, which it is connects the two sides of the crack in the concrete and thus prevents the failure of concrete early a and reduces large cracks.

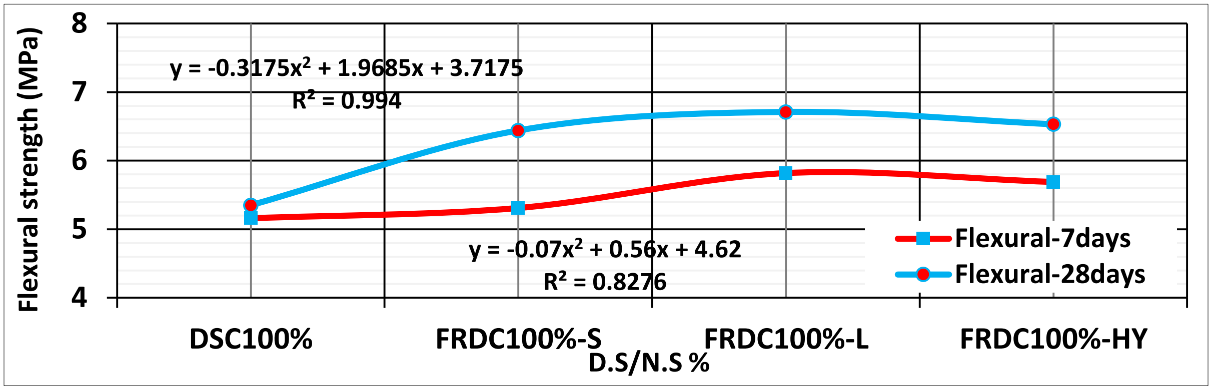


Figure 4.32 The curves of flexural strength for specimens containing sand dunes (100%) and reinforced with fiber.

4.2.1.2.3 Splitting tensile strength results

The splitting tensile strength test results at the age of 7 and 28 days for concrete specimens (cylinders 100 ×200mm) containing sand dunes as an alternative to sand and reinforced with short, long, and hybrid steel fibers well as for specimens without fibers were listed in Table 4.4. noted that all concrete specimens and reinforced with long steel fibers or hybrid at 1% of the concrete volume, which showed a positive effect better than short fibers in terms of split tensile resistance, especially with dunes sand as an alternative to the sand of ratios (0% - 60%) and it can be clarified as follows:

At age 7 days : The results of the split tensile strength test at the 7-day age for concrete specimens that contain sand dunes as an alternative to sand indicate the ratios (20%,40%,60%,80%,100%) without steel fibers, in addition to the reference specimen (0%) without dunes sand and fibers. The specimen (0%D.S) achieved the split tensile strength of 2.83MPa. When sand dunes is used as an alternative to sand, noticed an increase in tensile strength, where the specimen (40%D.S) achieved the highest tensile strength of 3.4MPa, an increase of about 20.1% higher than the reference specimen, it is also higher than the specimens that contain sand dunes for the ratios (20%, 60%, 80%,100%) by about (9.6%,10.3%,39%,64.2%), respectively.

Table 4.4 Results test of splitting tensile strength for the concrete specimens

D.S/Sand Percentage %	Average split tensile strength (Ft) MPa 7days	Average split tensile strength (Ft) MPa 28days	%change in split tensile strength at 28 days
0% D.S	2.83	3.27	-----
20% D.S	3.1	3.4	+3.97
40% D.S	3.4	4	+22.32
60% D.S	3.08	3.3	+0.91
80% D.S	2.44	2.7	-17.43
100% D.S	2.07	2.31	-29.35
0%D.S+1%S.F.S	3.59	4.04	+23.54
0%D.S+1%S.F.L	4.59	5.8	+77.37
0%D.S+1%H.S.F	4.26	5.6	+71.25
20%D.S+1%S.F.S	3.36	4	+17.64
20%D.S+1%S.F.L	3.88	5	+47.05
20%D.S+1%H.S.F	4.03	5.2	+52.94
40%D.S+1%S.F.S	3.65	4.2	+5.00
40%D.S+1%S.F.L	4.17	5.1	+27.50
40%D.S+1%H.S.F	3.2	4.3	+7.50
60%D.S+1%S.F.S	3.4	3.8	+15.15
60%D.S+1%S.F.L	4.4	4.7	+42.42
60%D.S+1%H.S.F	4.25	4.6	+39.39
80%D.S+1%S.F.S	2.98	3.3	+22.22
80%D.S+1%S.F.L	3.7	4.9	+81.48
80%D.S+1%H.S.F	3.4	3.83	+41.85
100%D.S+1%S.F.S	2.91	3.03	+31.16
100%D.S+1%S.F.L	3.2	3.7	+60.17
100%D.S+1%H.S.F	3.01	3.24	+40.25

The tensile strength decreases with the increase the sand dunes content of the ratio (80% and 100%), with a decrease of about 13.8% and 26.8%, respectively, compared to the reference specimen .

The results of tensile strength at the age of 7 days for concrete specimens that contain single and hybrid steel fibers show an increase in tensile strength and in varying proportions according to the type of added fibers, where the specimen (0%D.S + 1%S.F.L) recorded the highest tensile strength of 4.59 MPa an increase of about 62.1% higher than the reference specimen without fibers. It is also higher than the specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) by 27.8% and

7.74%, respectively. When sand dunes is replaced for the ratio (100%), the tensile strength decreases, as the specimen (100% D.S + 1% S.F.S) recorded the lowest tensile strength of 2.91 MPa, with a decrease of about 3.3% and 9% compared to the specimens (100%D.S+1%H.S.F) and (100%D.S+1%S.F.L) respectively.

At age 28 days: The results of the splitting tensile strength test of concrete specimens without fibers indicate increasing in tensile strength, where the reference specimen (0%D.S) achieved a tensile strength of 3.27MPa. The specimen (40% D.S) also achieved the highest tensile strength of 4 MPa (i.e. 22.3% higher than the reference specimen). When sand dunes is replaced for the ratios (20%,60%), the tensile strength of concrete increases, where the specimens achieved an increase in tensile strength of 3.4MPa and 3.3MPa, with an increase of 3.97%,0.91%, respectively, compared to the specimen (0%D.S without fibers) . The tensile strength decreases with the increase of the sand dunes content in the mixtures. The specimen (80%D.S) achieved a tensile strength of 2.7MPa, with a decrease of about 17.43% compared to the reference specimen. When sand dunes is used for the ratio of 100% without fibers, the tensile strength decreases by about 29.35% compared to the reference specimen as shown in Figure 4.33, the reason for the decrease in tensile strength is due to the increase in the fineness of the fine aggregate, which negatively affected the splitting tensile strength. Figure 4.34 shows the failure patterns of concrete cylinders (100×200) mm after splitting tensile testing.

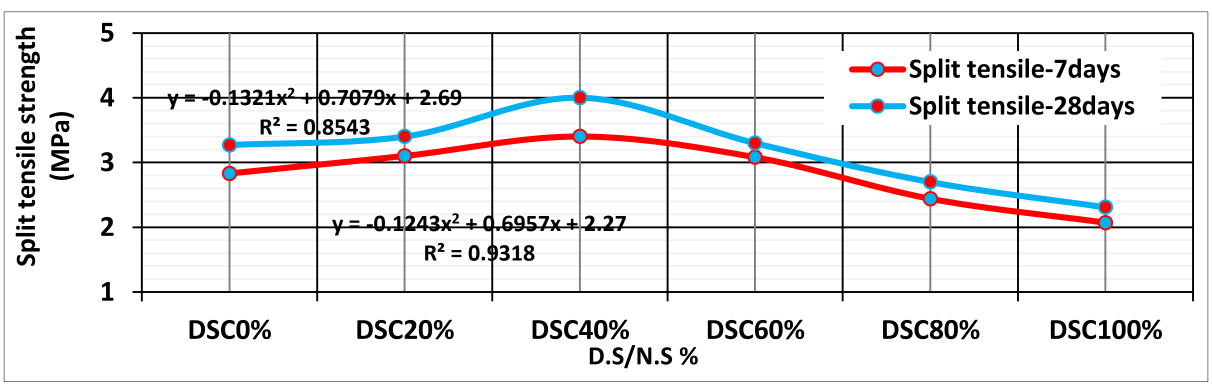


Figure 4.33 The splitting tensile strength curves for specimens without fibers.

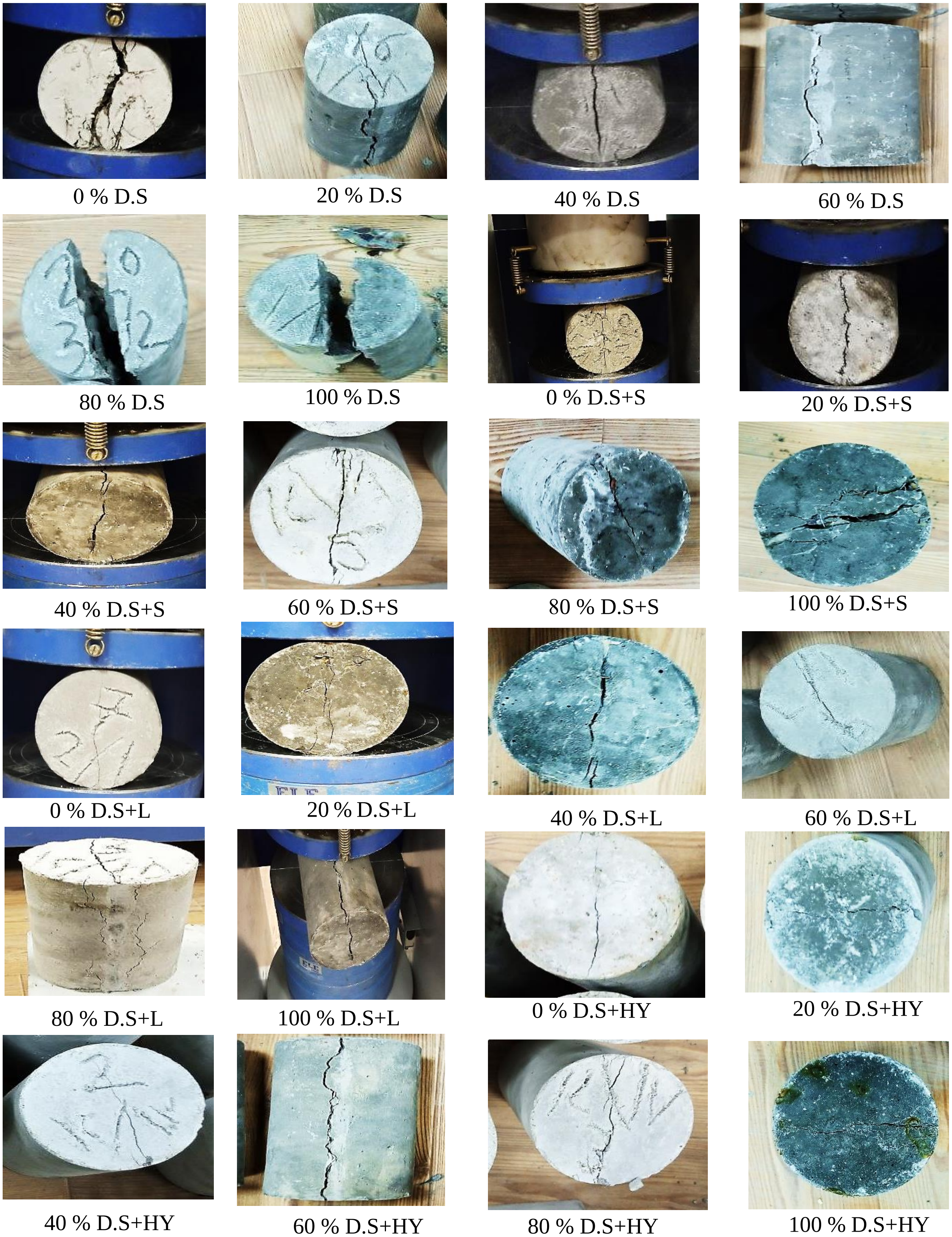


Figure 4.34 Failure modes of concrete specimens containing sand dunes.

The results of the reinforced mixtures with short steel fibers and replacement ratios (0%-100%), showed that the mixture (40% D.S + 1%S.F.S) achieved the highest split tensile strength compared to all the mixtures reinforced with short steel fibers and replacement ratios (0%, 20%, 60%,80%,100%), with an increase of about (3.9%, 5%, 10.5%, 27.3%, and 38.61%), respectively, as shown in Figure 4.35.

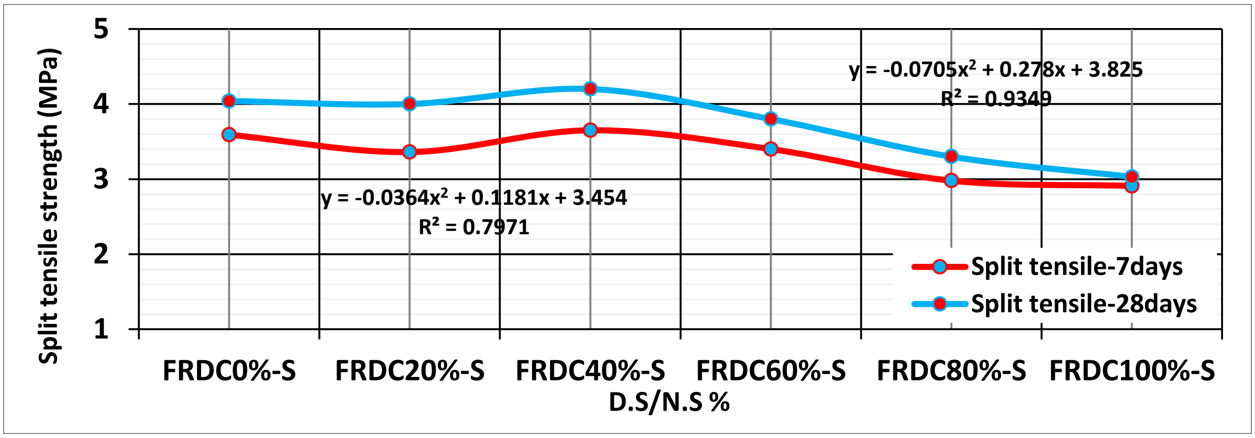


Figure 4.35 The splitting tensile strength curves for mixtures containing S.F.S

The results of the mixtures reinforced with long steel fibers and replacement ratios (0%-100%), showed that the mixture without sand dunes (0%D.S+1%S.F.L) achieved the highest split tensile strength compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (16%, 13.7%, 23.4%, 18.36%, and 56.7%), respectively, as shown in Figure 4.36.

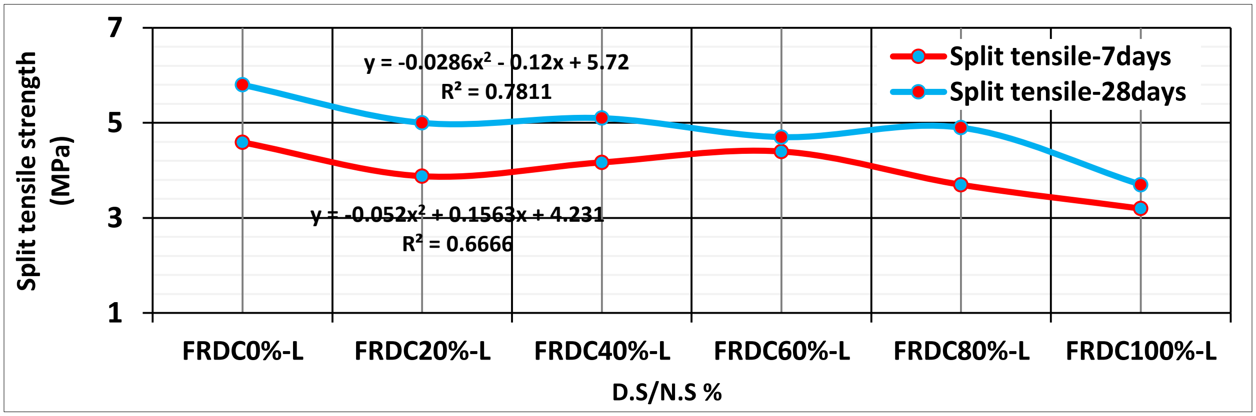


Figure 4.36 The splitting tensile strength curves for mixtures containing S.F.L

The results of the mixtures reinforced with hybrid steel fibers and replacement ratios (0%-100%), showed that the hybrid mixture without sand dunes (0%D.S + 1%H.S.F) achieved the highest tensile strength compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (7.7%, 30.2%, 21.7%, 46.2%, and 72.8%) respectively, as shown in Figure 4.37.

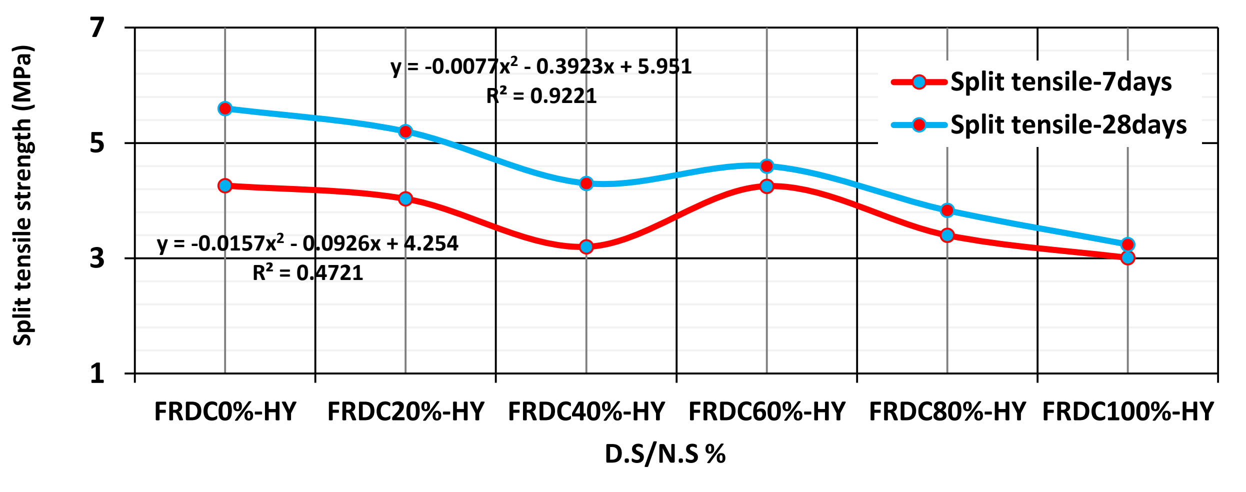


Figure 4.37 The splitting tensile strength curves for mixtures containing H.S.F

The results of the split tensile strength test of specimens containing short, long, and hybrid steel fibers show an increase in tensile strength. The concrete specimen without sand dunes and reinforced with short steel fibers (0%D.S+1%S.F.S) achieved an increase in tensile strength of 4.04 MPa (namely 23.5%higher than the reference specimen). While the specimen (0%D.S+1%H.S.F) containing hybrid steel fibers achieved a tensile strength of 5.6MPa, an increase of about 71.25% compared to the reference specimen. Also, the concrete specimen containing long steel fibers (0%D.S+1%S.F.L) achieved the highest tensile strength of 5.8MPa (i.e. 77.37% higher than the reference specimen without fibers. Where higher than the specimens (0%D.S+1% S.F.S) and (0% D.S + 1% H.S.F) by about 3.5% and 34.5%, respectively, as shown in Figure 4.38.

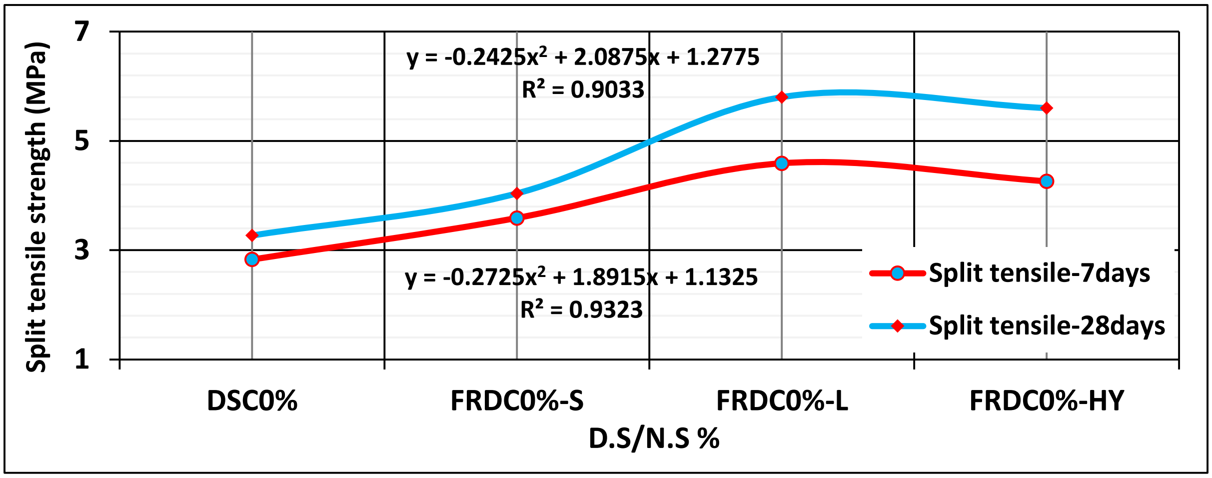


Figure 4.38 The curves of split tensile strength for specimens containing sand dunes (0%) and reinforced with fiber.

When sand dunes is used as an alternative to the sand of ratio 20%, the tensile strength increases, where the specimens (20%D.S+1%S.F.S) and (20%D.S+1%S.F.L) achieved tensile strength of 4.5MPa with an increase of about 17.6 % and 47.05% compared to the specimen (20%D.S without fibers). Also, the hybrid fiber specimen (20%D.S + 1%H.S.F) achieved an increase in tensile strength of 5.2MPa (i.e. 52.9%, 30%, and 4%) higher than the specimens (20%D.S without fibers), (20%D.S +1%S.F.S) and (20%D.S+1%S.F.L) respectively, as shown in Figure 4.39, where the role of hybrid fibers helped to improve the split tensile resistance so that the short fibers (straight) by 0.35% had an important role in reducing the initial cracks and increasing the maximum tensile resistance. As for the long fibers (hook end) by 0.65%, they have durability, also noted that the effect of the fineness of the sand dunes inside the concrete has achieved acceptable results for the splitting tensile strength of hybrid concrete and concrete containing single fibers due to the fusion of its fine grains between the components of gravel and sand.

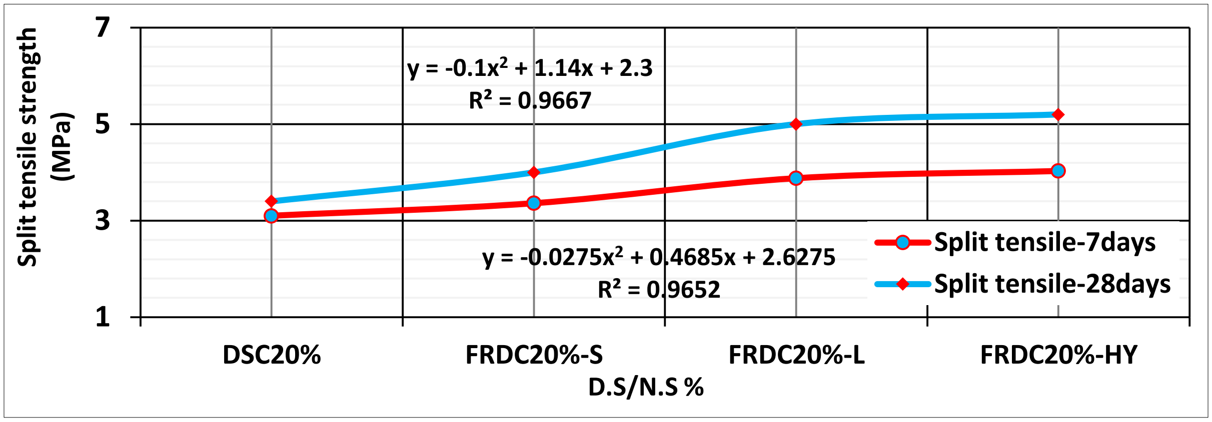


Figure 4.39 The curves of split tensile strength for specimens containing sand dunes (20%) and reinforced with fiber.

The split tensile strength increases with the increasing in the sand dunes content in the mixtures, where specimens containing sand dunes of 40% and reinforced with short steel fiber (40%D.S + 1%S.F.S) achieved an increase in tensile strength of 4.2MPa with an increase of about 5% Higher than the specimen (40%D.S without fibers), also, the specimen (40% D.S + 1% H.S.F) had a tensile strength of 4.3 MPa, higher than the specimen (40% D.S without fibers) by about 7.5% , while the tensile strength increases with specimens reinforced with long steel fibers, where the specimen (40% D.S + 1% S.F.L) achieved a tensile strength of 5.1 MPa with an increase of about 27.5% higher than the specimen (40% without fibers), as well as higher than the specimens (40% D.S + 1%S.F.S) and (40% D.S + 1%H.S.F) by about 21.4% and 18.6%, respectively, as shown in Figure 4.40.

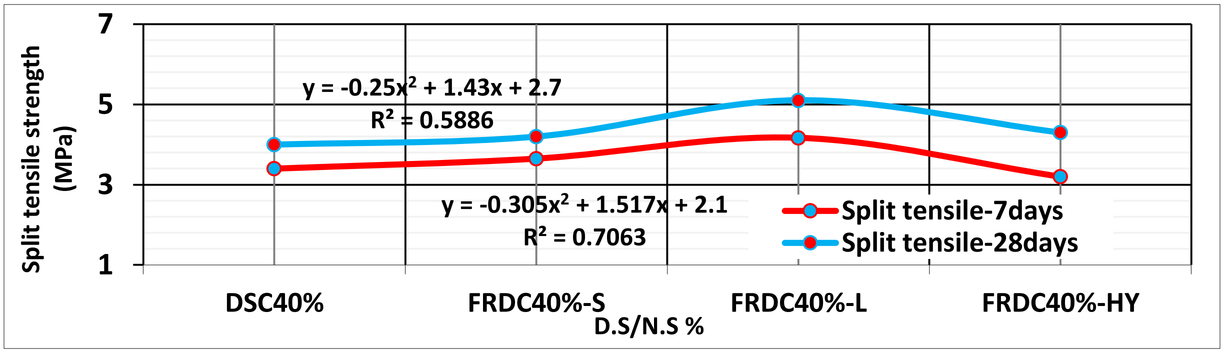


Figure 4.40 The curves of split tensile strength for specimens containing sand dunes (40%) and reinforced with fiber.

The tensile strength of concrete specimens reinforced with short single fibers decreases with the increasing of the sand dunes content of the ratios 60%, 80%, 100%,where the concrete specimens (60%D.S+1%S.F.S) and (60%D.S+1%H.S.F) achieved a tensile strength of 3.8MPa and 4.6MPa, namely 15.1% and 39.4%, respectively, higher than the specimen (60%D.S without fibers). While the specimen (60%D.S+1%S.F.L) achieved a tensile strength of 4.7MPa, with an increase of 42.4%, 23.7%, and 2.2% higher than the specimens (60%D.S without fibers), (60%D.S+1%S.F.S) and (60% D.S + 1% H.S.F), respectively, as shown in Figure 4.41.

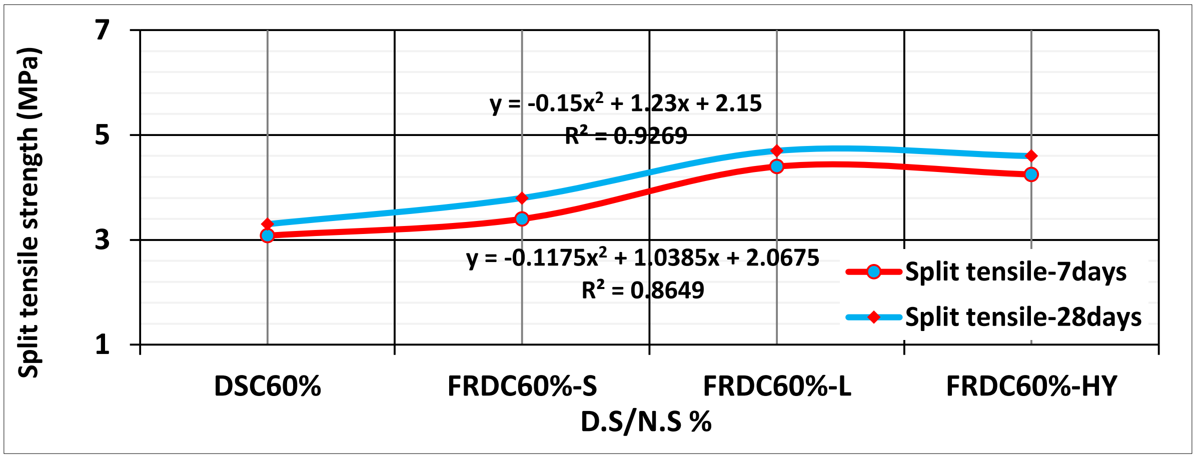


Figure 4.41 The curves of split tensile strength for specimens containing sand dunes (60%) and reinforced with fiber.

The specimens achieved (80%D.S + 1%S.F.S) and (80%D.S +1%H.S.F) tensile strength of MPa3.3 and 3.8 MPa, (i.e. 22.2% and 41.8%), respectively, higher than the specimen (80%DS without fibers). While the specimen achieved (80%D.S+1%S.F.L) tensile strength of 4.9MPa, with an increase of about 81.5%, 48.5%, and 27.9% higher than the specimens (80%D.S without fibers), (80%D.S+1%S.F.S) and (80% D.S + 1% H.S.F), respectively, as shown in Figure 4.42.

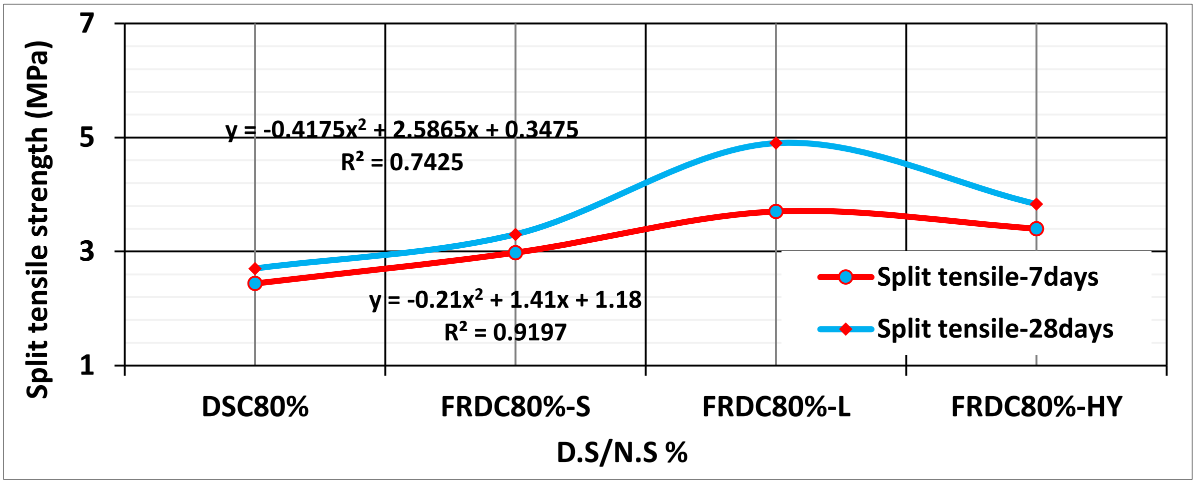


Figure 4.42 The curves of split tensile strength for specimens containing sand dunes (80%) and reinforced with fiber.

The split tensile strength decreases when sand dunes is used as an alternative to the sand of ratio 100%, where the specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L), and (100%D.S+1 %H.S.F) achieved tensile strength of 3.03, 3.7, and 3.24 MPa, but it is higher than the specimen (100%D.S without fibers) by 31.16%, 60.17%, and 40.25%, respectively, also, the tensile strength of the specimen (100%D.S+1%S.F.L) was higher than the tensile strength of the specimens (100%D.S+1%S.F.S) and (100%D.S+1%H.S.F) by 22.1% and 14.1% respectively, and as shown in Figure 4.43 .

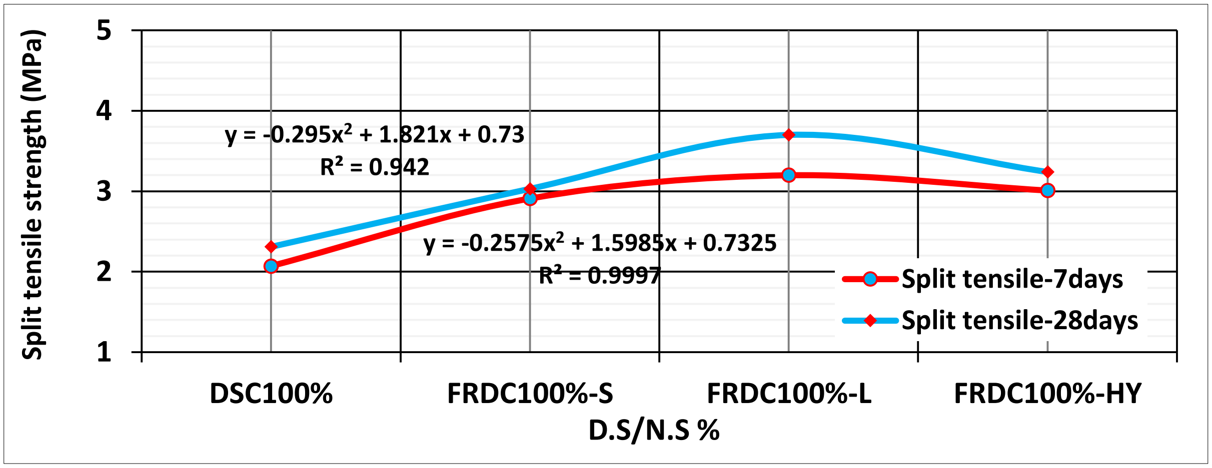


Figure 4.43 The curves of split tensile strength for specimens containing sand dunes (100%) and reinforced with fiber.

4.2.1.3 Results of physical Properties

4.2.1.3.1 Dry Density results

The results of the dry density test of concrete specimens (cubes) containing sand dunes for the ratios (0%,20%,40%,60%,80%,100%) and reinforced with short, long, and hybrid steel fibers, as well as for specimens without fibers, are listed in Table 4.5. The results show achieving the highest dry density of concrete specimens containing sand dunes of ratios (0% - 60%) and can be clarified as follows:

At age 7 days: The results of the dry density at the age of 7 days for specimens containing sand dunes showed an increase in the density with the increase of the sand dunes content. Where the specimen (40% D.S without fibers) achieved a dry density of 2411.15 kg/m^3 with an increase of about 6.09% higher than the reference specimen. When the sand dunes content increases for the ratios (60%,80%,100%), the density increases where the specimens achieved a dry density of 2398.96kg/m^3, 2351.80kg/m^3 and 2353.3kg/m^3, an increase of about 5.56%,3.48%,3.54%, respectively, higher than the reference specimen. While the reference specimen achieved the lowest dry density.

Density results for specimens containing steel fibers show an increase in density and higher than specimens without fibers. The hybrid concrete (20%D.S + 1%H.S.F) achieved the highest dry density of 2498.76 kg/m^3, an increase of about 0.52% higher than the specimen (0%D.S +1%H.S.F). It is also higher than specimens (20%D.S + 1%S.F.S) and (20%D.S +1%S.F.L) by about 2.7% and 0.49%, respectively. When dune sand is used for ratio (100%), the density of the specimens decreases compared to other replacement ratios, where the specimen (100%D. S+1%H.S.F) achieved the lowest dry density by about 5.7% compared with the specimen (0%D.S +1%H.S.F). Figure 4.44 shows the dry density test for the concrete specimens (cubes 150×150×150) mm.

Table 4.5 Results test of dry density for the concrete specimens

Dune sand/Sand Percentage %	Average Density kg/m^3 7days	Average Density kg/m^3 28days	%change in density at 28 days
0% D.S	2272.63	2382.41	----
20% D.S	2369.92	2371.55	-0.45
40% D.S	2411.15	2427.35	+1.88
60% D.S	2398.96	2400.58	+0.76
80% D.S	2351.80	2355.20	-1.14
100% D.S	2353.3	2348.83	-1.40
0%D.S+1%S.F.S	2487.30	2516.73	+5.63
0%D.S+1%S.F.L	2491.55	2564.13	+7.62
0%D.S+1%H.S.F	2485.93	2501.92	+5.01
20%D.S+1%S.F.S	2432.78	2441.67	+2.95
20%D.S+1%S.F.L	2486.50	2522.37	+6.35
20%D.S+1%H.S.F	2498.76	2527.60	+6.58
40%D.S+1%S.F.S	2456.98	2463.30	+1.48
40%D.S+1%S.F.L	2468.14	2471.99	+1.83
40%D.S+1%H.S.F	2486.90	2548.44	+4.98
60%D.S+1%S.F.S	2404.04	2443.85	+1.80
60%D.S+1%S.F.L	2423.55	2454.41	+2.24
60%D.S+1%H.S.F	2441.08	2451.70	+2.12
80%D.S+1%S.F.S	2377.92	2391.40	+1.53
80%D.S+1%S.F.L	2409.77	2474.17	+5.05
80%D.S+1%H.S.F	2389.93	2399.4	+1.87
100%D.S+1%S.F.S	2373.52	2378.81	+1.27
100%D.S+1%S.F.L	2357.62	2363.25	+0.61
100%D.S+1%H.S.F	2341.77	2352.91	+0.17

Figure 4.44 The dry density test for the concrete specimens (cubes).

At age 28 days: The results, at the age of 28 days for specimens without fibers, showed an increase in density, where the reference specimen (0%D.S without fibers) achieved a density of 2382.41 kg/m^3, and when sand dunes was replaced, the density increased where the specimen (40%D.S without fibers) achieved a highest density of 2427.35 kg/m^3, an increase of about 1.88% higher than the reference specimen. Followed by the specimen (60%D.S without fibers), which achieved an increase in density by about 0.76% higher than the reference specimen. The fineness of the sand dunes, its spherical shape, and its overlap between the grains of gravel and sand, which helped to fill all the gaps and pores inside the concrete, and the use of sand dunes in partial ratios with the sand contributed in increasing the density of concrete. When the dunes sand content was increased to 80% and 100%, the density decreased, where the specimens achieved a density of 2355.20 kg/m^3 and 2348.83 kg/m^3, with a decrease of 1.14% and 1.40% compared to the reference specimen as shown in Figure 4.45.

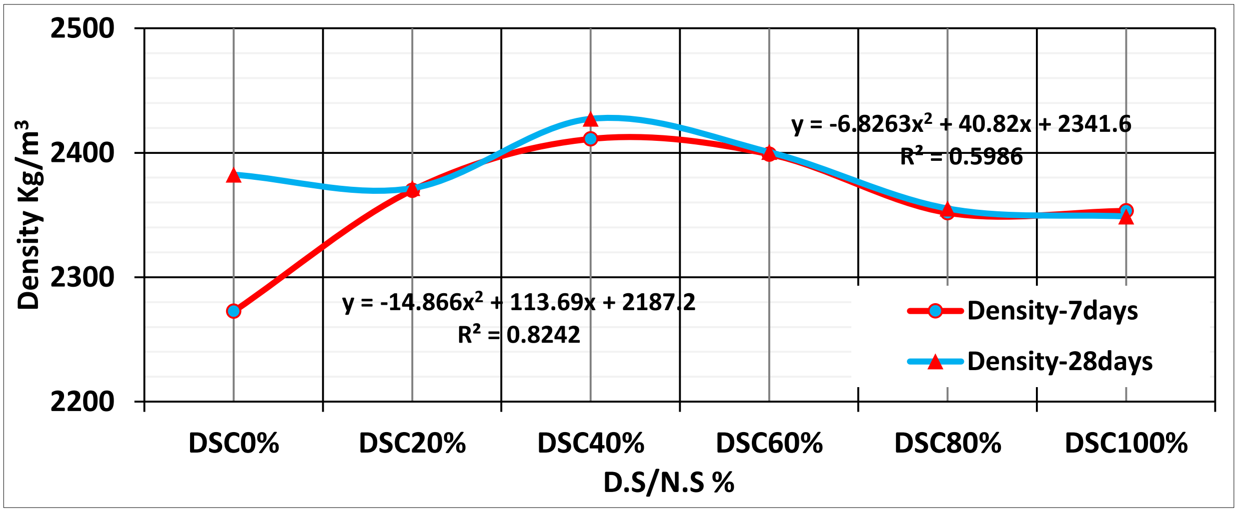


Figure 4.45 The dry density curves for specimens containing (D.S) without fibers.

The results of reinforced mixtures with short steel fibers and replacement ratios (0%-100%), showed that the mixture (0%D.S + 1%S.F.S) achieved the highest dry density compared to all mixtures reinforced with short fibers and replacement ratios (20%, 40%, 60%,80%, 100%) with an increase of (3.07%, 2.16%, 2.98%, 5.24%, and 5.79%) respectively, as shown in Figure 4.46.

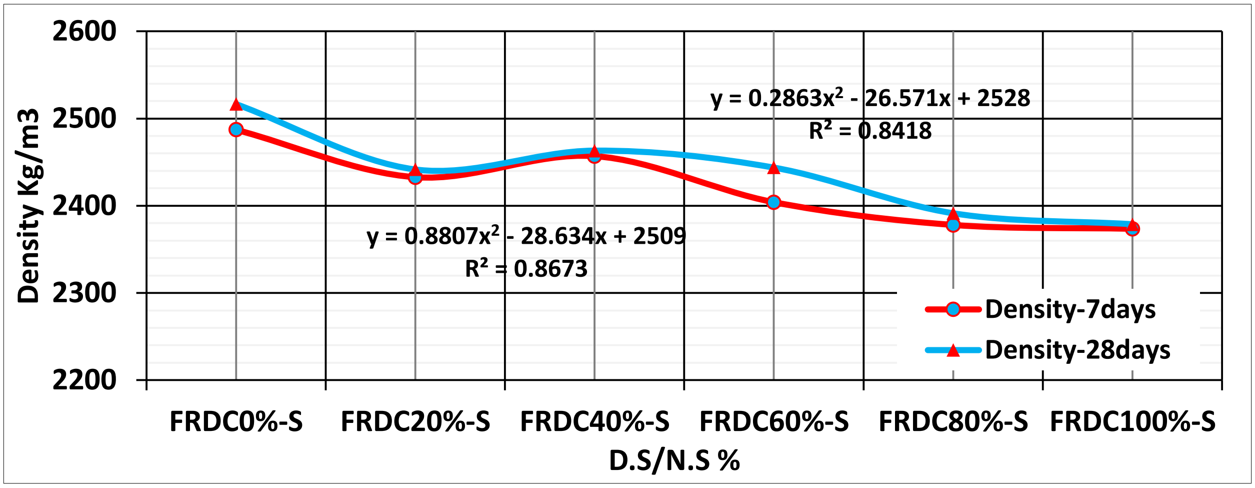


Figure 4.46 The dry density curves for specimens containing S.F.S.

The results of the mixtures reinforced with long steel fibers and replacement ratios (0%-100%), showed that the mixture without sand dunes (0%D.S+1%S.F.L) achieved the highest dry density compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of (1.65%, 3.72%, 4.47 %, 3.63%, and 8.5%) respectively, as shown in Figure 4.47.

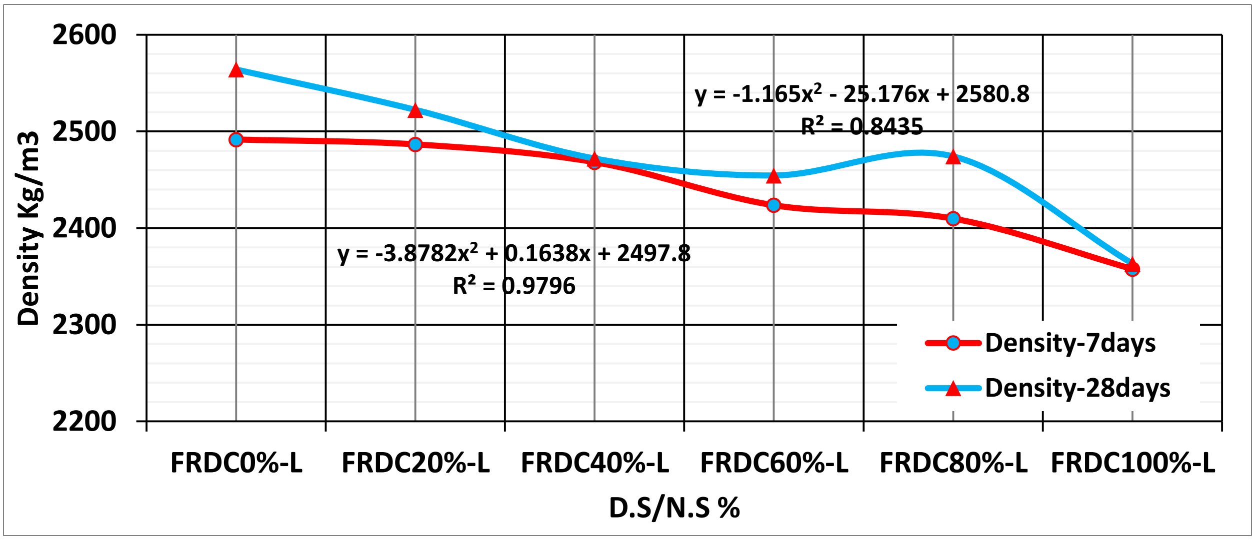


Figure 4.47 The dry density curves for specimens containing S.F.L.

The results of the mixtures reinforced with hybrid steel fibers , showed that the hybrid mixture (40% D.S + 1% H.S.F) achieved the highest dry density compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (0%, 20% , 60%, 80%, 100%) with an increase of about (1.85%, 0.82%, 3.94%, 6.21% and 8.31%) respectively, as shown in Figure 4.48.

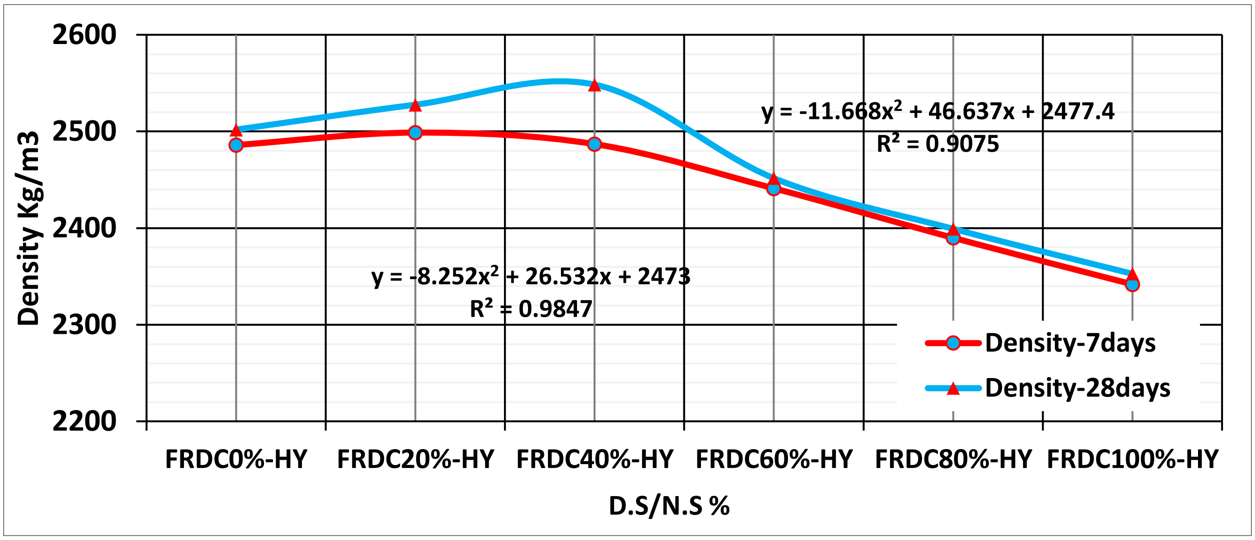


Figure 4.48 The dry density curves for specimens containing H.S.F.

The results at the age of 28 days for specimens containing sand dunes as an alternative to sand and reinforced with single and hybrid steel fibers indicate an increase in density, where the specimen (0%D.S + 1%S.F.L) achieved the highest density of 2564.13 kg/m^3 with an increase of about 7.62% higher than the reference specimen, also higher by about 1.88% and 2.48% compared to the specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) respectively. While the specimens containing short fibers and hybrid (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) achieved an increase in density higher than the reference specimen by about 5.63% and 5.01%, respectively, and as shown in Figure 4.49.

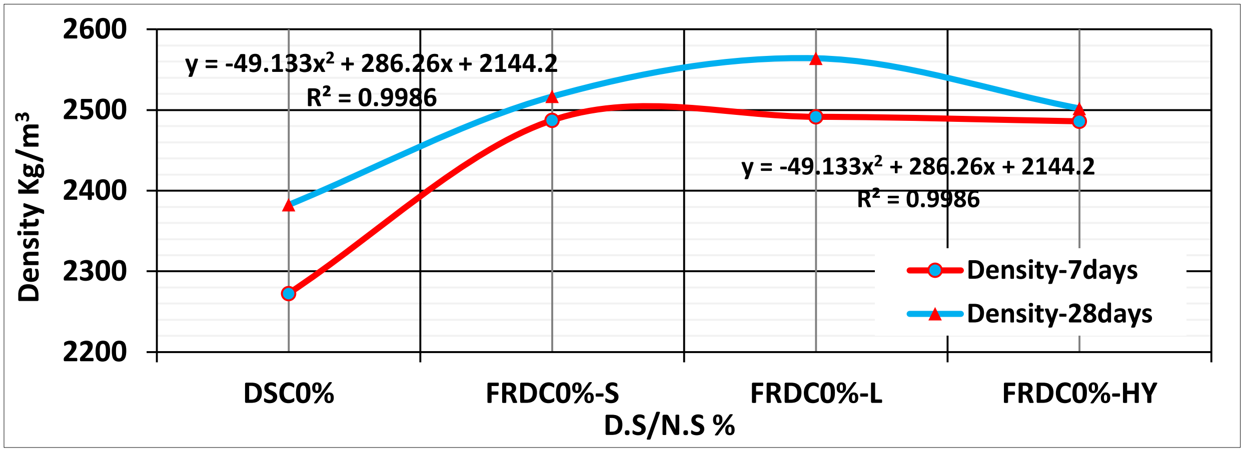


Figure 4.49 The curves of dry density for specimens containing (0%D.S) with S.F.

The density increases with the increase of the sand dunes content for the ratios 20%,40%, and 60%,where the specimens (20%D.S+1%S.F.S), (20%D.S+1%S.F.L), and (20%D.S+1%H.S.F) achieved increased in density by about 2.95%,6.35% and 6.58% higher than the specimen (20%D.S without fibers) , also, the hybrid specimen (20%D.S+1%H.S.F) achieved the highest density compared to the specimens (20%D.S+1%S.F.S)and (20%D.S+1%S.F.L) by about 3.52% and 0.21%, respectively and as shown in Figure 4.50.

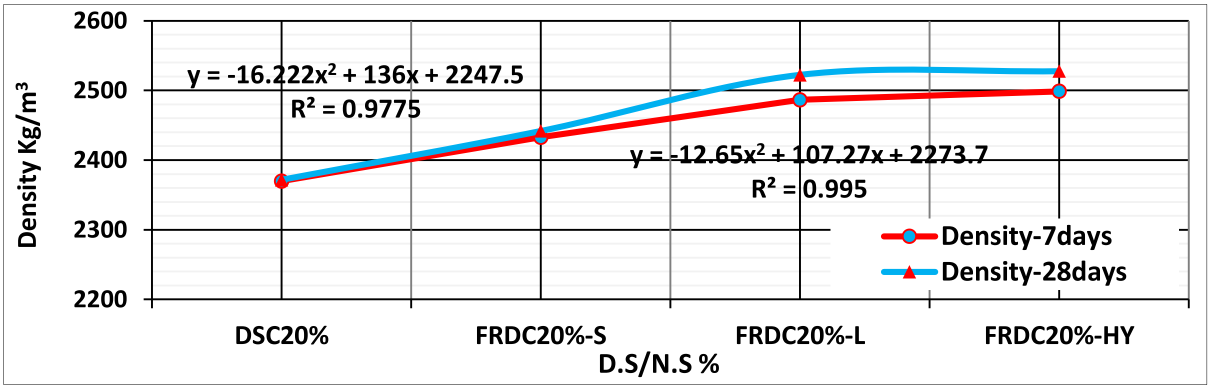


Figure 4.50 The curves of dry density for specimens containing (20%D.S) with S.F.

At the 40% replacement ratio, the hybrid specimen (40% D.S + 1%H.S.F) achieved an increase in density of 2548.44 kg/m^3 with an increase of about 4.98% higher than the sample (40%D.S without fibers), as well as higher than the specimens (40%D.S + 1%S.F.S) and (40% D.S + 1%S.F.L) with an increase of about 3.45% and 3.1%, respectively, where the role of hybrid fibers at this ratio is better than short and long steel fibers, as shown in Figure 4.51.

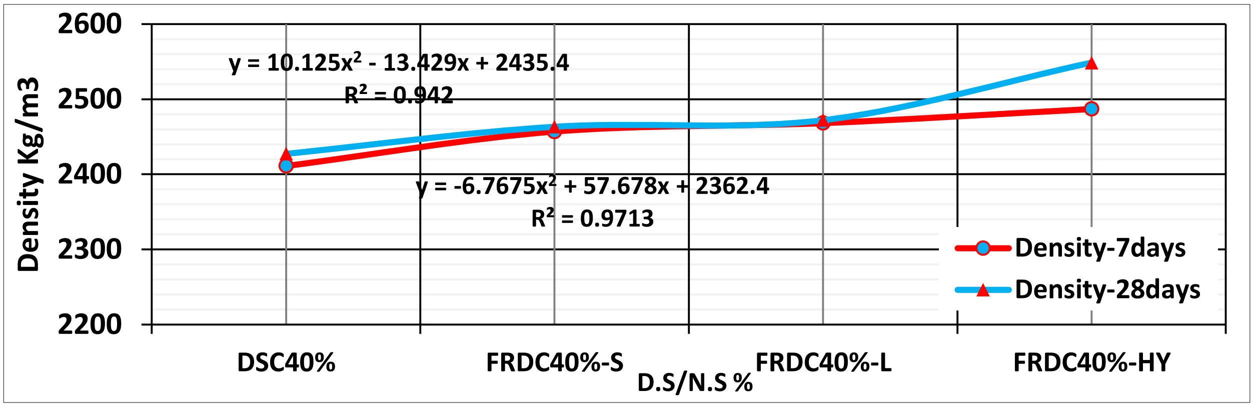


Figure 4.51 The curves of dry density for specimens containing (40%D.S) with S.F.

When the sand dunes content is increased as an alternative to sand to ratio 60%, the density increases, where the specimens (60%D.S+1%SFS), (60%D.S+1%SFL) and (60%D.S+1%HSF) achieved a density of 2443.85 kg/m^3, 2454.4 kg/m^3 and 2451.70 kg/m^3, an increase of about 1.8%, 2.24% and 2.12% higher than the specimen (60%D.S without fibers). The specimen (60%D.S+1%S.F.L) also achieved an increase in density by about 0.43% and 0.11% compared to the specimens (60%D.S+1%S.F.S) and (60%D.S+1%H.S.F), respectively , and as shown in Figure 4.52.

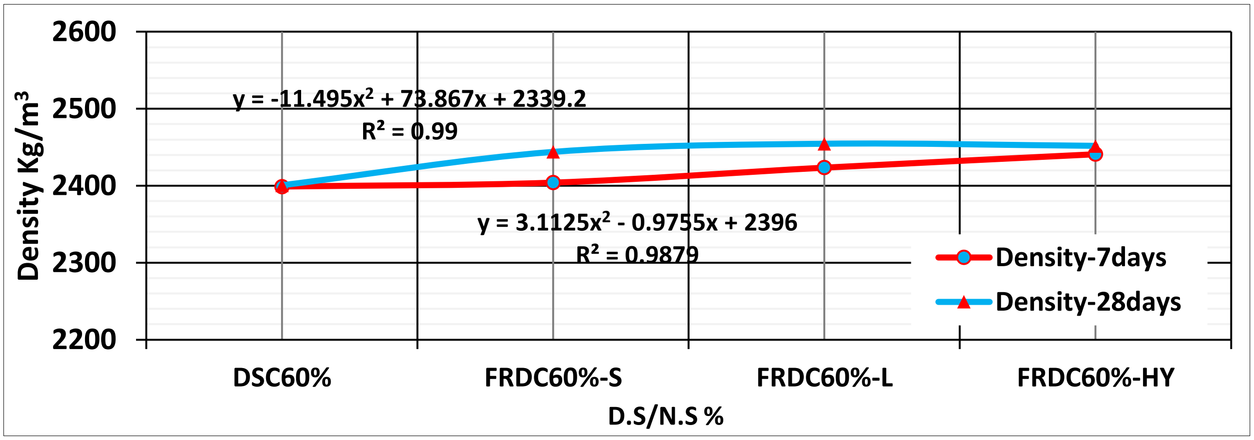


Figure 4.52 The curves of dry density for specimens containing (60%D.S) with S.F.

The density decreases with the increasing of the sand dunes content as an alternative to the sand of the ratio 80%, where the specimens (80%D.S+1%S.F.S), (80%D.S+1%S.F.L) and (80%D.S+1%H.S.F) achieved density of 2391.40 kg/m3,2474.17 kg/m^3 and 2399.4 kg/m^3, an increase of about 1.53%,5.05% and1.87% higher than the specimen (80%D.S without fibers). The specimen (80% D.S + 1% S.F.L) also achieved an increase in density about 3.46% and 3.11% compared to the specimens (80% D.S + 1% S.F.S) and (80% D.S + 1% H.S.F) respectively, where that the role of the long single steel fibers at this ratio is better than the short and hybrid fibers, as shown in Figure 4.53.

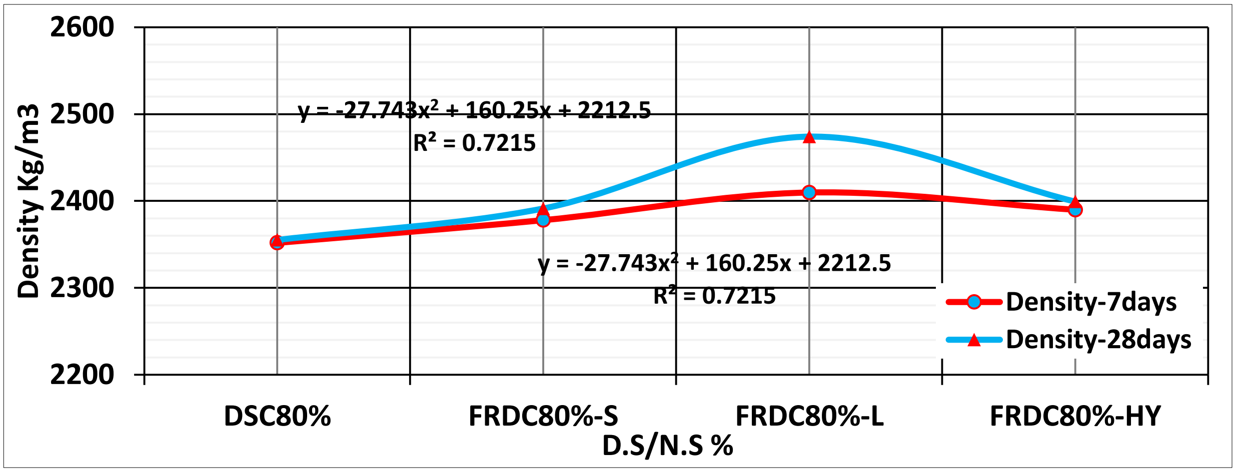


Figure 4.53 The curves of dry density for specimens containing (80%D.S) with S.F.

Density decreases when sand dunes is used as an alternative to sand for ratio100% compared to other ratios, where the specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L) and (100%D.S+ 1%H.S.F) achieved a density of 2378.81 kg/m^3,2363.25 kg/m^3 and 2352.91 kg/m^3, an increase of 1.27%,0.61%,0.17% higher than the sample (100%D.S without fibers). While the specimen (100% D.S + 1% S.F.S) achieved a higher density than the specimens (100% D.S + 1% S.F.L) and (100% D.S + 1% H.S.F) by about 0.65% and 1.1%, respectively. Where the performance of short fibers is better than long and hybrid steel fibers at the replacement rate of 100% due to the good properties of the short fibers and their compatibility with the complete fineness of fine aggregates, as shown in Figure 4.54.

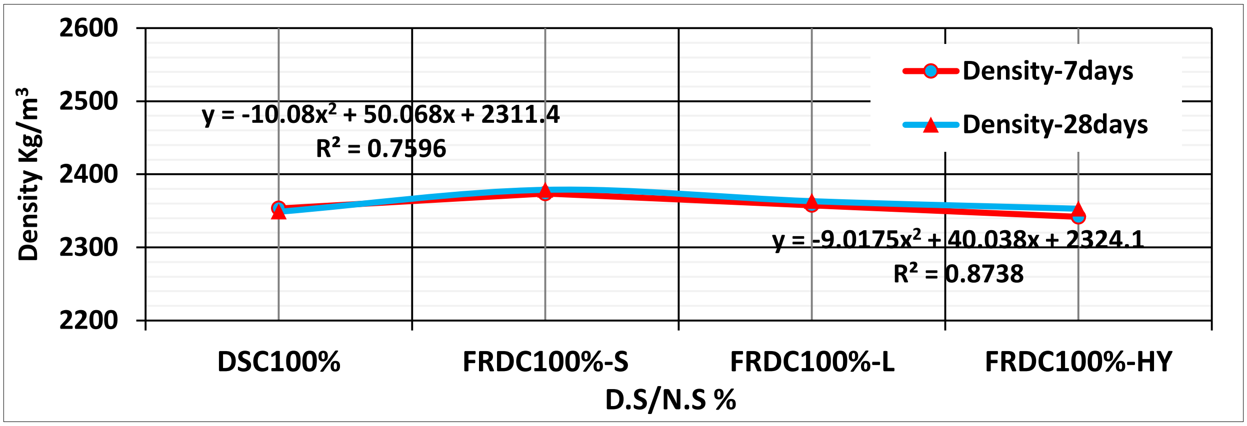


Figure 4.54 The curves of dry density for specimens containing (100%D.S) with S.F.

4.2.1.3.2 Ultrasonic pulse velocity (UPV) results

Ultrasonic pulse velocity test results for concrete specimens (cubes) containing sand dunes as an alternative to sand for ratios (0%,20%,40%,60%,80%,100%) and reinforced with short, long and hybrid steel fibers, as well as for specimens without fibers aged 28 days are listed in Table 4.6 . Noted the results of pulse velocity for all concrete specimens between the limits (4400-6200 m/s), and this indicates that the quality of concrete is very good and homogeneous according to the limits of is code, BS 1881,1983, PART116 [47]. Figure 4.55 shows the ultrasonic pulse velocity test for the concrete specimens (cubes 150×150×150) mm.

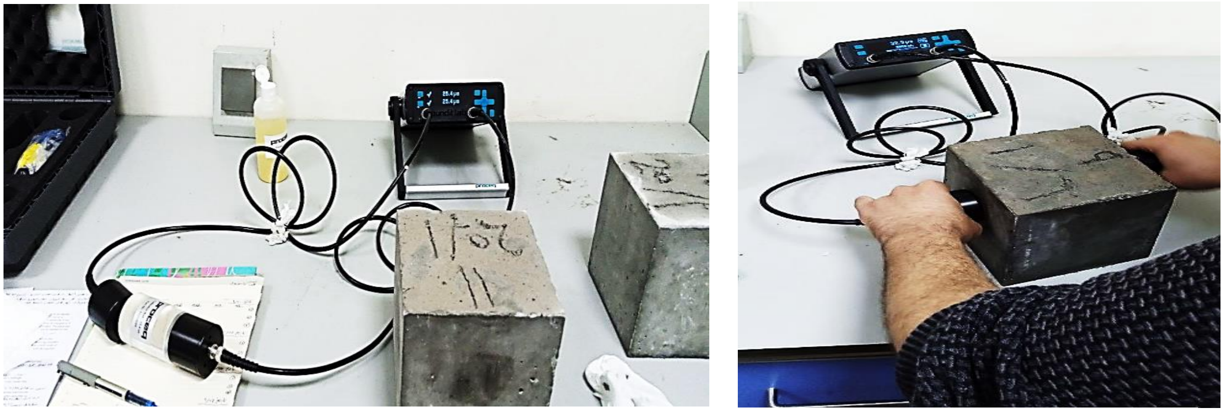


Figure 4.55 The ultrasonic pulse velocity test for the concrete specimens (cubes).

Table 4.6 Results test of ultrasonic pulse velocity for the concrete specimens

Dune sand/Sand Percentage %	Average UPV (m/s) 28 days	Concrete quality according to BS 1881,IS code	Limits of BS 1881-1983[47], IS Code[48], pulse velocity (km/s)	%change in UPV at 28 days
0% D.S	4894	Very good	Above 4.0	---
20% D.S	4991	Very good	Above 4.0	+1.98
40% D.S	4855	Very good	Above 4.0	-0.79
60% D.S	4715	Very good	Above 4.0	-3.65
80% D.S	4559	Very good	Above 4.0	-6.84
100% D.S	4482	Very good	Above 4.0	-8.41
0%D.S+1%S.F.S	5017	Very good	Above 4.0	+2.51
0%D.S+1%S.F.L	6191	Very good	Above 4.0	+26.50
0%D.S+1%H.S.F	6212	Very good	Above 4.0	+26.93
20%D.S+1%S.F.S	5423	Very good	Above 4.0	+8.65
20%D.S+1%S.F.L	6068	Very good	Above 4.0	+21.57
20%D.S+1%H.S.F	5969	Very good	Above 4.0	+19.59
40%D.S+1%S.F.S	4907	Very good	Above 4.0	+1.07
40%D.S+1%S.F.L	4894	Very good	Above 4.0	+0.80
40%D.S+1%H.S.F	4934	Very good	Above 4.0	+1.63
60%D.S+1%S.F.S	4834	Very good	Above 4.0	+2.52
60%D.S+1%S.F.L	4921	Very good	Above 4.0	+4.36
60%D.S+1%H.S.F	4728	Very good	Above 4.0	+0.27
80%D.S+1%S.F.S	4596	Very good	Above 4.0	+0.81
80%D.S+1%S.F.L	4703	Very good	Above 4.0	+3.15
80%D.S+1%H.S.F	4753	Very good	Above 4.0	+4.25
100%D.S+1%S.F.S	4703	Very good	Above 4.0	+4.93
100%D.S+1%S.F.L	4514	Very good	Above 4.0	+0.71
100%D.S+1%H.S.F	4630	Very good	Above 4.0	+3.30

The test results show that the reference specimen (0%D.S without fibers) has achieved a pulse velocity of 4894m/s. When sand dunes is replaced as an alternative to sand for the ratio 20%D.S, the pulse velocity increases by 1.98% higher than the reference specimen. The pulse velocity decreases with the increase the sand dunes content of the ratio(40%,60%,80%,100%), where the specimens achieved a pulse velocity of 4855m/s, 4715m/s,4559m/s and 4482m/s, with a decrease of about 0.79%,3.65%, 6.84%, and 8.41%, respectively, compared to the reference specimen. Whereas, the lowest pulse velocity is for the specimen (100% D.S without fibers),the reason for the decrease in the pulse velocity may be due to the fineness of the sand dunes and the increase in the specific surface area of the fine aggregate, which absorbs a larger amount of the mixing water, causing the appearance of gaps or pores inside the concrete, which appears by reading the pulse velocity of the concrete specimens and as shown in Figure 4.56.

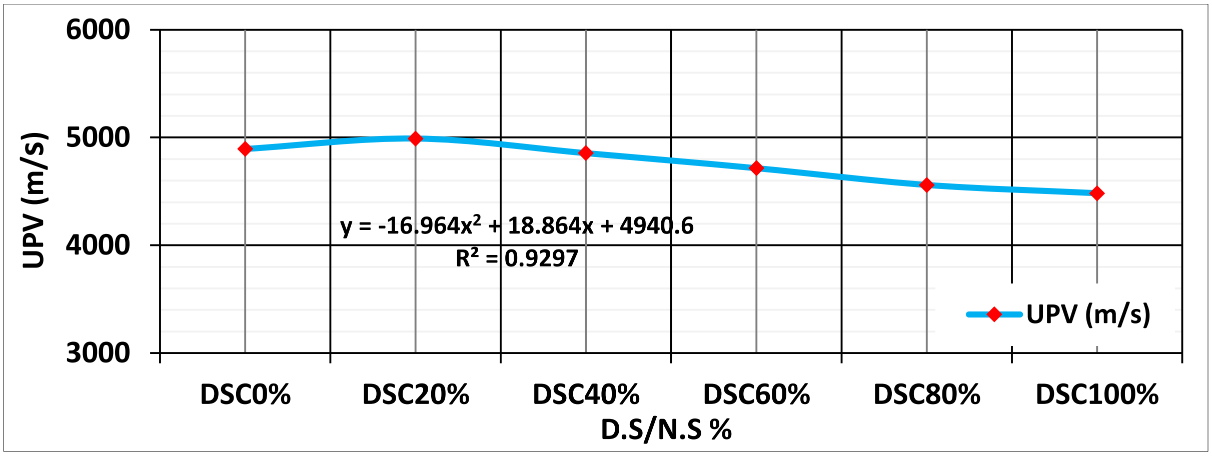


Figure 4.56 The ultrasonic pulse velocity curve for specimens containing sand dunes without fibers.

The results of the mixtures reinforced with short steel fibers and replacement ratios (0% - 100%), showed that the mixture (20% D.S + 1% S.F.S) achieved the highest pulse velocity compared to all mixtures reinforced with short steel fibers and replacement ratios (0%, 40%, 60%,80%,100%), with an increase of about (8.09%, 10.5%, 12.18%, 17.9%, and 15.3%), respectively, as shown in Figure 4.57.

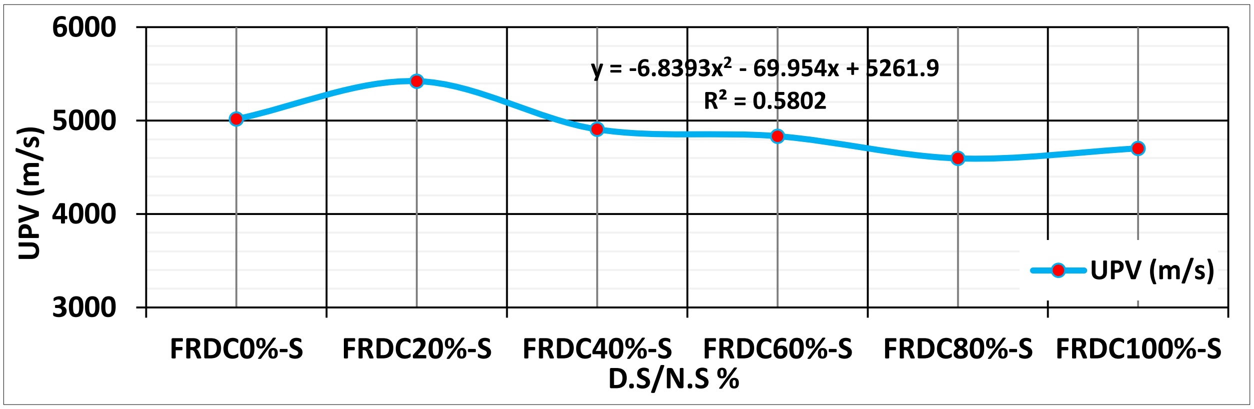


Figure 4.57 The ultrasonic pulse velocity curve for specimens containing S.F.S.

The results of the mixtures reinforced with long steel fibers showed that the mixture without sand dunes (0%D.S+1%S.F.L) achieved the highest pulse velocity compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%,80% ,100%), an increase of about (2.03%, 26.5%, 25.8%, 31.6%, and 37.1%), respectively, as shown in Figure 4.58.

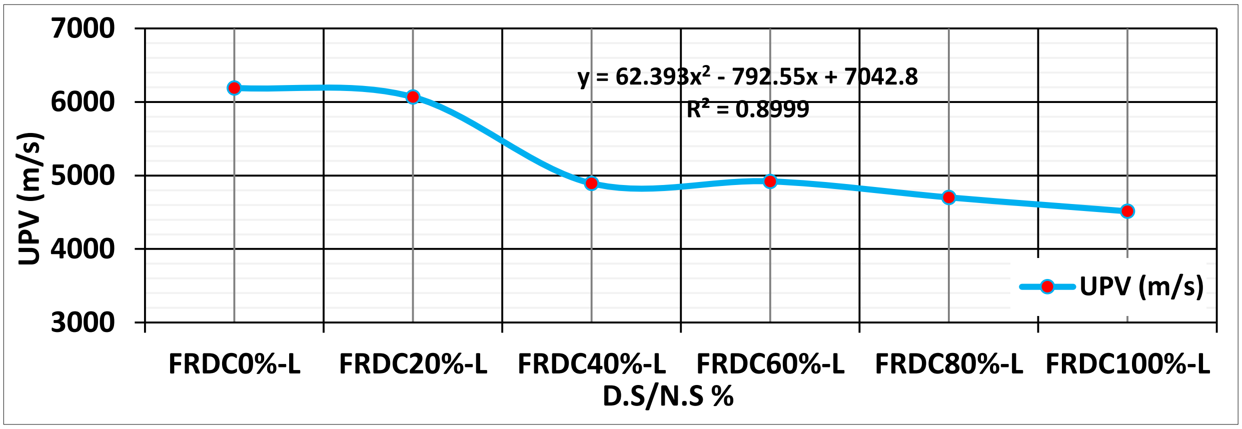


Figure 4.58 The ultrasonic pulse velocity curve for specimens containing S.F.L.

The results of the mixtures reinforced with hybrid steel fibers showed that the hybrid mixture (0%D.S + 1%H.S.F) achieved the highest pulse velocity compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%,40%, 60%, 80%, 100%) with an increase of about (4.1%, 25.9%, 31.3%, 30.6%, and 34.1%) respectively, as shown in Figure 4.59.

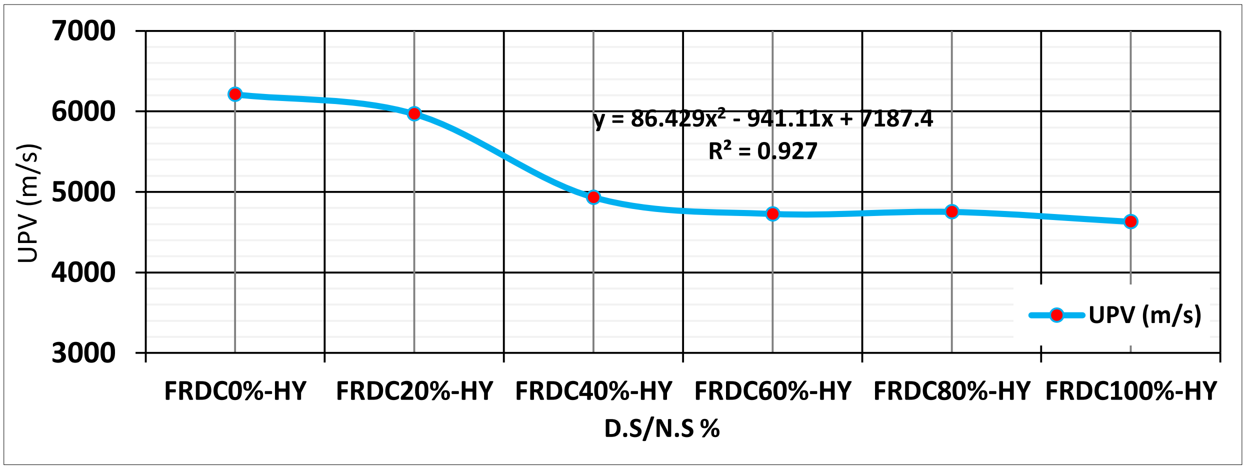


Figure 4.59 The ultrasonic pulse velocity curve for specimens containing H.S.F.

The results of the concrete specimens reinforced with steel fibers show that the hybrid specimen (0%D.S + 1%H.S.F) achieved the highest value of the pulse velocity of 6212m/s higher than the reference specimen by about 26.93%, as well as higher than the specimens (0%D.S +1%S.F.S) and (0%D.S+1%S.F.L) by about 23.8% and 0.34%, respectively. Also, specimens (0%D.S+1%S.F.S) and (0%D.S+1%S.F.L) achieved an increase in pulse velocity by about 2.51% and 26.5% compared to the reference specimen as shown in Figure 4.60 and the quality of concrete for these specimens is considered very good according to BS1881, 1983[47].

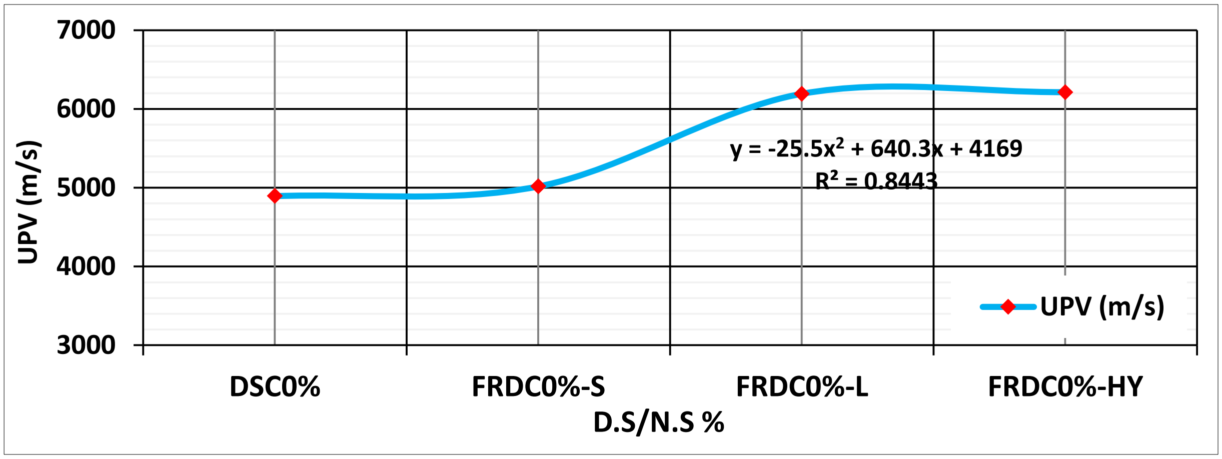


Figure 4.60 The curve of ultrasonic pulse velocity for specimens containing sand dunes (0%) with S.F.

When sand dunes is used as an alternative for the sand of ratio 20%, the specimens (20%D.S+1%S.F.S), (20%D.S+1%S.F.L), and (20%D.S+1%H.S.F) achieved a pulse velocity of 5423m/s ,6068m/s and 5969m/s increased by about 8.56%, 21.57% and 19.59% higher than the specimen(20%D.S without fibers). Also, the pulse velocity of the specimen (20%D.S + 1%S.F.L) is higher than the specimens (20%D.S +1%S.F.S) and (20%D.S +1%H.S.F) by about 11.8% and 1.65%, respectively. The quality of concrete for these specimens is very good according to BS 1881 [47] and as shown in Figure 4.61.

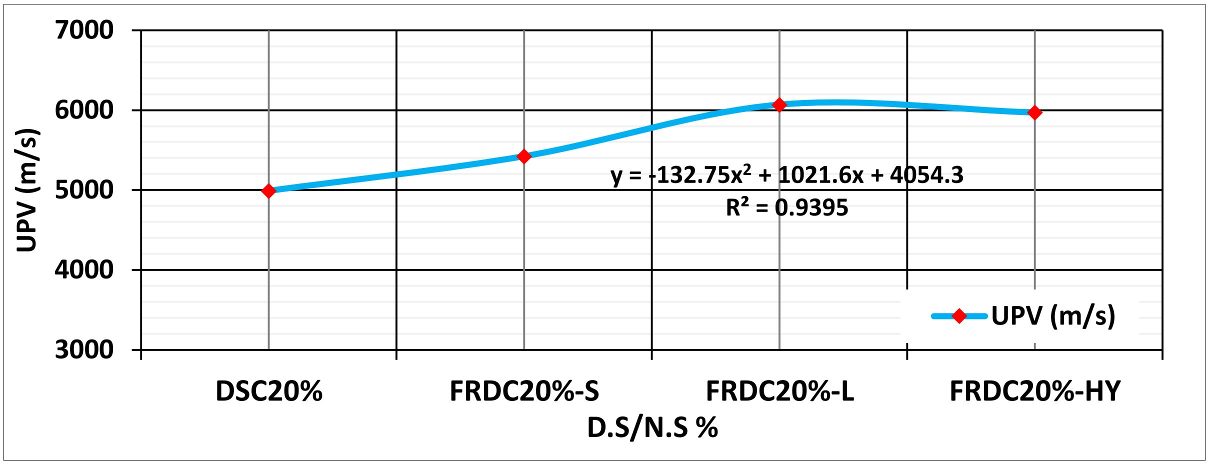


Figure 4.61 The curve of ultrasonic pulse velocity for specimens containing sand dunes (20%) with S.F.

The pulse velocity decreases with the increasing in the content of sand dunes as an alternative to sand with the ratios (40%,60%,80%,100%), but it is higher than the specimens without fibers, where the specimens achieved (40%D.S+1%S.F.S),(40%D.S+1%S.F.L) and (40%D.S+1%H.S.F) an increased in the pulse velocity by about 1.07%, 0.80% and1.63% higher than the specimen(40%D.S without fibers). Also, the hybrid specimen (40% D.S + 1% H.S.F) achieved pulse velocity higher than the specimens (40% D.S + 1% S.F.S) and (40% D.S + 1% S.F.L) by about 0.55% and 0.82 % respectively, and the quality of concrete for the specimens for these specimens is very good according to BS1881 [47] and as shown in Figure 4.62.

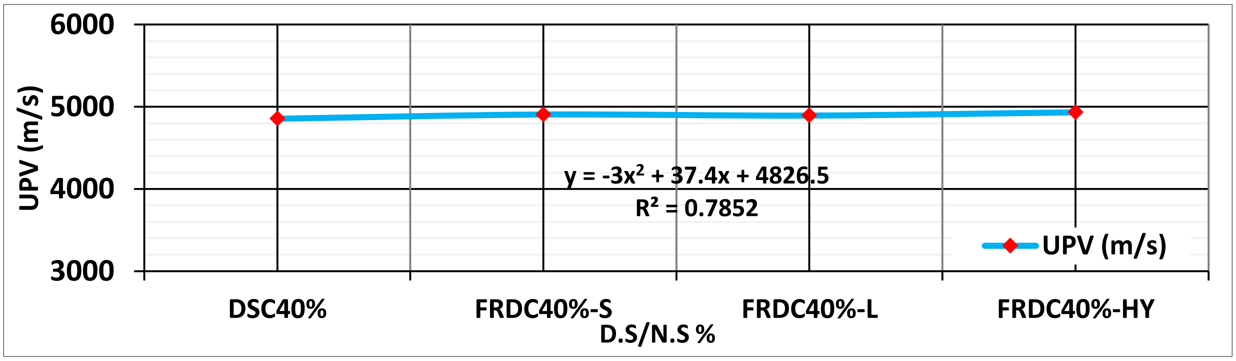


Figure 4.62 The curve of ultrasonic pulse velocity for specimens containing sand dunes (40%) with S.F.

Also, the specimens (60%D.S+1%S.F.S), (60%D.S+1%S.F.L) and (60%D.S+1%H.S.F) recorded a pulse velocity of 4834m/s ,4921m/s and 4728m/s with an increase of about 2.52%,4.36% and 0.27% higher than the specimen a higher (60%D.S without fibers). The hybrid specimen (60% D.S + 1% S.F.L) also achieved pulse velocity than the specimens (60% D.S + 1% S.F.S) and (60% D.S + 1% H.S.F) by about 1.8% and 4% respectively, and the quality of concrete for these specimens is very good according to BS 1881 [47] as shown in Figure 4.63.

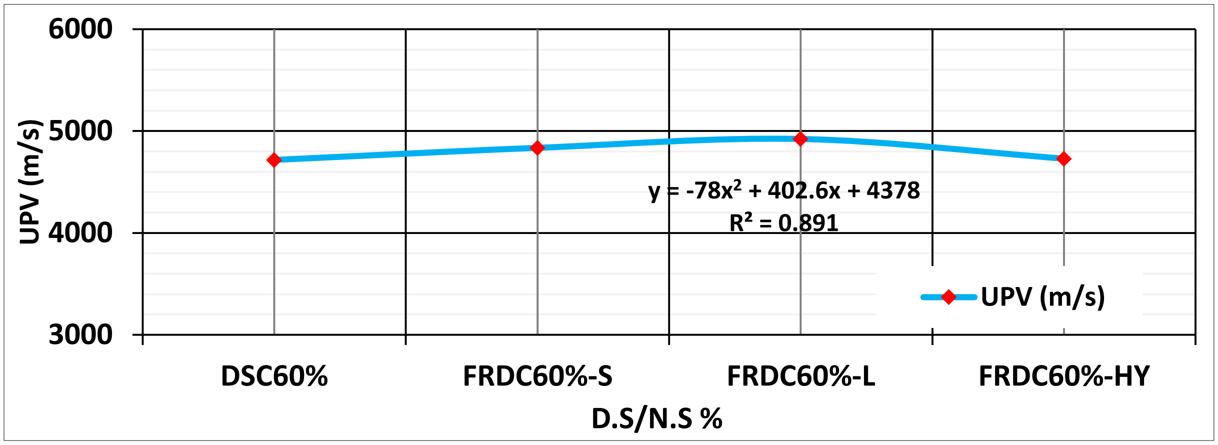


Figure 4.63 The curve of ultrasonic pulse velocity for specimens containing sand dunes (60%) with S.F.

When sand dunes is used as an alternative to the sand of ratio 80% and reinforced with short, long, and hybrid steel fibers, (80%D.S+1%S.F.S), (80%D.S+1%S.F.L) and (80%D.S+1%H.S.F) the pulse velocity of the specimens was 4596m/s,4703m/s and4753m/s, an increase of about 0.81%,3.15% and 4.25% higher than the specimen (80%D.S without fibers), also, the hybrid specimen (80%D.S+1%H.S.F) achieved pulse velocity higher than the specimens (80%D.S+1%S.F.S) and (80%D.S+1%S.F.L) by about 3.4% and 1.1% respectively, and the concrete quality of the specimens is considered very good according to BS1881[47]and as shown in Figure 4.64 .

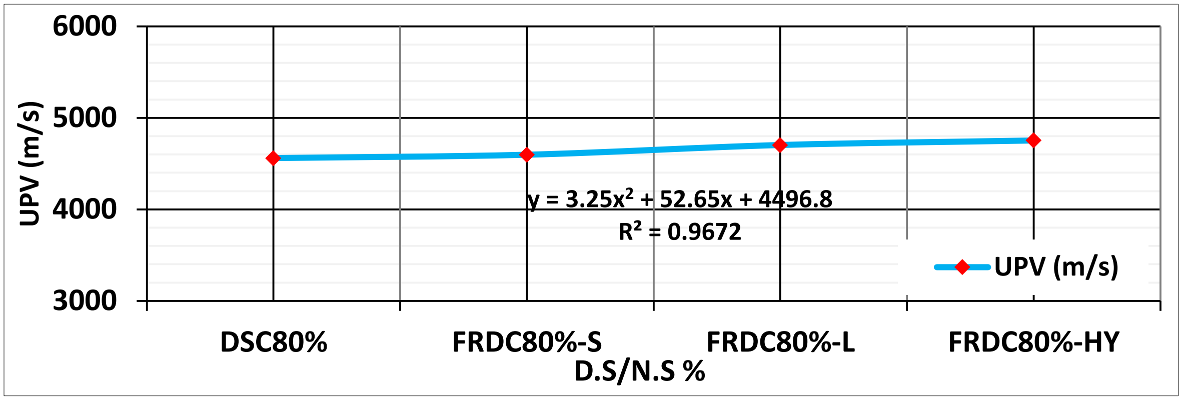


Figure 4.64 The curve of ultrasonic pulse velocity for specimens containing sand dunes (80%) with S.F.

hen sand dunes is used as an alternative for the sand of ratio 100%, the specimens(100%D.S+1%S.F.S), (100%D.S+1%S.F.L)and (100%D.S+1%H.S.F) achieved a pulse velocity of 4703m/s, 4514m/s, and 4630m/s, an increase of about 4.93%,0.71% and 3.3% compared to the specimen (100%D.S without fibers) . The specimen (100% D.S + 1% S.F.S) also achieved an increase in pulse velocity by about 4.2% and 1.6% higher than the specimens (100% D.S + 1% S.F.L) and (100% D.S + 1% H.S.F) respectively, and the concrete quality of the specimens is considered very good according to [47] as shown in Figure 4.65.

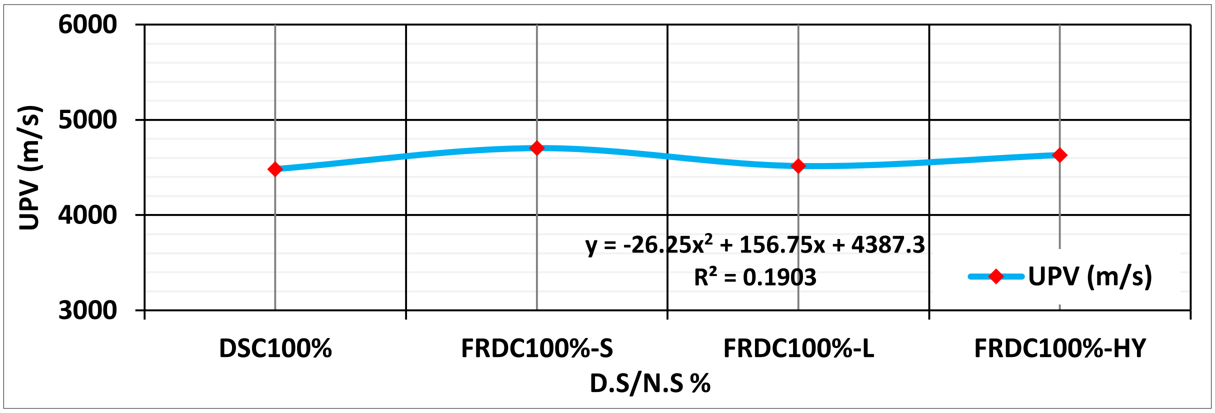


Figure 4.65 The curve of ultrasonic pulse velocity for specimens containing sand dunes (100%) with S.F.

Generally, the pulse velocity decreases especially hybrid fibers when the sand dunes content increases in the specimens. But the addition of steel fibers, helped to increase the pulse velocity due to the role of the fibers in the cohesion and homogeneity of the concrete components. Despite the decrease in the pulse velocity in some specimens when the dunes sand content increases. However, the pulse velocity did not decrease below 4000 m/s, which is a very good and acceptable results according to code, BS1881, 1983[47]. This is evidence that the effect of sand dunes on concrete specimens was little and did not reduce the quality of concrete to a large extent due to the addition of steel fibers that increase the concrete cohesion.

4.2.1.3.3 The results of absorption

The results test of concrete absorption of water for concrete specimens containing sand dunes as an alternative to sand for ratios (0%,20%,40%,60%,80%,100%) and reinforced with short, long, and hybrid steel fibers, as well as for specimens without fibers, are listed in Table 4.7. The results show achieving the lowest concrete absorption for specimens without fibers, as well as for specimens reinforced with single and hybrid steel fibers, namely that the absorption decreases with the addition of steel fibers, especially with specimens that contain sand dunes for the ratios (0%-60%). Noted that the reference specimen (0%D.S) achieved water absorption of 2.17, and when sand dunes is used as an alternative to sand, an increase in the absorption concrete of water, where the specimen (20%D.S without fibers) achieved a water absorption of 2.21, an increase of about 1.84% compared to the reference specimen, where the quality of concrete is good (low water absorption) according to (assessment criteria for water absorption CEB: 1989) [51]. Figure 4.66 shows the absorption concrete specimens test (cubes). When the sand dunes content as increased, we note that the specimen (40% D.S without fibers) achieved the lowest water absorption of 1.44 (i.e. 33.64% less than the reference specimen) and the quality of concrete is considered good according to CEB: 1989 [51].

Figure 4.66 The water absorption test of the concrete specimens.

Table 4.7 Results test of the water absorption for the concrete specimens

D.S/Sand	Dry weight w_1 (kg)	Weight of specimen after submerged in water w_2 (kg)	Water Absorption %	Concrete quality as per(CEB 1989; 192) [51]	%change in water absorption at 28 days
0% D.S	7.879	8.050	2.17	Good	----
20% D.S	7.812	7.985	2.21	Good	1.84+
40% D.S	7.975	8.090	1.44	Good	-33.64
60% D.S	7.882	8.088	2.61	Good	20.27+
80% D.S	7.802	8.043	3.08	Average	41.93+
100% D.S	8.047	8.308	3.24	Average	49.30+
0%D.S+1%S.F.S	8.201	8.264	0.76	Good	-64.97
0%D.S+1%S.F.L	8.235	8.361	1.53	Good	-29.49
0%D.S+1%H.S.F	8.239	8.306	0.81	Good	-62.67
20%D.S+1%S.F.S	7.970	8.180	2.63	Good	19.00+
20%D.S+1%S.F.L	8.045	8.252	2.57	Good	16.28+
20%D.S+1%H.S.F	8.272	8.434	1.95	Good	-11.76
40%D.S+1%S.F.S	8.190	8.297	1.30	Good	-9.72
40%D.S+1%S.F.L	8.197	8.292	1.15	Good	-20.13
40%D.S+1%H.S.F	8.210	8.321	1.35	Good	-6.25
60%D.S+1%S.F.S	7.877	8.110	2.95	Good	13.02+
60%D.S+1%S.F.L	7.904	8.132	2.88	Good	10.34+
60%D.S+1%H.S.F	7.962	8.193	2.90	Good	11.11+
80%D.S+1%S.F.S	7.837	8.110	3.48	Average	12.98+
80%D.S+1%S.F.L	7.620	7.874	3.33	Average	8.11+
80%D.S+1%H.S.F	7.924	8.193	3.39	Average	10.06+
100%D.S+1%S.F.S	7.580	7.881	3.97	Average	22.53+
100%D.S+1%S.F.L	7.621	7.915	3.85	Average	18.83+
100%D.S+1%H.S.F	7.638	7.936	3.90	Average	20.37+

Concrete's water absorption increases with the increasing of the sand dunes content as an alternative to the sand of the ratios(60%,80%,100%), where the specimen (60% D.S without fibers) achieved a water absorption of 2.61, with the increase of about 20.27% compared to the reference specimen and it is considered good concrete according to CEB [51].While the specimens (80%D.S) and (100%D.S) without fibers achieved an increase in water absorption of 3.03 and 3.24, i.e. 41.9% and 49.3% higher than the reference specimen, and the quality of concrete for these specimens is considered average according to CEB:1989 [51], this increase in the rate of absorption when the content of sand dunes in the specimen increases, maybe due to the fineness of the sand dunes grains, which absorb a larger amount of mixing water, and the increase in the surface area of the fine aggregate, which generates voids or pores, which in turn increases the rate of absorption , and as in Figure 4.67 the relationship between water absorption rate and concrete specimens containing sand dunes as an alternative to sand without steel fibers.

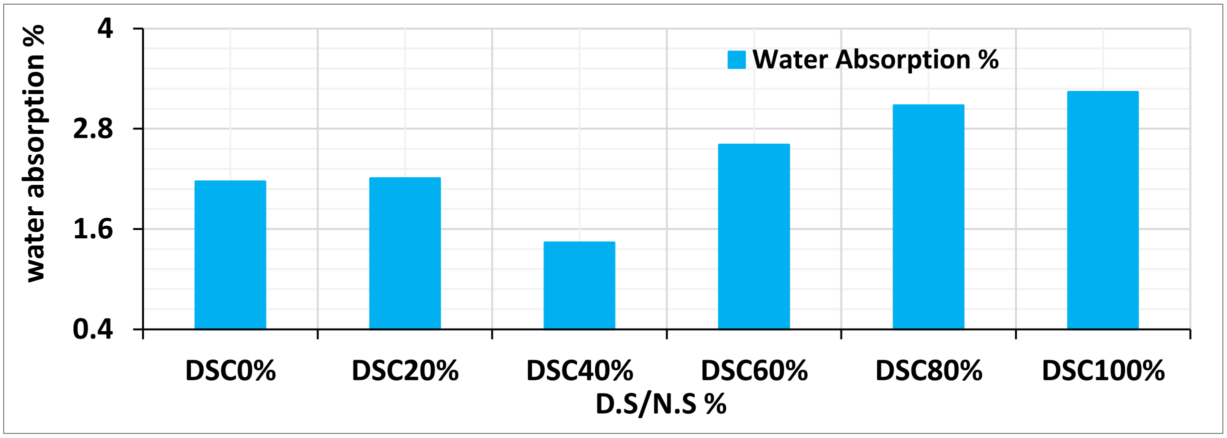


Figure 4.67 Relationship between water absorption and replacement ratios of sand dunes for concrete specimens without steel fibers.

The results of the mixtures reinforced with short steel fibers and replacement ratios (0%-100%), showed that the mixture without sand dunes (0%D.S + 1%S.F.S) achieved the lowest absorption compared to all the mixtures reinforced with short fibers and replacement ratios (20%, 40%, 60%, 80%, 100%), with a decrease of

(71.1%, 41.5%, 74.12%, 78.1%, and 80.8%), respectively. The quality of concrete for this specimen is considered good according to CEB: 1989; 192, as shown in Figure 4.68.

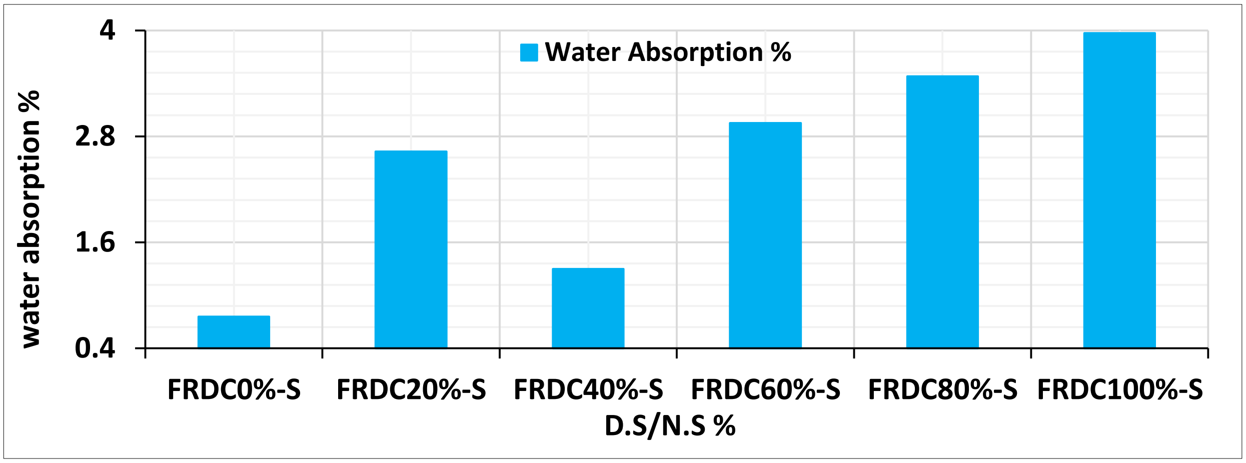


Figure 4.68 Relationship between water absorption and replacement ratios of sand dunes for concrete specimens with S.F.S.

The results of the mixtures reinforced with long steel fibers showed that the mixture (40% D.S + 1%S.F.L) achieved the lowest water absorption compared to all mixtures reinforced with long steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with a decrease of (24.8%, 55.2%, 60.1%, 65.4%, and 70.1%) respectively. The quality of concrete for this specimen is considered good according to CEB: 1989; 192, as shown in Figure 4.69.

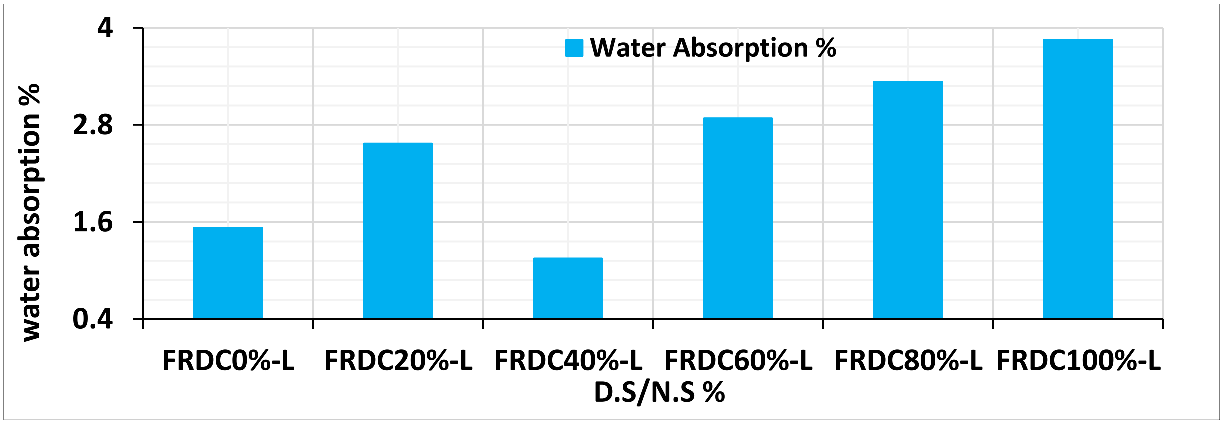


Figure 4.69 Relationship between water absorption and replacement ratios of sand dunes for concrete specimens with S.F.L.

The results of the mixtures reinforced with hybrid steel fibers showed that the hybrid mixture (0% D.S + 1% H.S.F) achieved the lowest absorption compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with a decrease of (58.4%, 40%, 72%, 76.1%, and 79.2%) respectively. The quality of concrete for this specimen is good according to CEB: 1989; 192, as shown in Figure 4.70.

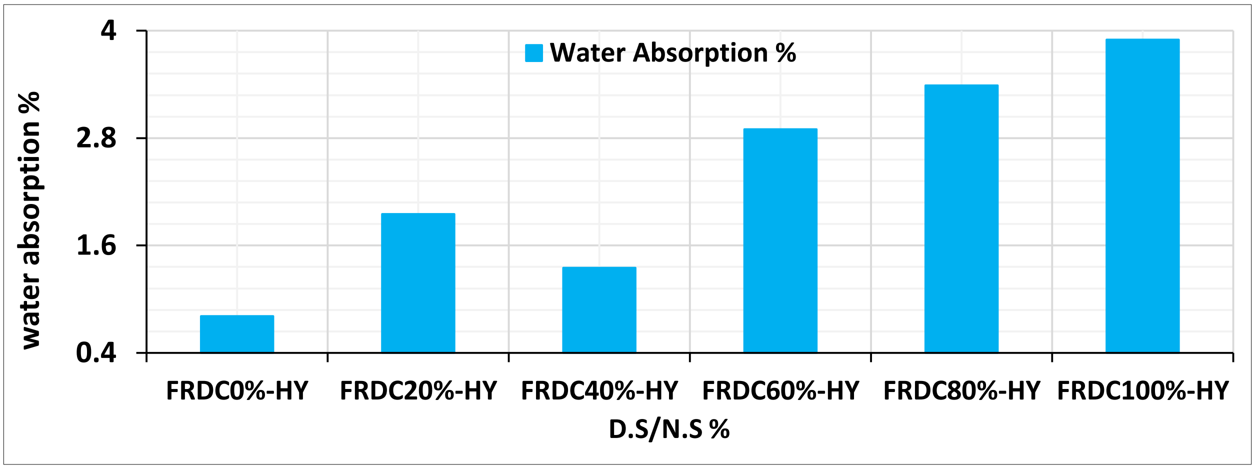


Figure 4.70 Relationship between water absorption and replacement ratios of sand dunes for concrete specimens with H.S.F.

The results of absorption for concrete specimens reinforced with single and hybrid steel fibers are shown as in Table 4.7, where notice a decrease in the absorption of concrete (0%D.S + 1%S.F.L) of 1.53 (i.e. 29.5% less than the reference specimen), as well as the hybrid specimen (0%D.S + 1%H.S.F), which achieved absorption of 0.81 with a decrease of about 62.7% less than the reference specimen, it is also less than the rest of the hybrid specimens that contain sand dunes as an alternative to the sand of ratios (20% - 100%).

The specimen (0%D.S + 1%S.F.S) achieved the lowest water absorption of 0.76, which is the lowest absorption compared to all specimens (i.e. 65% less than the reference specimen), as well as less than the specimens (0%D.S + 1%S.F.L) and (0% D.S + 1%H.S.F) by about 50.3% and 6.2% respectively, and the quality of concrete for these specimens is considered good according to CEB: 1989 and as shown in Figure 4.71.

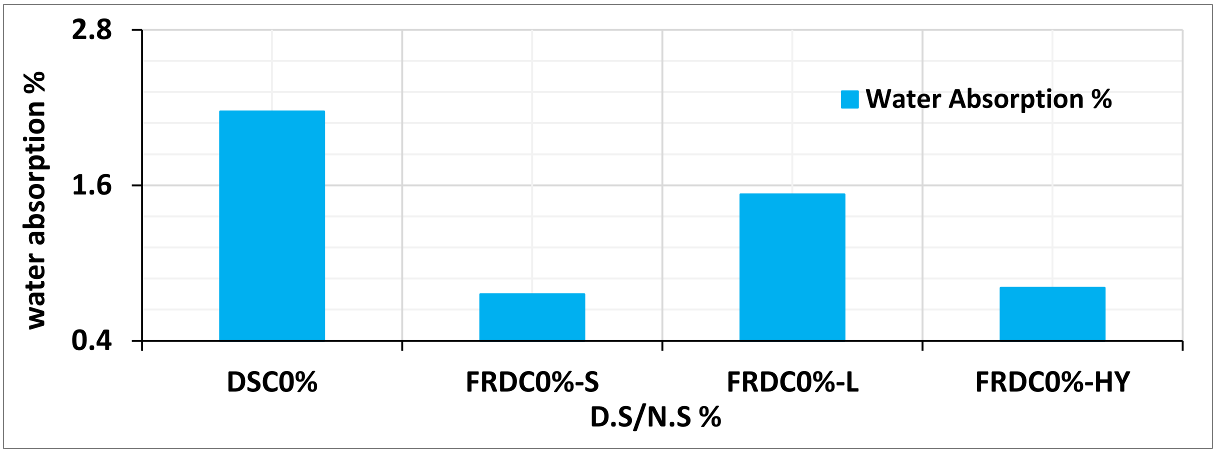


Figure 4.71 Relationship between water absorption and replacement ratios of sand dunes (0%) for concrete specimens.

When using sand dunes as an alternative to sand for a ratio of 20%, the absorption rate of the specimens increased (20%D.S + 1%S.F.S) and (20%D.S + 1%S.F.L), where achieved an absorption of 2.63 and 2.57, i.e. 19% and 16.3% less than the specimen (20%D.S without fibers). While the absorption rate with the specimen (20%D.S + 1%H.S.F) decreased by about 11.76% less than the reference specimen. It is also lower than the specimens (20%D.S + 1%S.F.S) and (20%D.S +1%S.F.L) by 25.8% and 24.1%, respectively, and the quality of concrete for these specimens is good (low water absorption) according to CEB, as in Figure 4.72.

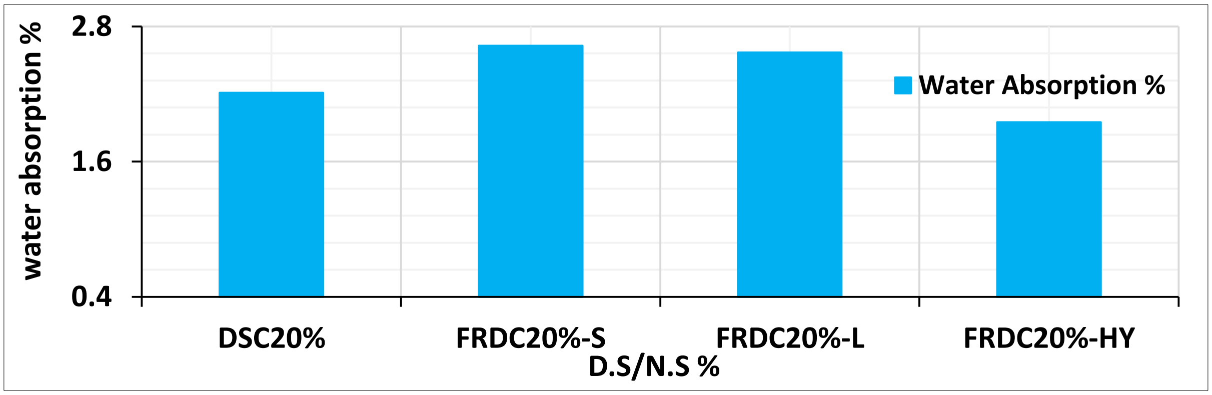


Figure 4.72 Relationship between water absorption and replacement ratios of sand dunes (20%) for concrete specimens with steel fibers.

The water absorption rate decreased when using sand dunes as an alternative to sand of ratio 40%, where the specimens achieved (40%D.S+1%S.F.S), (40%D.S+1%S.F.L) and (40%D.S+1% H.S.F) absorption of 1.3,1.15,and 1.35, with a decrease of about 9.7%, 20.1%, and 6.2% compared to the specimen (40%D.S without fibers). The specimen (40%D.S+1%S.F.L) also achieved a reduction in absorption by about 11.5% and 14.8% compared to the specimens (40%D.S+1%S.F.S) and (40%D.S+1%H.S.F) respectively, and the quality of concrete for these specimens is considered good according to CEB: 1989 and as shown in Figure 4.73.

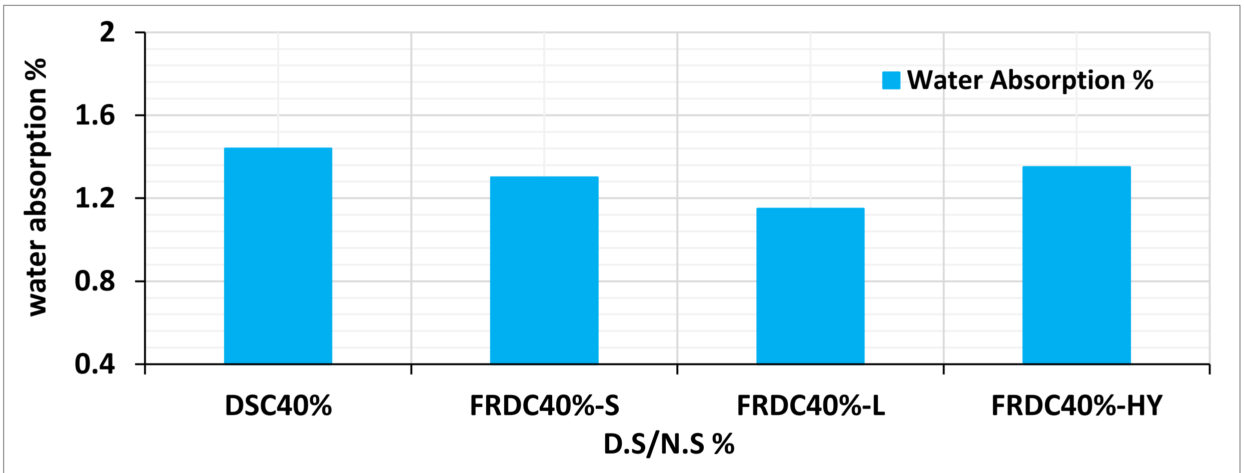


Figure 4.73 Relationship between water absorption and replacement ratios of sand dunes (40%) for concrete specimens with steel fibers.

The absorption increases with the increase of the sand dunes content for ratio 60%, where the specimens achieved (60%D.S+1%S.F.S), (60%D.S+1%S.F.L) and (60%D.S+1%H.S.F) absorption of 2.95, 2.88, 2.90, an increase of about 13.03%,10.34%,11.11% compared to the specimen (60%D.S without fibers). Also, the specimen (60% D.S + 1% S.F.L) achieved a decrease in absorption compared to the specimens (60% D.S + 1% S.F.S) and (60% D.S + 1% H.S.F) by about 2.4% and 0.68% respectively, the quality of concrete for these specimens is considered good according to CEB: 1989 and as shown in Figure 4.74.

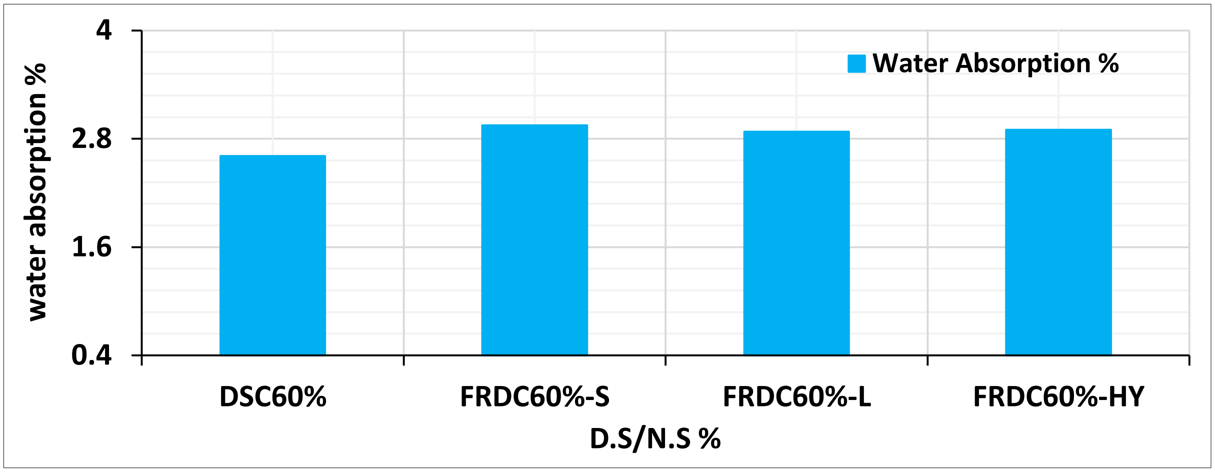


Figure 4.74 Relationship between water absorption and replacement ratios of sand dunes (60%) for concrete specimens with steel fibers.

When sand dunes is replaced as an alternative to sand for ratio 80%, the concrete absorption rate of water increases, where the specimens recorded (80%D.S+1%S.F.S), (80%D.S+1%S.F.L) and (80%D.S+ 1%H.S.F) absorption of 3.48 ,3.33 and 3.39, an increase of about 12.98% ,8.11% and10.06% compared to the specimen (80%D.S without fibers), the hybrid specimen (80%D.S + 1%H.S.F) also achieved an increase in absorption by about 2.58% and 1.80% higher than the specimens (80%D.S+1%S.F.S) and (80%D.S +1%S.F.L)respectively, and the quality of concrete for these specimens is considered average according to CEB, as shown in Figure 4.75.

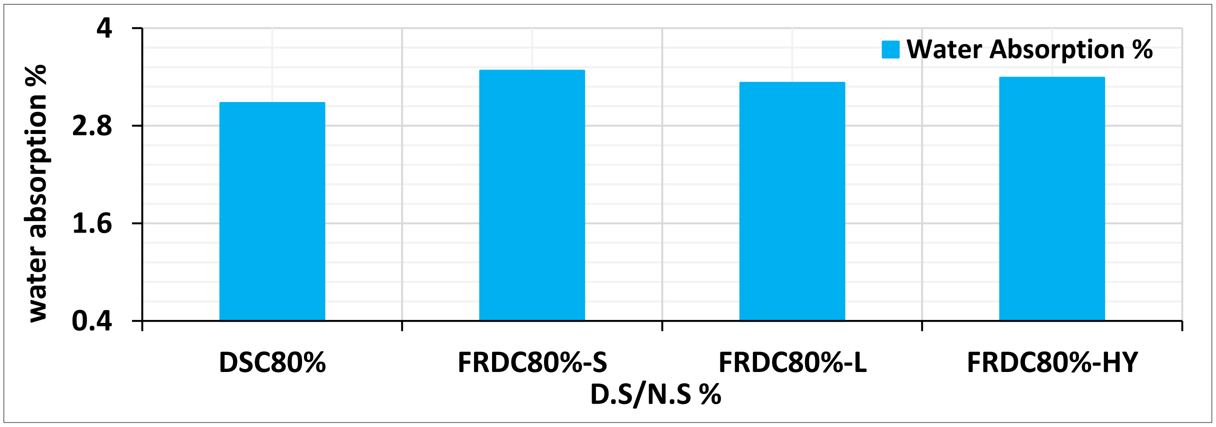


Figure 4.75 Relationship between water absorption and replacement ratios of sand dunes (80%) for concrete specimens with steel fibers.

When sand dunes is replaced as an alternative to sand of ratio 100%, the absorption rate of water increases. The specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L) and (100%D.S+1%H.S.F) achieved an increase in absorption of 3.97,3.85 and3.90, i.e. 22.53%,18.83% and20.37% higher than the specimen (100%D.S without fibers),the specimen (100%D.S+1%S.F.S) also achieved an increase in absorption by about 3.11% and 1.79% compared to the specimens (100%D.S+1%S.F.L) and (100%D.S+1%H.S.F), respectively. The concrete quality of the specimens is considered average according to CEB, as shown in Figure 4.76.

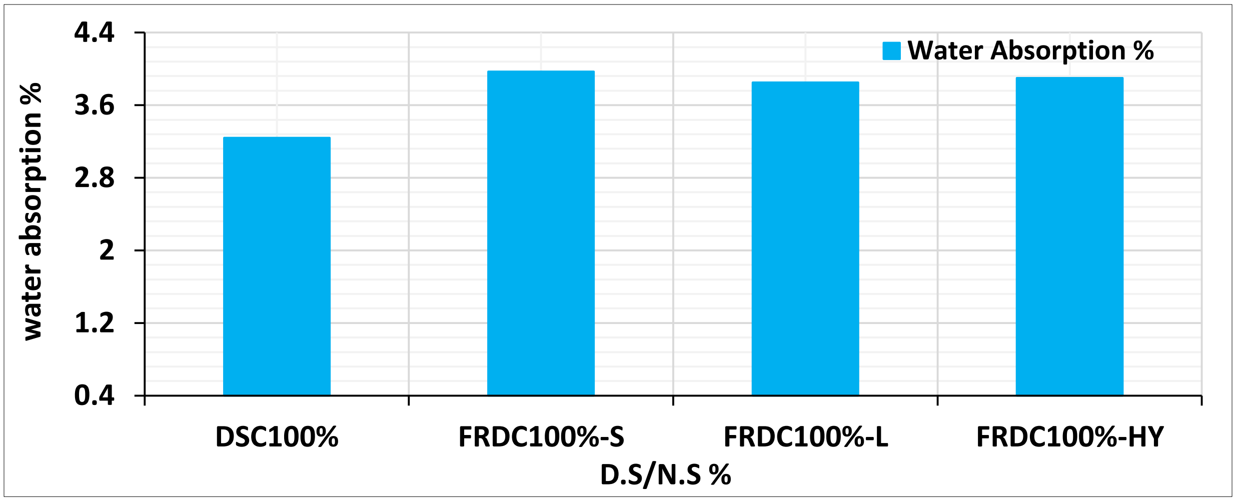


Figure 4.76 Relationship between water absorption and replacement ratios of sand dunes (100%) for concrete specimens with steel fibers.

In general, the rate of absorption increases with the increase in the content of sand dunes in the mixture and with varying percentages of increase when adding steel fibers, due to the effect of dunes sand on the specific surface area and its greater water absorption. Also, the fibers reduce the rate of absorption, and the excess absorption weakens the concrete and causes it to have gaps, and thus reduces the durability and quality of concrete. All specimens in this study showed a positive effect within the acceptable limits of absorption. I did not get from the results an absorption rate higher than 4%, where the lowest absorption effect of concrete (0%

D.S + 1% S.F.S) and the highest absorption effect of concrete (100%D.S + 1% S.F.S) were obtained. As well as for hybrid concrete, which showed a positive effect for absorption, where obtained the lowest absorption effect of the specimen without dunes sand (0%D.S + 1%H.S.F) and the maximum effect of absorption with the specimen (100%D.S + 1%H.S.F) due to the increase in the surface area Fine aggregates, where the concrete absorption of water increases.

4.2.1.3.4 Static Modulus of Elasticity results

The results of the modulus of elasticity test at the age 28 days for concrete specimens (cylinders 150 ×300mm) containing sand dunes as and reinforced with steel fiber as well as for specimens without fibers are listed in Table 4.8. The results are compared with the results of the following code equation ACI318-14[52]:

$$E_C = 0.043\ \Upsilon_C^{1.5}\sqrt{f_{c^-}} \qquad \text{Eq. 4.1}$$

Where, E_C: Code equation for Static Modulus of Elasticity

Υ_C : Concrete unit weight at 28 days age in kg/m^3,

f_{c^-} : Cylinder compressive strength in MPa.

The results show for specimens without fibers, that the reference specimen (0%D.S) has achieved a modulus of elasticity of 31.61GPa, but with a slight decrease by about 0.72% compared to the result of the code equation ACI318.

When sand dunes is used, the elastic modulus of the specimens increases for the ratios (20%, 40%, 60%), where the specimen (40%D.S without fibers) achieved the highest elastic modulus of 35.51GPa, an increase of about 12.3% higher than the reference specimen. Also, higher than the ACI code equation by about 2.95%, where that is the optimal percentage for replacement without fibers. The specimens (20%D.S and 60%D.S) achieved an increase in the modulus of elasticity by about 6.54% and 5.12%, respectively, compared to the reference specimen. It is also higher than the code's equation by 1.11% and 2.37%, respectively.

Table 4.8 Results test of the static elastic modulus for the concrete specimens

D.S/Sand %	Experimental Modulus of Elasticity(E) (GPa)	Elastic modulus ACI 318 -14 Eq. $E_C = 0.043\, \gamma_C^{1.5} \sqrt{f_c^-}$ (GPa)	changing in elastic modulus %	%Changing between (E) and (E_c) ACI code
0% D.S	31.61	31.84	----	-0.72
20% D.S	33.68	33.31	+6.54	.11
40% D.S	35.51	34.49	+12.34	2.95
60% D.S	33.23	32.46	+5.12	2.37
80% D.S	26.65	27.63	-15.69	-3.54
100% D.S	22.98	24.43	-27.30	-5.93
0%D.S+1%S.F.S	41.35	39.37	+30.81	5.03
0%D.S+1%S.F.L	45.62	43.21	+44.32	5.57
0%D.S+1%H.S.F	40.58	38.73	+28.37	4.77
20%D.S+1%S.F.S	35.07	35.53	+4.13	- 1.29
20%D.S+1%S.F.L	40.32	38.59	+19.71	4.48
20%D.S+1%H.S.F	41.90	39.44	+24.41	6.23
40%D.S+1%S.F.S	38.01	36.31	+7.04	4.68
40%D.S+1%S.F.L	38.94	37.59	+9.65	3.59
40%D.S+1%H.S.F	43.57	41.78	+22.69	4.28
60%D.S+1%S.F.S	34.62	33.87	+4.18	2.21
60%D.S+1%S.F.L	36.67	34.52	+10.35	6.23
60%D.S+1%H.S.F	35.04	34.31	+5.45	2.13
80%D.S+1%S.F.S	28.35	29.06	+6.38	- 2.44
80%D.S+1%S.F.L	30.92	32.36	+16.02	- 4.45
80%D.S+1%H.S.F	29.63	29.68	+11.18	- 0.17
100%D.S+1%S.F.S	25.34	26.21	+14.62	-3.31
100%D.S+1%S.F.L	28.04	27.59	+22.02	1.63
100%D.S+1%H.S.F	26.08	26.47	+17.18	-1.47

The modulus of elasticity decreases with the increase of the sand dunes content of the ratios (80% and 100%) in concrete, where the specimens recorded the lowest modulus of elasticity with a decrease of 15.69% and 27.30%, respectively, compared to the reference specimen. It is also less than the code equation by about 3.54% and 5.93%, respectively. Where the compressometer reading increases (the value of the change in length ΔL increases), whenever the sand dunes content increases in the specimens and the strain increases and thus the modulus of elasticity decreases. Figure 4.77 shows the static elastic modulus test of the concrete specimens (cylinders) .Figure 4.78 shows the relationship between the experimental static modulus of elasticity and the code with concrete specimens containing dunes sand as an alternative for sand without fibers.

Figure 4.77 The static elastic modulus test of the concrete specimens (cylinders).

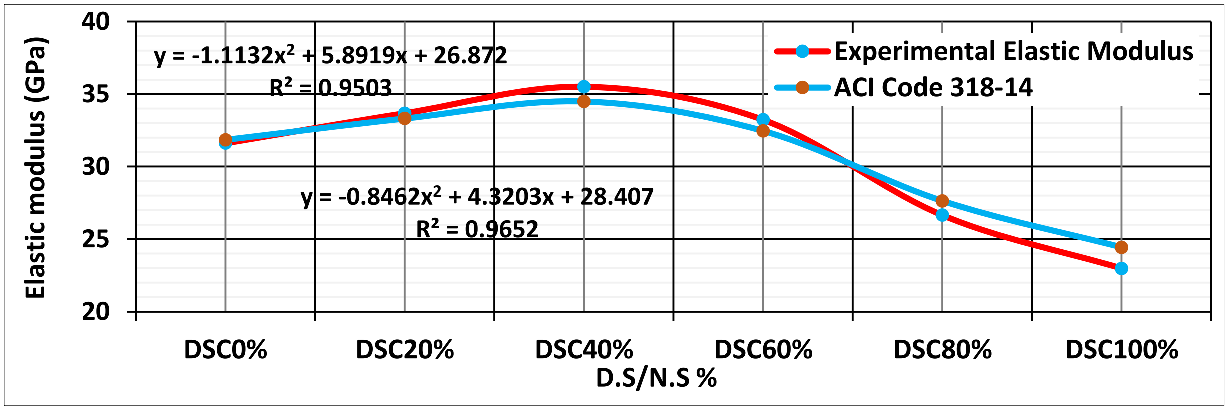


Figure 4.78 The static modulus of elasticity curves for specimens containing sand dunes without fibers.

The results of the mixtures reinforced with short steel fibers and replacement ratios (0% - 100%) showed that the mixture (0%D.S + 1%S.F.S) achieved the highest static elastic modulus compared to all the mixtures reinforced with short fibers and replacement ratios (20%, 40 %, 60%, 80%, 100%) with an increase of about (17.9%, 8.7%, 19.4%, 45.8%, and 63.1%) respectively. An increase in the content of sand dunes leads to an increase in the stress on the specimens, and therefore the modulus of elasticity decreases, as shown in Figure 4.79.

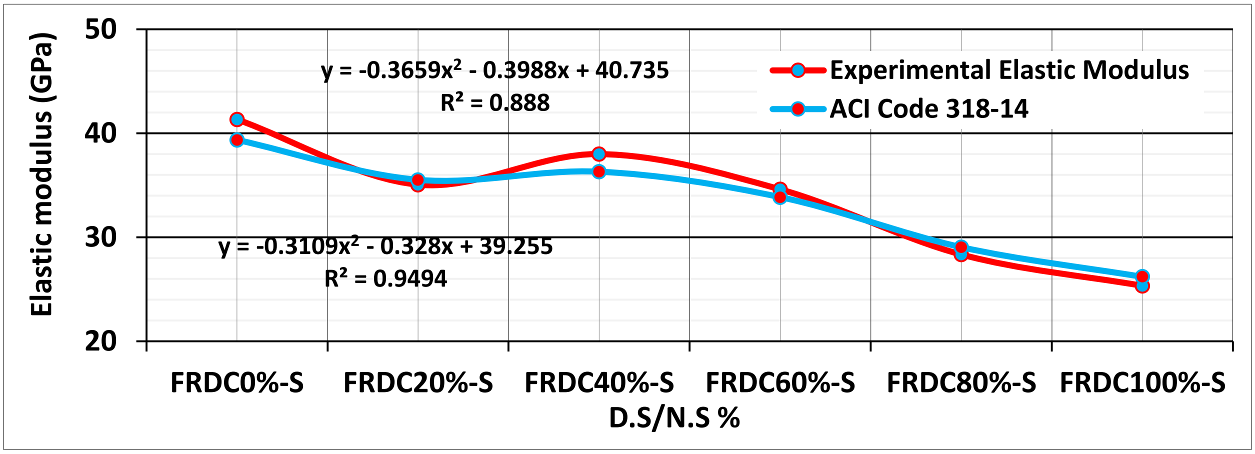


Figure 4.79 The static modulus of elasticity curves for specimens with S.F.S.

The results of the mixtures reinforced with long steel fibers showed that the mixture (40% D.S + 1%S.F.L) achieved the highest static elastic modulus compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (13.1%, 17.1%, 24.4%, 47.5%, and 62.6%), respectively, as shown in Figure 4.80.

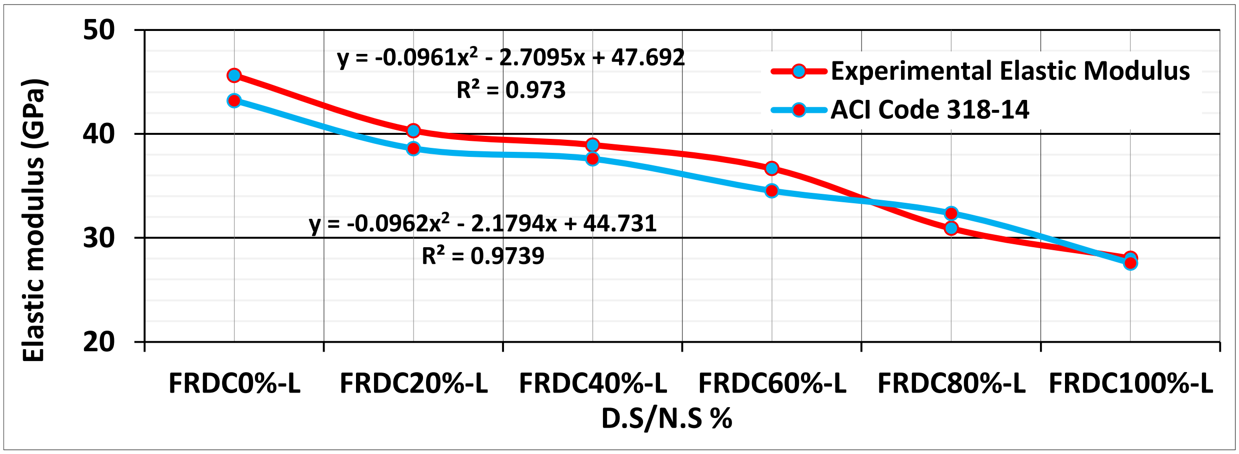


Figure 4.80 The static modulus of elasticity curves for specimens with S.F.L.

The results of the mixtures reinforced with hybrid steel fibers showed that the hybrid mixture (40% D.S + 1% H.S.F) achieved the highest static elastic modulus compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of about (7.3%, 3.9%, 24.3%, 47%, and 67.1%) respectively, as shown in Figure 4.81.

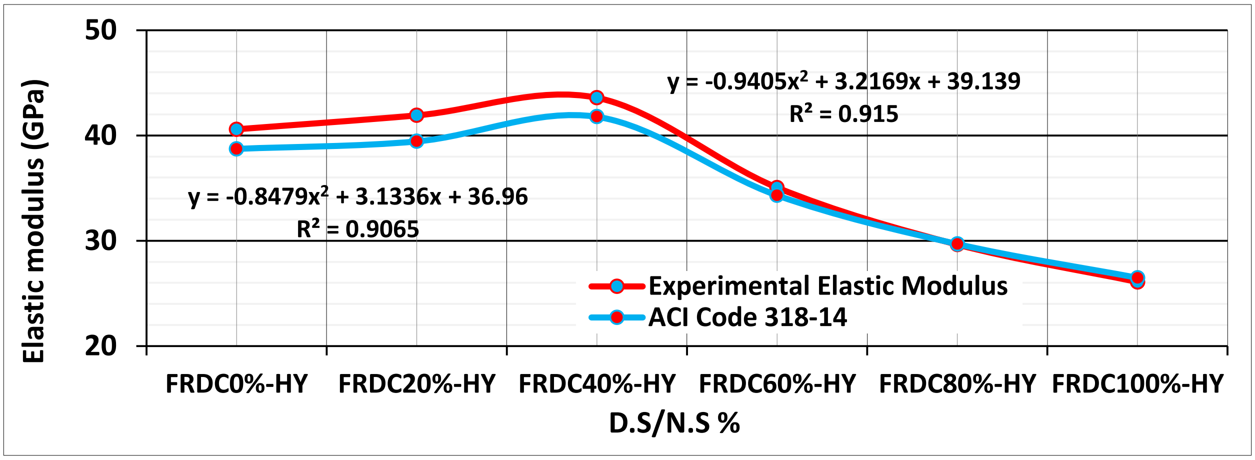


Figure 4.81 The static modulus of elasticity curves for specimens with H.S.F.

The results of specimens indicated that an increase in the modulus of elasticity, where the specimen reinforced with long steel fibers without sand dunes (0%D.S + 1%S.F.L) achieved the highest modulus of elasticity of 45.62GPa with an increase of about 44.32% higher than the reference specimen, it is also higher by about 5.57%, 10.32% and 12.41% compared to the (code equation ACI), (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F), respectively. The specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) have achieved a modulus of elasticity with an increase of 30.81% and 28.37% , respectively compared to the reference specimen, where the ability of concrete to withstand deformations better with long steel fibers when stress is applied to the specimen, as shown in Figure 4.82.

When sand dunes is used for ratio 20%, the static modulus of elasticity increases, where the specimens (20%D.S+1%S.F.S), (20%D.S+1%S.F.L), and (20%D.S+1%H.S.F) achieved an increase in the elastic modulus of 35.07GPa, 40.32GPa, and 41.90GPa, of about 4.13%, 19.71%, and 24.41%, respectively compared to the specimen (20%D.S without fibers). The hybrid specimen

(20%D.S+1%H.S.F) also achieved a higher modulus of elasticity than the specimens (20%D.S+1%S.F.S), (20%D.S+1%S.F.L) and the code equation by about 19.5%, 3.92%, and 4.48%, respectively, as shown in Figure 4.83.

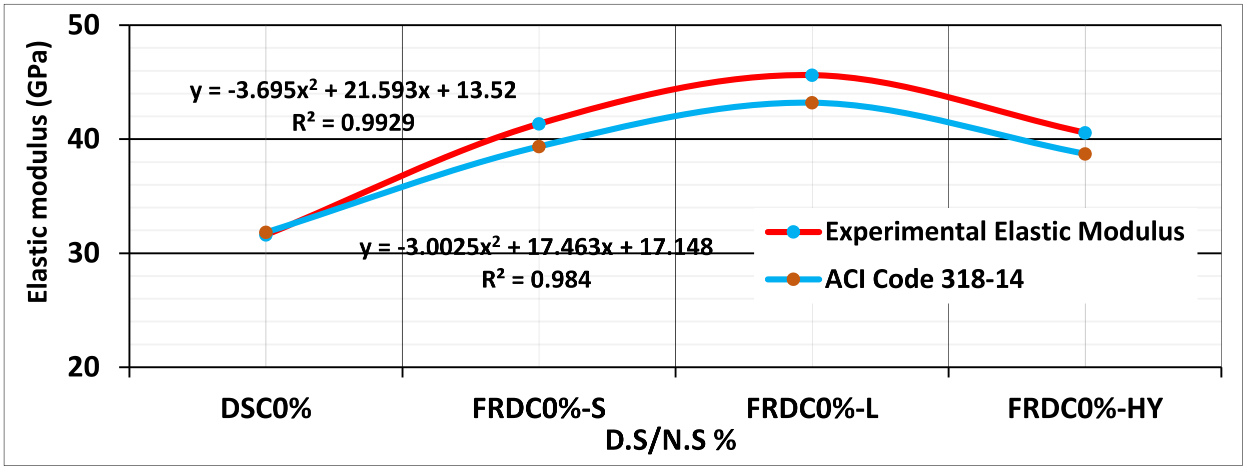


Figure 4.82 The curves of elastic modulus for specimens containing (0% D.S).

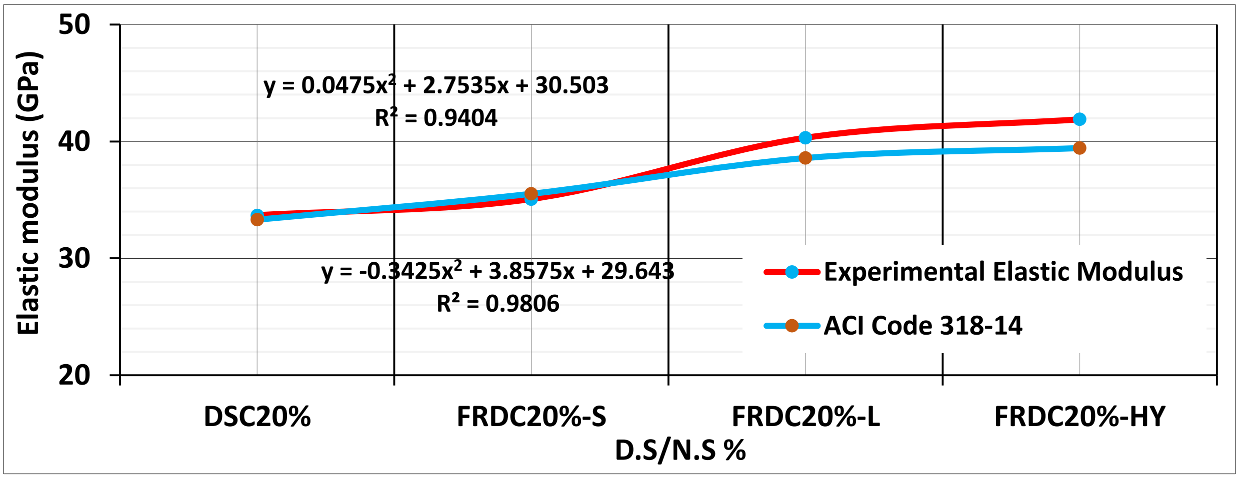


Figure 4.83 The curves of elastic modulus for specimens containing (20%D.S).

The modulus of elasticity increases with the increase of the sand dunes content of the ratios 40% and 60%, where the specimens (40%D.S+1%S.F.S), (40%D.S+1%S.F.L), and (40%D.S+1%H.S.F) achieved a modulus of elasticity of 38.01GPa, 38.94GPa, and 43.57GPa, with an increase of about 7.04%, 9.65%, and 22.69%, respectively, higher than the specimen (40%D.S without fibers). It is also higher than the code equation by 4.68%, 3.59% and 4.28%, respectively. While the hybrid specimen (40% D.S + 1% H.S.F) achieved an increase in elastic modulus by about 14.6% and11.8% higher than the specimens (40% D.S + 1% S.F.S) and (40% D.S + 1%S.F.L), respectively, where we notice that when the sand dunes content increases, the stress on the specimens increases, and thus the modulus of elasticity increases, as shown in Figure 4.84.

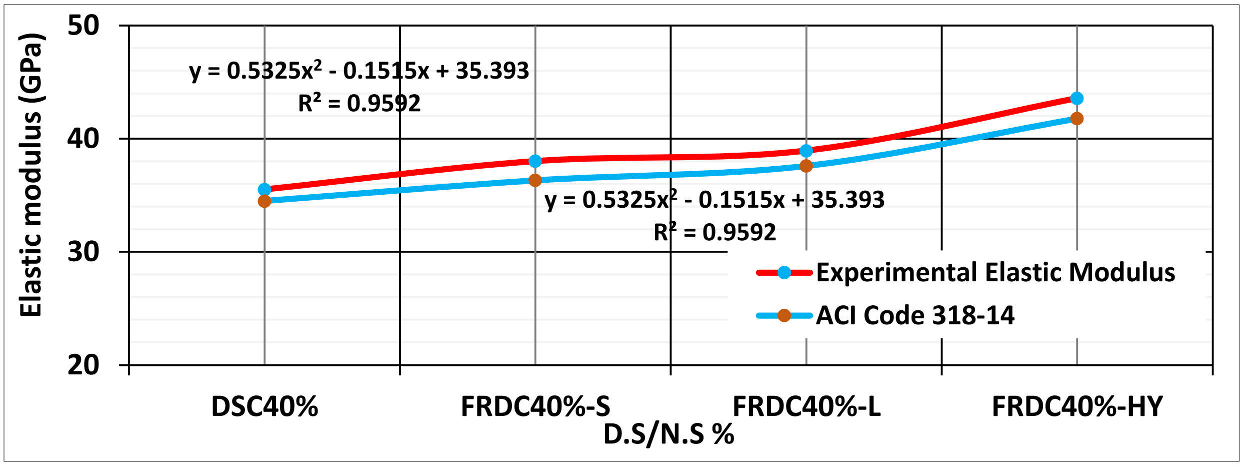


Figure 4.84 The curves of elastic modulus for specimens containing (40%D.S).

The modulus of elasticity increases with the increase of the sand dunes content, where the specimens (60%D.S+1%S.F.S), (60%D.S+1%S.F.L), and (60%D.S+1%H.S.F) achieved an increase in the modulus of elasticity by about 4.18%, 10.35%, and 5.45%respectively, higher than the specimen (60%D.S without fibers), it is also higher than the code equation by 2.21%, 6.23% and 2.13%, respectively. While the specimen containing long steel fibers achieved an increase in the modulus of elasticity by about 5.92% and 4.65% higher than the specimens (60% D.S + 1% S.F.S) and (60% D.S + 1%H.S.F) respectively, as shown in Figure 4.85.

The modulus of elasticity decreases with the increase of the sand dunes content of the ratios 820% and 100%compared to the other replacement ratios that contain steel fibers, but it is higher than the specimens without the fibers, where the specimens achieved (80%D.S+1%S.F.S), (80%D.S+1%S.F.L), and (80%D.S+ 1%H.S.F) a modulus of elasticity of 28.35GPa, 30.92GPa and 29.63GPa, an increase of about 6.38%,16.02% and11.18% higher than the specimen (80%D.S without fibers), while the specimens achieved a decrease in the modulus of elasticity by about 2.44%,4.45%,0.17% compared to the code equation . The specimen (80%D.S+1%S.F.L) also recorded an increase in the modulus of elasticity by about 9.06% and 4.35% higher than the specimens (80%D.S+1%S.F.S) and (80%D.S+1%H.S.F) respectively, we note that the long steel fibers increase the modulus of elasticity of concrete better than the short and hybrid steel fibers, as shown in Figure 4.86.

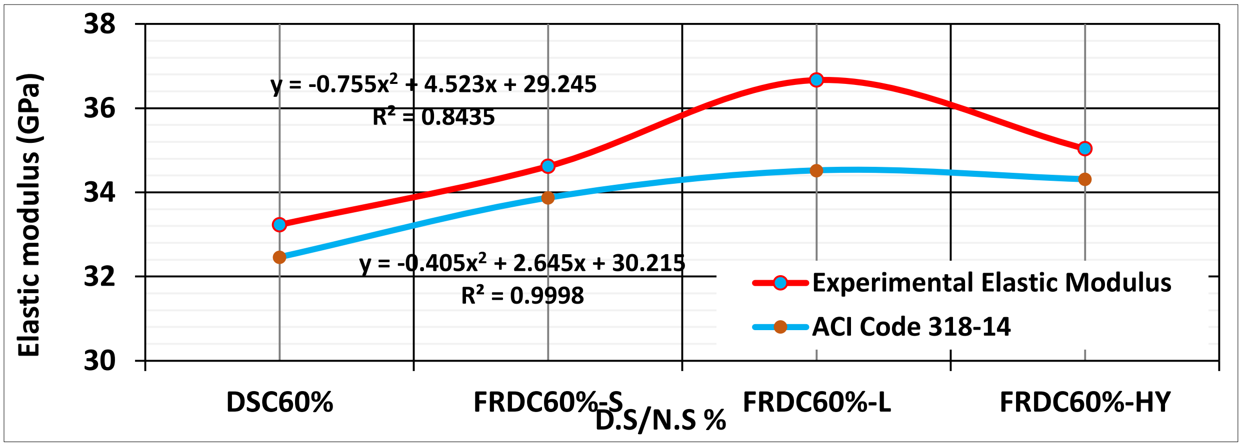


Figure 4.85 The curves of elastic modulus for specimens containing (60%D.S).

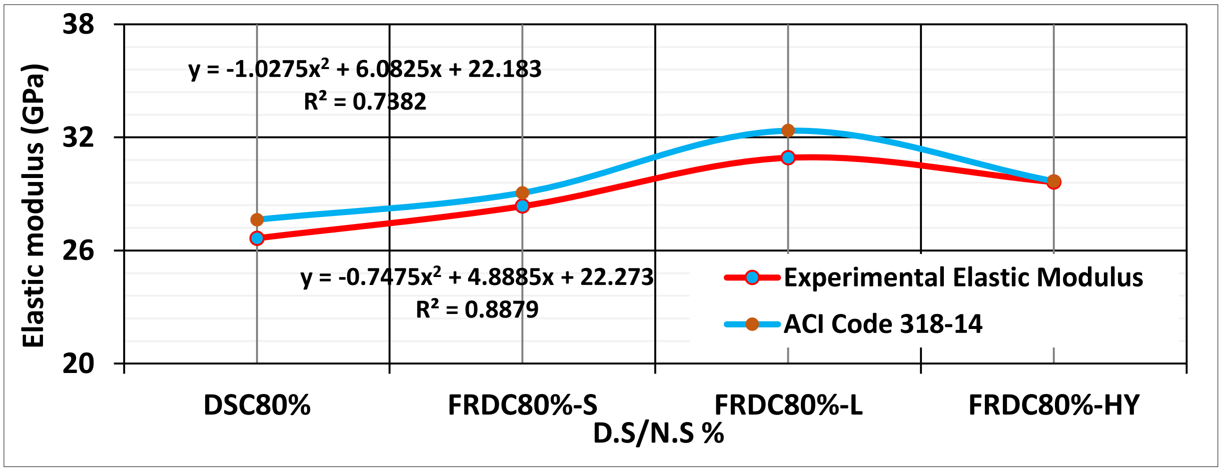


Figure 4.86 The curves of elastic modulus for specimens containing (80%D.S).

When sand dunes is used as an alternative for the sand of ratio 100%, the modulus of elasticity decreases compared to the other replacement ratios, where the specimens (100%D.S+1%S.F.S), (100%D.S+1%S.F.L) and (100%D.S+1%H.S.F) recorded a modulus of elasticity of 25.34 GPa ,28.04GPa and 26.08GP a, an increase of about 14.62%,22.02% and17.18% higher than the specimen (100%D.S without fibers), where the specimen (100% D.S + 1% S.F.S) recorded the lowest elastic modulus compared to all specimens that contain steel fibers. It is also 3.31% lower compared to the code equation, while the specimen containing long steel fibers (100% D.S + 1% S.F.L) recorded an increase in the modulus of elasticity, higher by about 10.65%, 7.51%, and 1.63% than the specimens (100% D.S + 1%S.F.S),(100 %D.S + 1%HSF) and code equation ACI318 respectively, whereas the performance of long steel fibers was better than short and hybrid steel fibers in terms of increasing the modulus of elasticity and concrete resistance to deformations for specimens containing sand dunes as an alternative to sand , as in Figure 4.87.

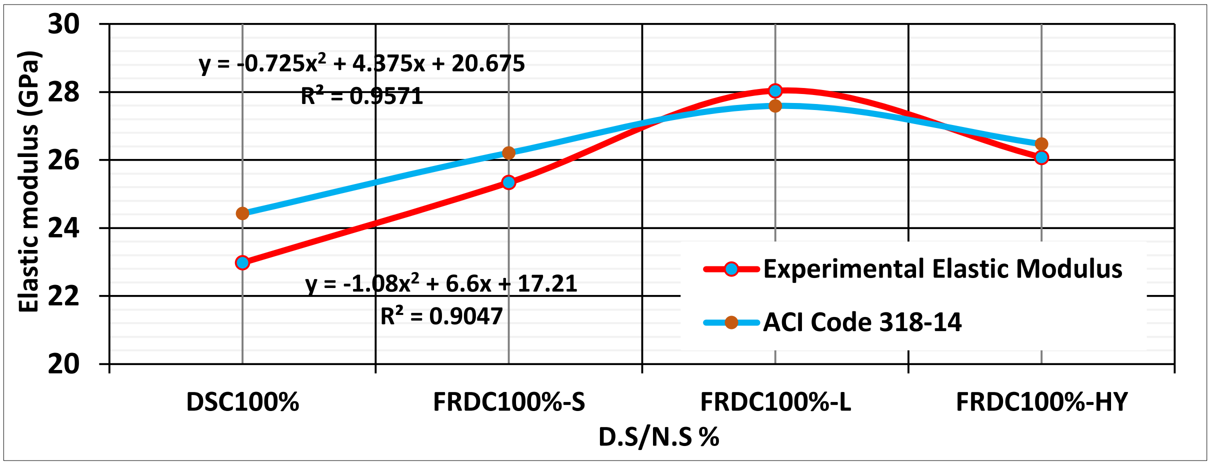


Figure 4.87 The curves of elastic modulus for specimens containing (100%D.S).

4.2.1.3.5 Dynamic Modulus of Elasticity results

The dynamic modulus of elasticity is calculated by measuring the ultrasonic pulse velocity of specimens (cubes) aged 28 days. It depends on the density of the concrete. The results of calculating the dynamic modulus of elasticity for concrete specimens containing sand dunes as an alternative to sand for the ratios (0%, 20%, 40%,60%,80%,100%) and reinforced with single and hybrid steel fibers, as well as for specimens without fibers is listed in Table 4.9. The results show that the dynamic modulus of elasticity is between (42.4 - 88.4GPa), the dynamic modulus of elasticity is calculated from the following relationship [48]:

$$\text{Dynamic Modulus of Elasticity (Ed)} = \left[\frac{V^2 \rho (1+\mu)(1-2\mu)}{(1-\mu)}\right] \qquad \text{Eq. 4.2}$$

Where: V= pulse velocity in Km/s, ρ = Concrete unit weight in Kg/m^3, μ= Poisson's ratio.

The dynamic modulus of elasticity of the reference specimen is 51.35GPa, when sand dunes is used as an alternative to sand for the ratios 20%and 40%, we notice an increase in the dynamic modulus of elasticity by about 3.54% and 0.27% compared to the reference specimen. When the sand dunes content is increased as an alternative to sand for the ratios 60%, 80% and 100%. The dynamic modulus of elasticity decrease by about 6.5%, 14.2%, and 17.3%, respectively compared to the reference specimen, and as shown in Figure 4.88.

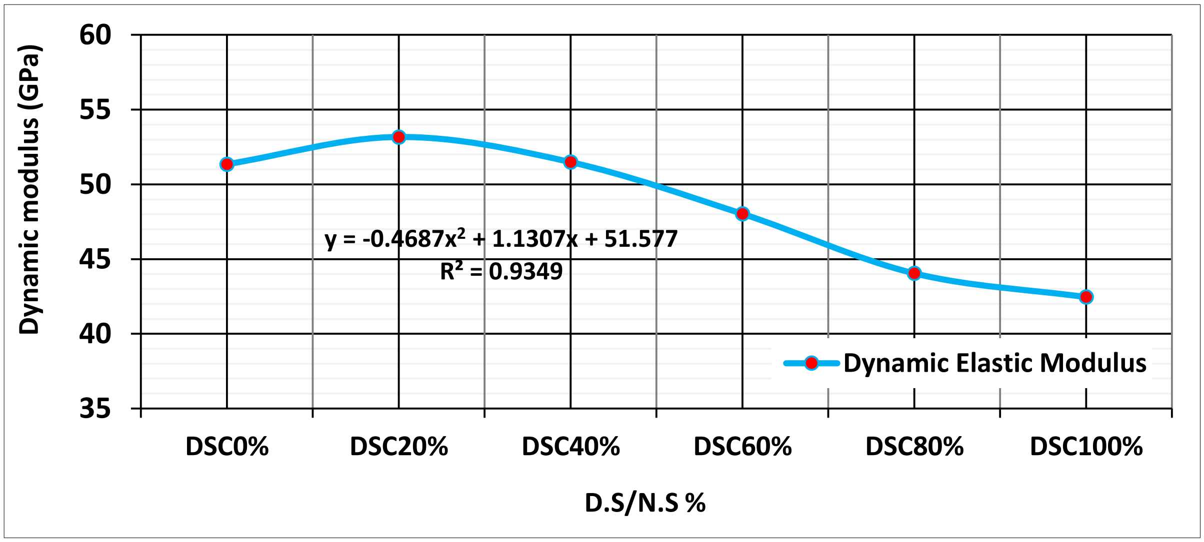


Figure 4.88 The dynamic elastic modulus curve for specimens containing sand dunes without fibers.

Table 4.9 Results the dynamic elastic modulus for the concrete specimens

D.S/Sand %	Average Density Kg/m³ 28days	Average UPV (Km/s)	Dynamic Modulus of Elasticity (Ed) GPa	%change in Dynamic modulus of elasticity at 28 days
0% D.S	2382.41	4.894	51.35	----
20% D.S	2371.55	4.991	53.17	+3.54
40% D.S	2427.35	4.855	51.49	+0.27
60% D.S	2400.58	4.715	48.03	-6.46
80% D.S	2355.20	4.559	44.05	-14.21
100% D.S	2348.83	4.482	42.46	-17.31
0%D.S+1%S.F.S	2516.73	5.017	57.01	+11.02
0%D.S+1%S.F.L	2564.13	6.191	88.45	+72.24
0%D.S+1%H.S.F	2501.92	6.212	86.89	+69.21
20%D.S+1%S.F.S	2441.67	5.423	64.63	+21.55
20%D.S+1%S.F.L	2522.37	6.068	83.58	+57.19
20%D.S+1%H.S.F	2527.60	5.969	81.05	+52.43
40%D.S+1%S.F.S	2463.30	4.907	53.38	+3.67
40%D.S+1%S.F.L	2471.99	4.894	53.28	+34.76
40%D.S+1%H.S.F	2548.44	4.934	55.83	8.43
60%D.S+1%S.F.S	2443.85	4.834	51.39	+6.99
60%D.S+1%S.F.L	2454.41	4.921	53.49	+11.36
60%D.S+1%H.S.F	2451.70	4.728	49.32	+2.68
80%D.S+1%S.F.S	2391.40	4.596	45.46	+3.20
80%D.S+1%S.F.L	2474.17	4.703	49.25	+11.80
80%D.S+1%H.S.F	2389.93	4.753	48.59	+10.30
100%D.S+1%S.F.S	2378.81	4.703	47.35	+11.51
100%D.S+1%S.F.L	2363.25	4.514	43.33	+2.04
100%D.S+1%H.S.F	2342.91	4.630	45.20	+6.45

The results of the mixtures reinforced with short steel fibers and replacement ratios (0%-100%), showed that the mixture (20%D.S+1%S.F.S) achieved the highest dynamic modulus of elasticity compared to all the mixtures reinforced with short fibers and replacement ratios (0%, 40%, 60%, 80%, 100%) with an increase of (13.3%, 21.1%, 25.7%, 42.1%, and 36.4%), respectively. As shown in Figure 4.89.

The results of the mixtures reinforced with long steel fibers showed that the mixture without sand dunes (0%D.S+1%S.F.L) achieved the highest dynamic elastic modulus compared to all mixtures reinforced with long steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (5.8%, 66%, 65.3%, 79.5%, and 104.1%), respectively, as shown in Figure 4.90 .

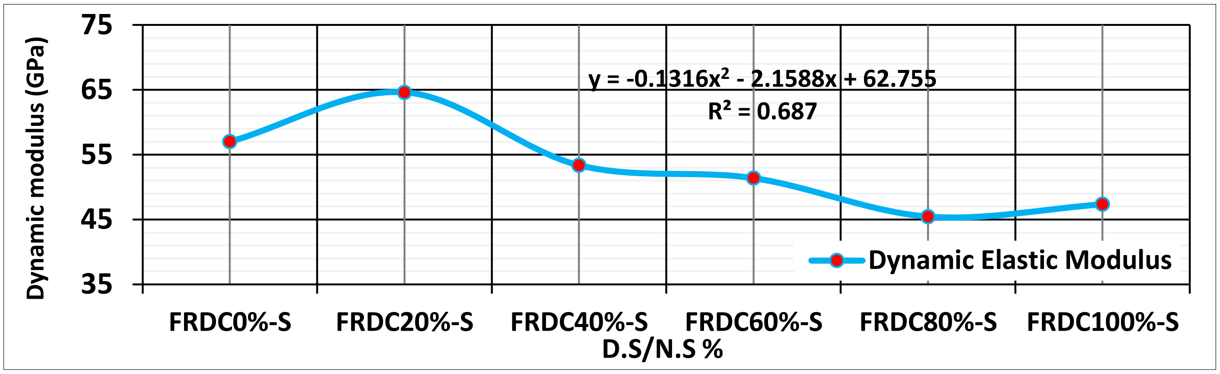


Figure 4.89 The dynamic modulus of elasticity curves for specimens with S.F.S.

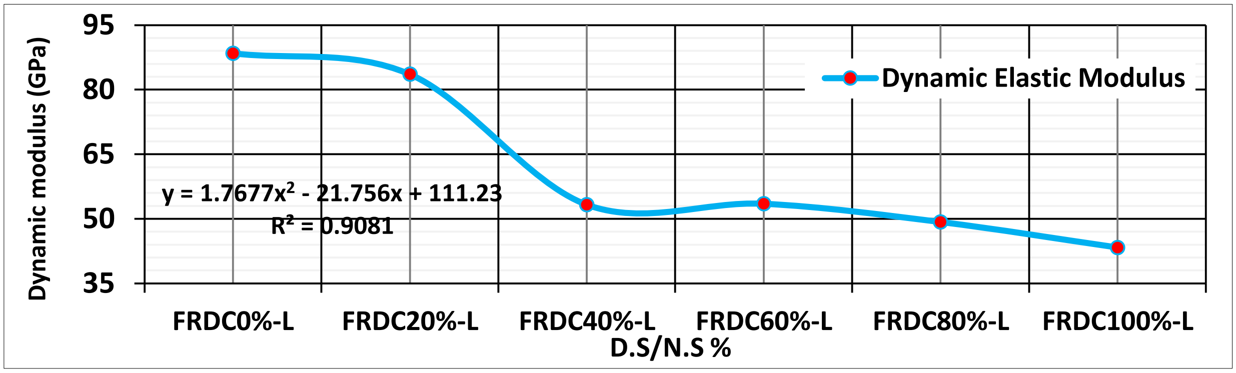


Figure 4.90 The dynamic modulus of elasticity curves for specimens with S.F.L.

The results of the mixtures reinforced with hybrid steel fibers showed that the hybrid mixture without sand dunes (0%D.S + 1%H.S.F) achieved the highest dynamic elastic modulus compared to all mixtures reinforced with hybrid steel fibers and replacement ratios (20 %, 40%, 60%, 80%, 100%), with an increase of about (7.2%, 55.6%, 76.1%, 78.8%, and 92.2%), respectively, as shown in Figure 4.91.

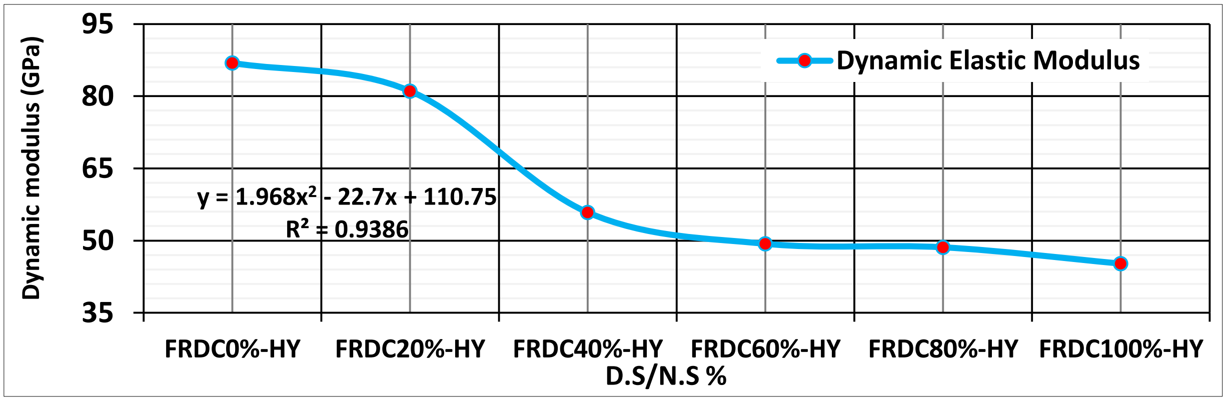


Figure 4.91 The dynamic modulus of elasticity curves for specimens with H.S.F.

The results of specimens reinforced with steel fibers indicate an increase in the dynamic modulus of elasticity, where the specimen without sand dunes (0%D.S + 1%S.F.L) achieved the highest dynamic modulus of elasticity of 88.45GPa, an increase of about 72.2% higher than the reference specimen, as well as higher than the specimens (0%D.S+1%S.F.S) and (0%D.S+1%H.S.F) by 55.1% and 1.8%, respectively. Followed by the hybrid specimen (0%D.S + 1%H.S.F) with an increase of about 69.2% and 52.4% compared to specimens (0%D.S without fibers) and (0%D.S + 1%S.F.S), respectively, this increase in the modulus of elasticity dynamic due to the increase in the pulse velocity and the high concrete density of these specimens, as shown in Figure 4.92.

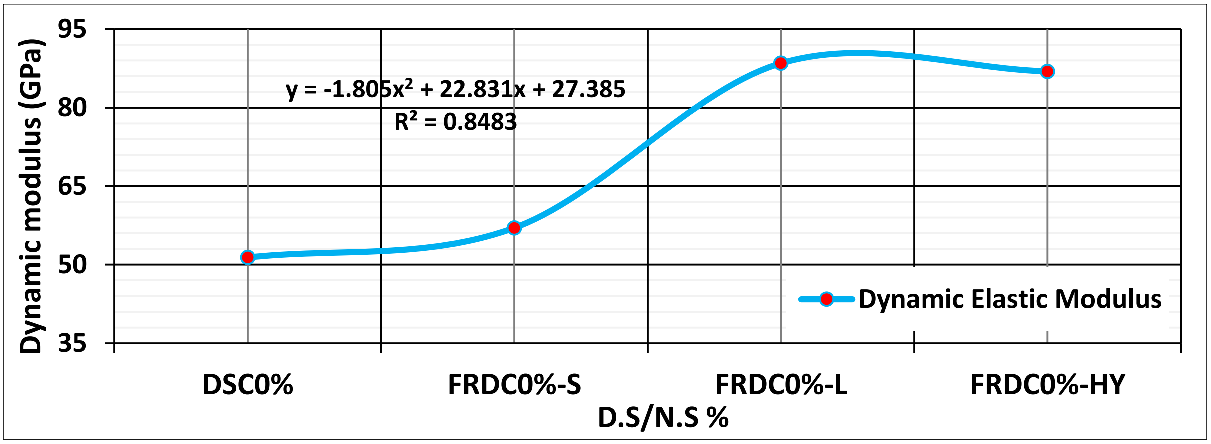


Figure 4.92 The curve of dynamic modulus for specimens containing (0%D.S).

When sand dune is used as an alternative to sand for a ratio of 20%, we notice an increase in the dynamic modulus of elasticity, where the specimens achieved (20%D.S+1%S.F.S), (20%D.S+1%S.F.L), and (20%D.S+1%H.S.F) Dynamic elastic modulus of 64.63GPa, 83.58GPa, and 81.05GPa, an increase of about 21.5%,57.2%, and 52.4%, respectively, compared to the specimen (20%D.S without fibers). The specimen (20%D.S+1%S.F.L) also achieved an increase in the modulus of elasticity by about 29.3% and 3.12% higher than the specimens (20%D.S+1%S.F.S) and (20%D.S+1%H.S.F) respectively, as shown in Figure 4.93.

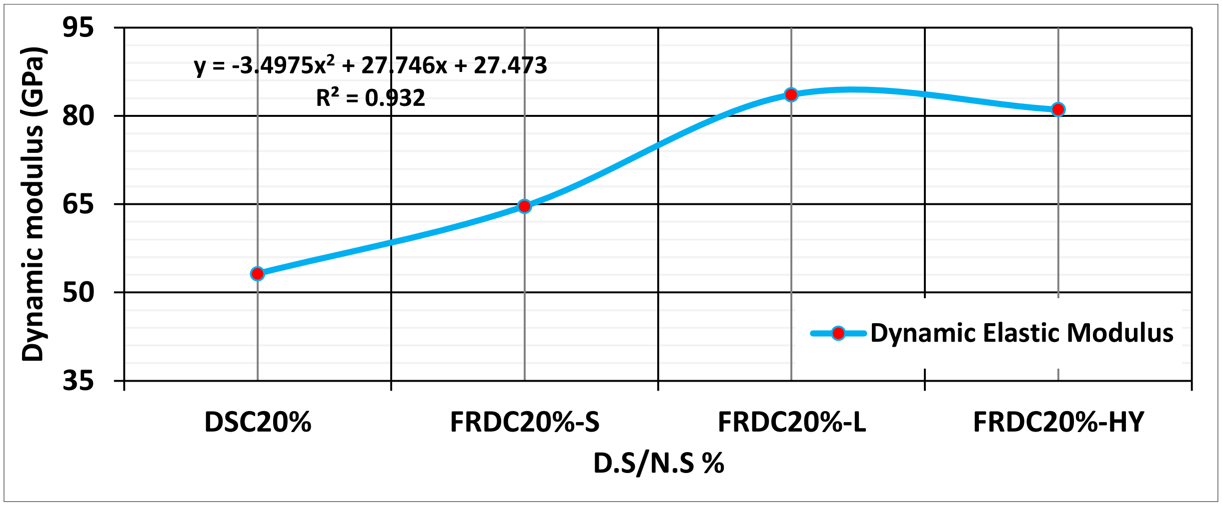


Figure 4.93 The curve of dynamic modulus for specimens containing (20%D.S).

The values of the dynamic modulus of elasticity gradually decrease compared to the other replacement ratios when sand dunes is used as an alternative to the sand of the ratios (40% -100%), but it is higher than the specimens without fibers, where the specimens achieved (40%D.S+1%S.F.S), (40%D.S+1%S.F.L) and (40%D.S+1%H.S.F) modulus of elasticity higher than the specimen (40%D.S without fibers) by about 3.67% ,3.47%, and 8.43%, respectively , also, the hybrid specimen (40%D.S+1%H.S.F) achieved a higher dynamic elasticity modulus than the specimens (40%D.S+1%S.F.S) and (40%D.S+1%S.F.L) by about 4.58%, and 4.78% respectively, and as shown in Figure 4.94 .

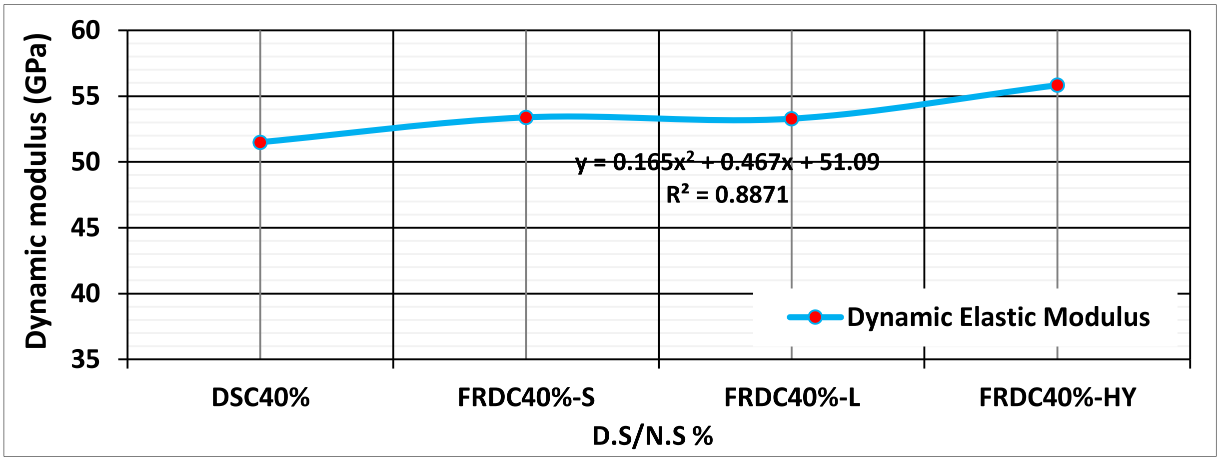


Figure 4.94 The curve of dynamic modulus for specimens containing (40%D.S).

When sand dunes is used as an alternative to sand for ratio 60% for specimens (60%D.S+1%S.F.S), (60%D.S+1%S.F.L), and (60%D.S+1%H.S.F), we notice an increase in the dynamic modulus of elasticity by about 6.9% ,11.4% , and 2.6% higher than the specimen (60%D.S without fibers). The specimen (60%D.S+1%S.F.L) also achieved an increase in the dynamic modulus of elasticity by 4.08% and 8.45% compared to the specimens (60%D.S+1%S.F.S) and (60%D.S+1%H.S.F) respectively, and as in Figure 4.95.

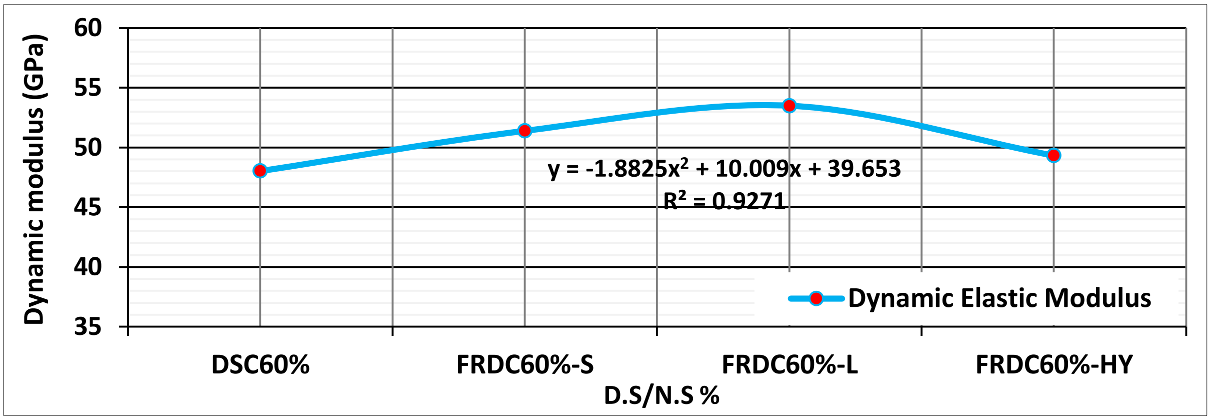


Figure 4.95 The curve of dynamic modulus for specimens containing (60%D.S).

As well as, the specimens achieved (80%D.S+1%S.F.S), (80%D.S+1%S.F.L), and (80%D.S+1%H.S.F) the dynamic modulus of elasticity higher than the specimen (80%D.S without fibers) by about 3.2%, 11.80%, and 10.30%, respectively, as well as the dynamic modulus of elasticity of the specimen (80%D.S + 1%S.F.L), is higher than the dynamic modulus of elasticity of the specimens (80%D.S + 1%S.F.S) and (80%D.S +1% H.S.F) by about 8.3% and 1.35%, respectively, and as shown in Figure 4.96 . When sand dunes is replaced as an alternative to sand for ratio100%, we notice a decrease in the dynamic modulus of elasticity, but it is higher than the specimens without fibers, where the specimens achieved (100%D.S+1%S.F.S), (100%D.S+1%S.F.L), and (100% D.S + 1%H.S.F) the dynamic elasticity modulus higher than the specimen (100%D.S without fibers) by about 11.5%, 2.04%, and 6.45%, respectively.

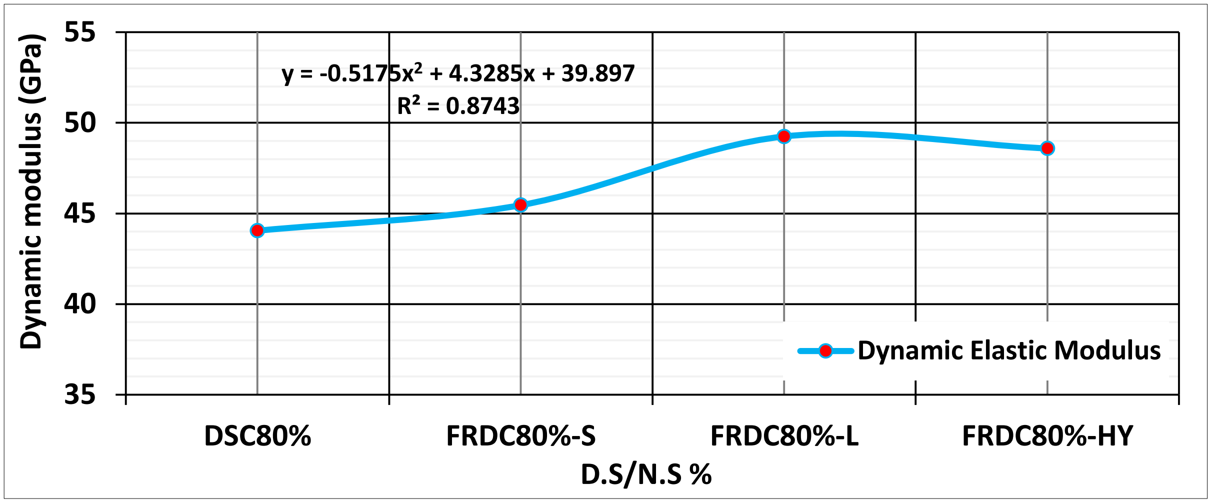


Figure 4.96 The curve of dynamic modulus for specimens containing (80%D.S).

Also, the dynamic modulus of elasticity of the specimen (100%D.S+1%S.F.S) is higher than the dynamic modulus of elasticity of the specimens (100%D.S+1%S.F.L) and (100%D.S+1%H.S.F) by about 9.3% and 4.7% respectively, and as shown in Figure 4.97.

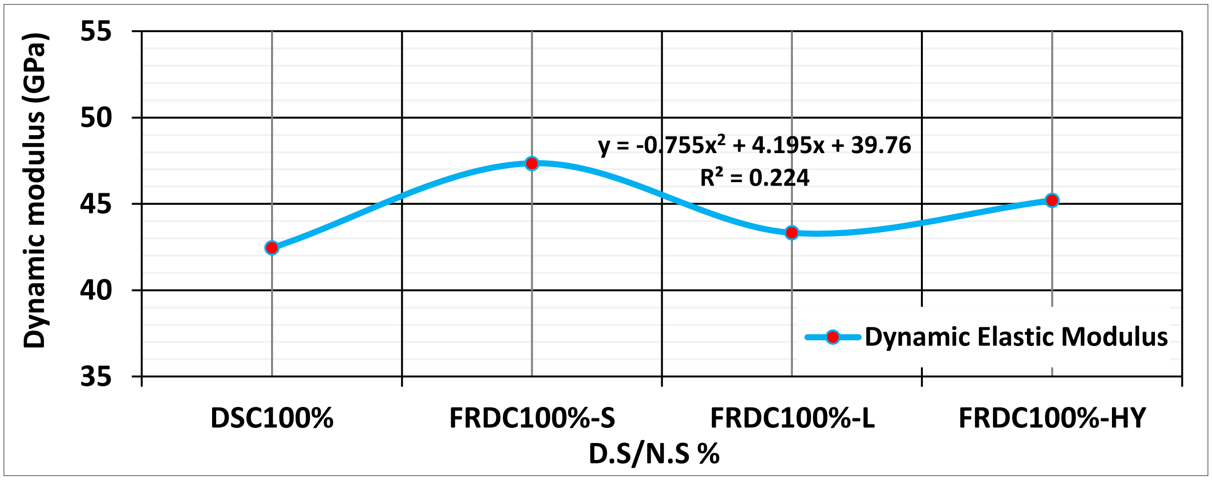


Figure 4.97 The curve of dynamic modulus for specimens containing (100%D.S).

The hybrid specimen (0% D.S + 1% H.S.F) has achieved the best positive effect among the hybrid specimens, and this indicates that this specimen is free of pores and gaps and the homogeneity of the components of the mixture, and the least effect of hybrid concrete (100% D.S + 1 %H.S.F).

4.2.2 Part (2): Structural behavior of concrete slabs

4.2.2.1 Structural behavior of concrete slabs containing sand dunes as replacement for sand

The tests of concrete slabs containing sand dunes as an alternative to sand without fibers showed a brittle behavior and flexural failure, where the ultimate failure load, deflection, and strain at the center of the slab are recorded. One slab without sand dunes (reference) and five specimens of slabs with different percentages of sand dunes as a partial and total alternative for sand without fibers are tested.

4.2.2.2 Structural behavior of concrete slabs containing sand dunes with steel fibers

The tests of concrete slabs containing sand dunes as a partial and total alternative for sand and reinforced with steel fibers showed ductility behavior and flexural failure pattern, where the ultimate failure load, strain, and deflection at the center of the slab are recorded, three control slabs without sand dunes and containing long, short, or hybrid steel fibers, fifteen slabs containing dunes sand in different proportions and reinforced with long, short, and hybrid steel fibers are tested. The test is under the action of flexural under one concentrated bearing point in the middle of the slab. Figure 4.98 shows the concrete slabs during the test.

Figure 4.98 Concrete slabs containing D.S with fibers under concentrated load.

Figure 4.98 Continued.

4.2.2.3 Slab ultimate load

4.2.2.3.1 Ultimate load for slabs without fiber

The ultimate failure load of concrete slabs containing sand dunes without steel fibers is recorded in Table 4.10. The ultimate failure load of the concrete slab DSC20% without fibers is 27.3kN (3.4% greater than the reference slab). While the slab (DSC 40% without fibers) achieved the highest value of the maximum failure load of 28 kN, an increase of about 6% compared to the reference slab. The ultimate failure load decreases with the increase of the sand dunes content of a ratio 60% in the slabs, where the slab (DSC60% without fibers) recorded a decrease in the value of the ultimate failure load of 26.1kN (1.13% less than the reference slab). For the dunes ratio 80% for the slab (DSC80% without fibers) a reduction in the maximum failure load of 21.8kN was observed with a decrease of about 17.4% less than the reference slab. When sand dunes is used as an alternative for the sand of ratio 80% for the slab (DSC80% without fibers) a reduction in the maximum failure load of 21.8kN was observed with a decrease of about 17.4% less than the reference slab. A total sand replacement by sand dunes for ratio 100% for the slab DSC100%, the lowest maximum failure load value of 20.3kN (about 23.1% less than the reference slab) was recorded. Figure 4.99 shows the relationship between the maximum failure load of concrete slabs containing sand dunes for all slabs without fibers.

Table 4.10 The maximum failure load of concrete slabs containing D.S without fiber

Slab remark	Fcu (MPa)	Fc⁻ (MPa)	Pu (kN) Ultimate failure load	Pu/Pu Reference slab %	Change in ultimate load%
DSC0%	51.02	40.816	26.4	1	R
DSC20%	51.44	41.152	27.3	1.034	3.409
DSC40%	56.30	45.04	28	1.061	6.06
DSC60%	51.6	41.28	26.1	0.989	-1.14
DSC80%	39.51	31.608	21.8	0.826	-17.4
DSC100%	31.2	24.96	20.3	0.769	-23.11

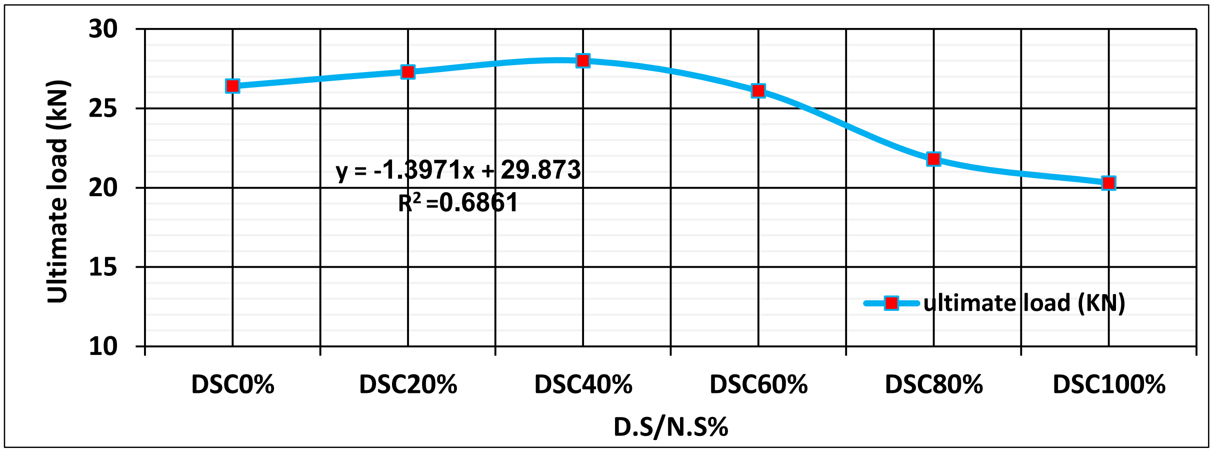


Figure 4.99 The curve of ultimate failure load for slabs without fibers.

4.2.2.3.2 Ultimate load for slabs reinforced with steel fiber

The maximum failure load of concrete slabs containing sand dunes and reinforced with single and hybrid steel fibers was recorded during the testing of the slabs in Table 4.11. The results of the slabs reinforced with short steel fibers and replacement ratios (0%-100%), showed that the slab (FRDC40%-S) achieved the highest value of the maximum failure load compared to all the slabs reinforced with short fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of (7.2%, 5.8%, 15.6%, 39.9%, and 47.5%), respectively. As shown in Figure 4.100.

Table 4.11 The maximum failure load of fibrous concrete slabs containing D.S

Slab remark	Fcu (MPa)	Fc⁻ (MPa)	Pu (kN) Ultimate failure load	Pu/Pu without fiber %	Change in ultimate load%
FRDC0%-S	65.8	52.64	30.4	1.152	15.2
FRDC0%-L	74.93	59.94	32.1	1.216	21.6
FRDC0%-HY	64.9	51.92	41.9	1.587	58.7
FRDC20%-S	58.7	46.96	30.8	1.128	12.8
FRDC20%-L	62.8	50.24	31.6	1.157	15.7
FRDC20%-HY	65.2	52.16	32.7	1.197	19.7
FRDC40%-S	59.72	47.78	32.6	1.164	16.4
FRDC40%-L	63.3	50.64	33.9	1.2107	21.07
FRDC40%-HY	71.3	57.04	35.1	1.253	25.3
FRDC60%-S	53.2	42.56	28.2	1.0804	8.04
FRDC60%-L	54.5	43.6	29.6	1.134	13.4
FRDC60%-HY	54.04	43.23	29	1.111	11.11
FRDC80%-S	41.8	33.44	23.3	1.069	6.88
FRDC80%-L	46.8	37.44	25.8	1.183	18.35
FRDC80%-HY	43.7	34.96	25.6	1.174	17.43
FRDC100%-S	34.6	27.68	22.1	1.088	8.87
FRDC100%-L	39.1	31.28	22.8	1.123	12.32
FRDC100%-HY	36.4	29.12	22.5	1.108	10.84

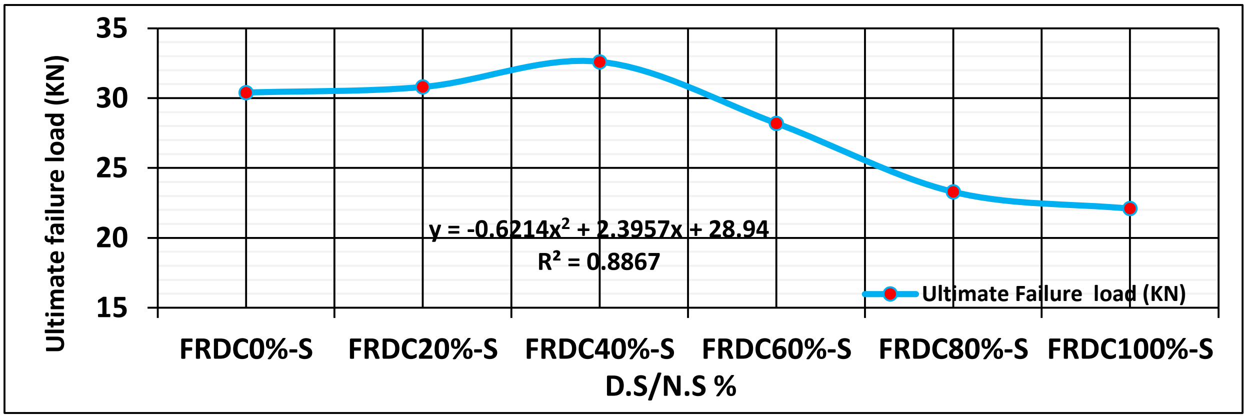


Figure 4.100 The curve of ultimate failure load for slabs reinforced with S.F.S.

The results of the slabs reinforced with long steel fibers showed that the slab (FRDC40%-L) achieved the highest value of the maximum failure load compared to all slabs reinforced with long steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of about (5.6%, 7.2%, 14.5%, 31.3%, and 48.6%), respectively, as shown in Figure 4.101.

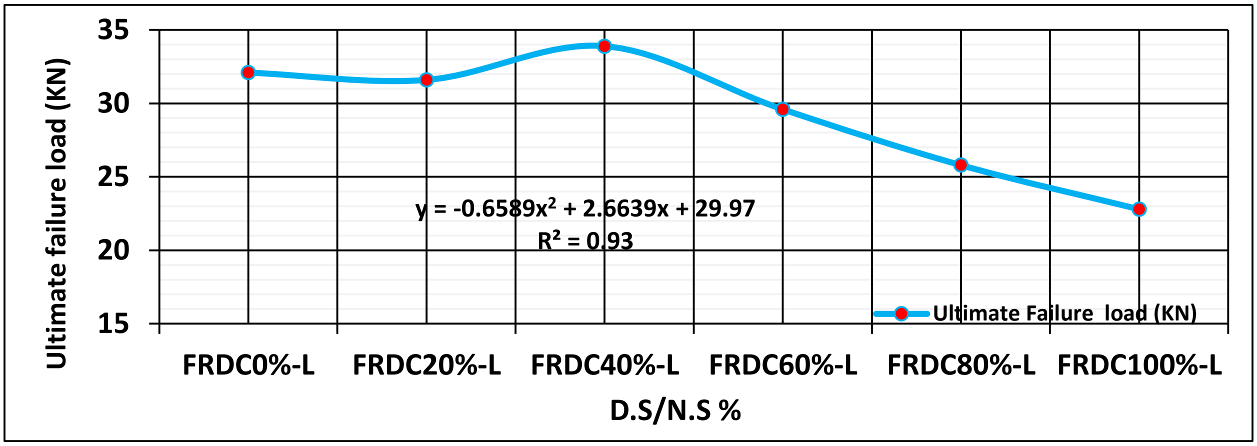


Figure 4.101 The curve of ultimate failure load for slabs reinforced with S.F.L.

The results of the slabs reinforced with hybrid steel fibers showed that the hybrid slab (FRDC0%-HY) achieved the highest value of the maximum failure load compared to all slabs reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (28.1%, 19.3%, 44.5%, 63.6%, and 86.2%) respectively, as shown in Figure 4.102.

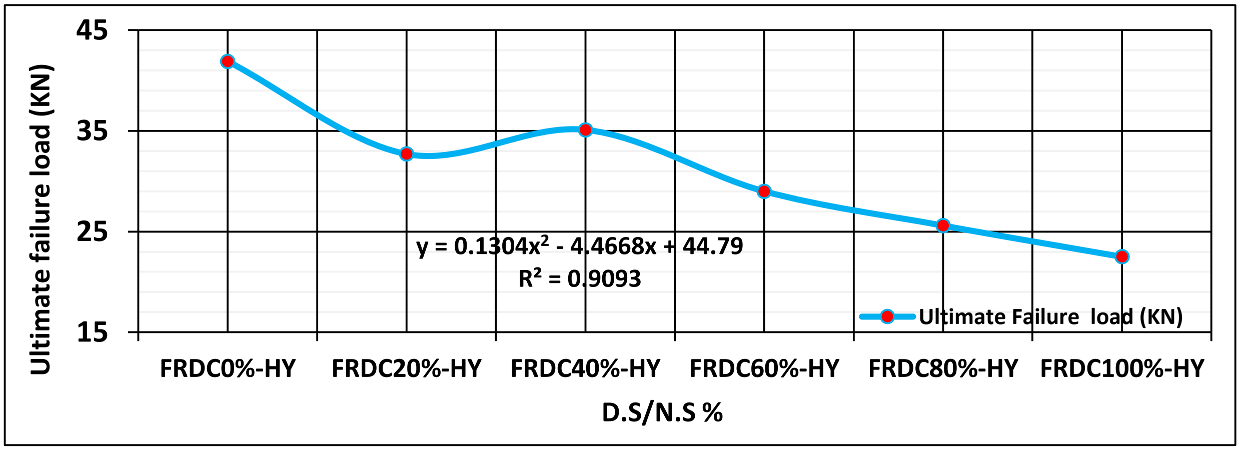


Figure 4.102 The curve of ultimate failure load for slabs reinforced with H.S.F.

The maximum failure load of the slab FRDC0%-S containing short steel fibers is 30.4 kN, an increase of about 15.1% compared to the reference slab DSC0 % without fiber. The results showed that the maximum failure load of slab FRDC0%-L containing long steel fibers is 32.1kN (i.e. 21.5% greater than the reference slab DSC0% without fibers), while the slab FRDC0%-HY containing hybrid steel fibers achieved the greatest value for the maximum failure load of 41.9kN which is greater than the maximum load for all slabs (58.7% greater than the reference slab DSC0% without fibers), as well as an increase of about 37.8% and 30.5% compared to slabs FRDC0%-S and FRDC0%-L, respectively, as shown in Figure 4.103.

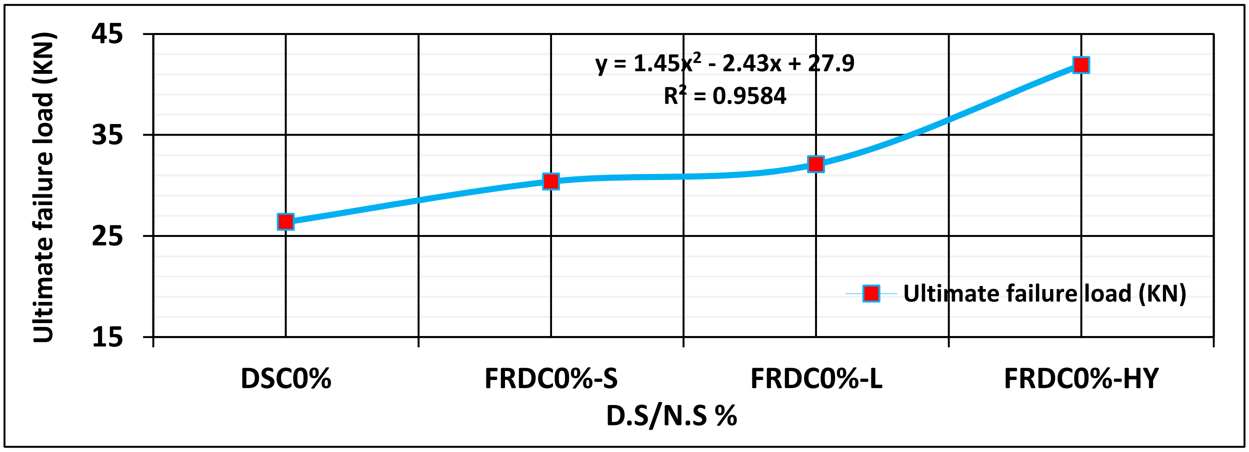


Figure 4.103 The curve of ultimate failure load for slabs containing (0%D.S).

When natural sand is replaced by 20% sand dunes, the maximum failure load for slab FRDC20%-S containing short steel fibers is 30.8kN (12.8% greater than the slab DSC20% without fibers), and the slab FRDC20%-L containing long steel fibers achieved the maximum failure load of 31.6kN, an increase of about 15.7% compared to the slab DSC20% without the fibers. While the slab FRDC20%-HY Containing hybrid steel fibers achieved the maximum failure load of 32.7kN (about 19.7% greater than the slab DSC20% without the fibers). Also, an increase of about 6.1% and 3.5% is greater than the slabs FRDC20%-S and FRDC20%-L, respectively. As shown in Figure 4.104.

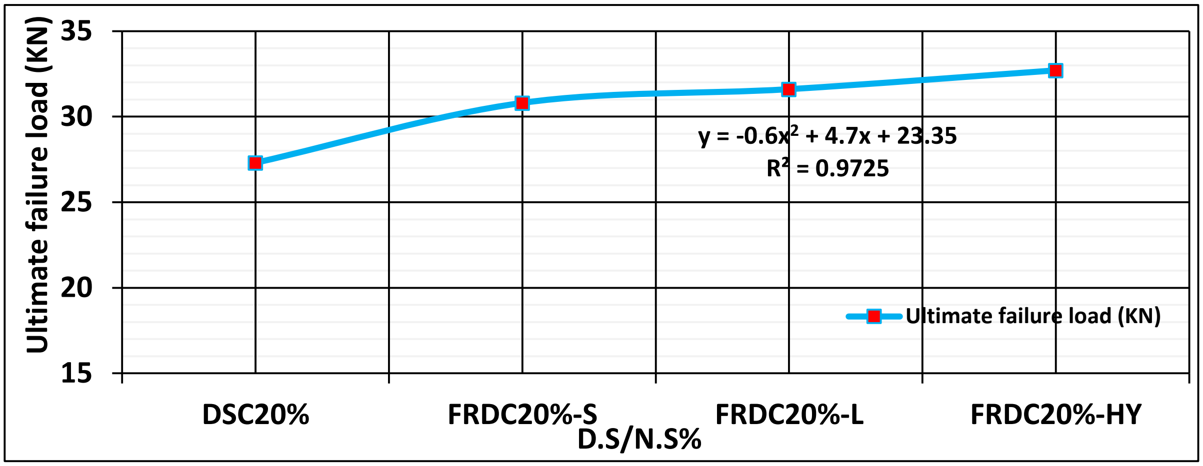


Figure 4.104 The curve of ultimate failure load for slabs containing (20%D.S).

At concrete slab FRDC40%-S that contains short steel fibers with sand dunes of ratio 40% as an alternative for sand, the maximum failure load was 30.8kN (16.4% greater than of the slab DSC40% without fibers). While the slab FRDC40%-L achieved a maximum failure load of 33.9kN (21% greater than the slab DSC 40% without fibers). Also, the slab FRDC40%-HY containing hybrid steel fiber achieved the highest value of 35.1kN, it is higher than all slabs containing sand dunes (that is, 25.3% greater than the slab DSC 40% without fibers), as well as 7.6% and 3.5% greater than the slabs FRDC40%-S and FRDC40%-L, respectively, as shown in Figure 4.105.

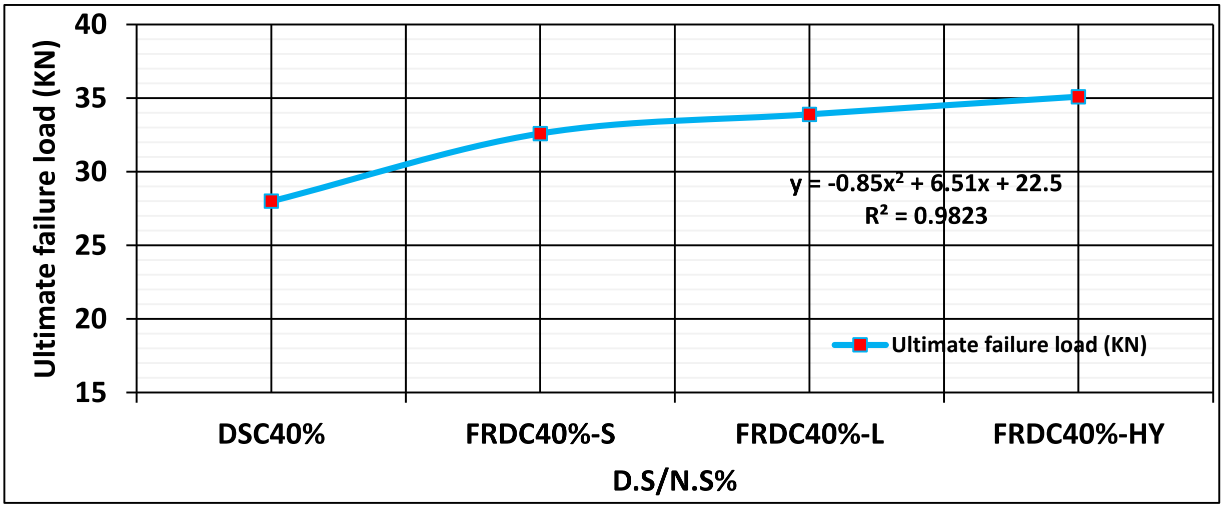


Figure 4.105 The curve of ultimate failure load for slabs containing (40%D.S).

When the sand dunes content by 60% an increased as an alternative for sand, the slab FRDC60%-S achieved a maximum failure load of 28.2kN (8.04% greater than the slab DSC60% without fibers). While the slab FRDC60%-L containing long steel fibers recorded a maximum load of 29.6kN (that is, 13.4% greater than the slab DSC60% without fibers). The maximum failure load of slab FRDC60%-HY is 29kN (namely about 11.1% greater than the slab DSC60% without fibers), it is also, highest than the slab FRDC60%-S by about 2.8%, but it is less by about 2% compared to the slab FRDC60%-L. and as in Figure 4.106 the relationship between the maximum failure load and slabs containing dunes sand of ratio 60% with fibers.

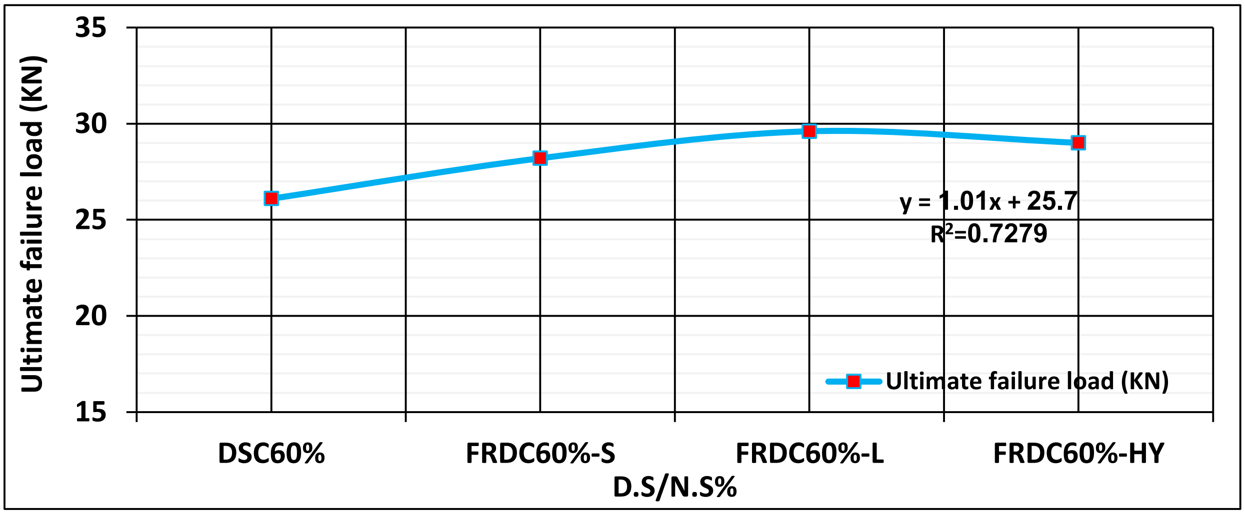


Figure 4.106 The curve of ultimate failure load for slabs containing (60%D.S).

The ultimate failure load of slab FRDC80%-S is 23.3kN (about 6.8% greater than the slab DSC80% without fibers), while the maximum failure load of slabs FRDC80%-L and FRDC80%-HY were 25.8kN and 25.6kN, an increase of about 18.3% and 17.4%, respectively, compared to the slab DSC80%without fibers. Also, the slab FRDC80%-HY achieved an increase of about 9.8% compared to the slab FRDC80%-S, but it is less by about 0.7% compared to the slab FRDC80%-L as shown in Figure 4.107.

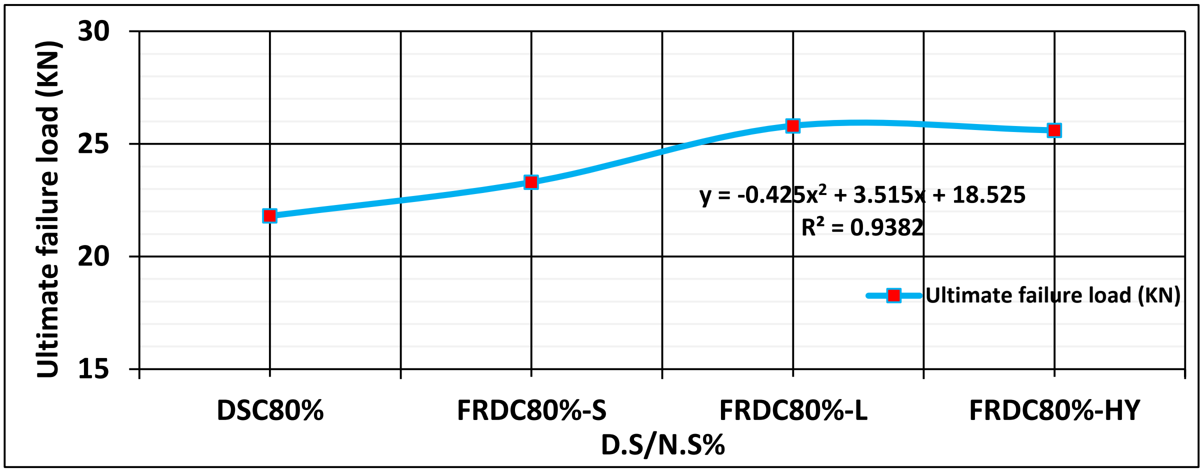


Figure 4.107 The curve of ultimate failure load for slabs containing (80%D.S).

When natural sand is replaced with 100% sand dunes for slab FRDC100%-S reinforced with short steel fibers, the results showed a reduction in maximum failure load of 22.1kN but higher by about 8.8% compared to the slab DSC100% without fibers. Also, the slabs FRDC100%-L and FRDC100%-HY recorded a maximum failure load of 22.8kN and 22.5kN (increased by about 12.3% and 10.8%, respectively compared to the slab DSC100% without fibers), also, the slab FRDC100%-HY recorded an increase in the maximum failure load of about 1.8% greater than of the slab FRDC100%-S, but it is less than the slab FRDC100%-L by about 1.3%, and as shown in Figure 4.108 the relationship between the maximum failure load and slabs containing sand dunes of ratio 100% with fibers.

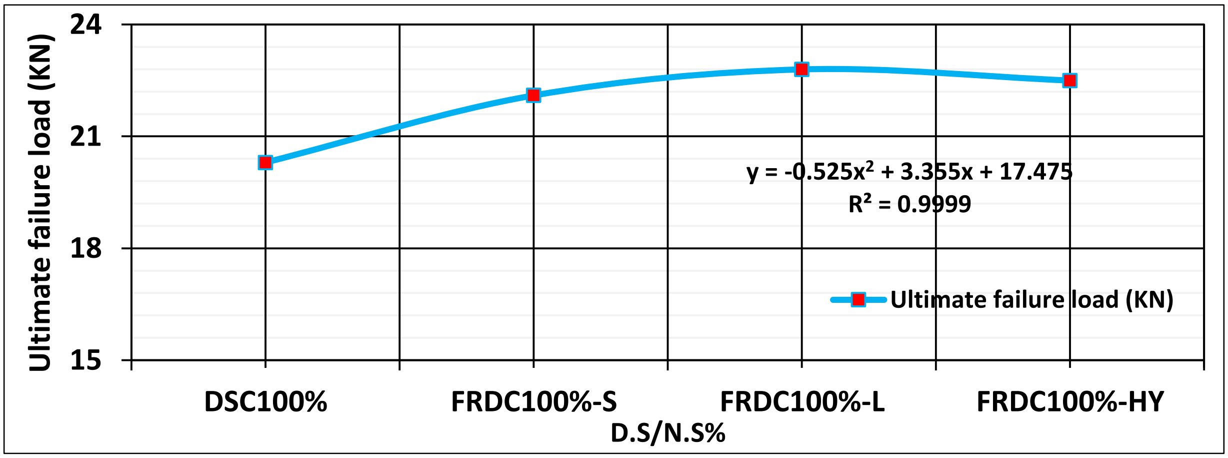


Figure 4.108 The curve of ultimate failure load for slabs containing (100%D.S).

4.2.2.4 Load – Deflection behavior

4.2.2.4.1 Load – Deflections behavior for slabs without steel fiber

The ultimate deflection was obtained during testing for all concrete slabs containing sand dunes as an alternative for sand without steel fibers and listed in Table 4.12, The load-deflection curve is drawn at mid-span for all slabs without fibers, as shown in Figure 4.109 . And draw the relationship between the ultimate deflection and slabs containing sand dunes as an alternative to sand, without fibers, as shown in Figure 4.110. The results showed that the reference concrete slab without fibers DSC0% achieved a maximum deflection of 22.685 mm, which is the highest deflection compared to all slabs that contain different percentages of sand dunes as an alternative to sand without fibers. The results also showed a gradual decrease in the maximum deflection with the increase of the sand dunes content as an alternative for sand in the concrete slabs. Whereas, the DSC 20% concrete slab recorded a deflection of 20.881mm with a decrease of about 7.95% compared to the reference slab. The results also showed a decrease in the maximum deflection with an increase in sand dunes content in the slabs, where the slabs DSC40%, DSC60%, and DSC80% recorded a maximum deflection of 20.396mm, 20.325mm, and 18.52mm with a decrease by about 10.09%, 10.40%, and 18.36%, respectively compared to with reference slab. While, the DSC100% concrete slab, which contains sand dunes of ratio 100%, achieved a maximum deflection of 19.94mm, with a decrease by about 12.1% compared to the reference slab.

The behavior of concrete slabs containing sand dunes as an alternative for sand without fibers through the path of descending ultimate deflection which decreases with increasing sand dunes content in concrete slabs is brittle behavior which is to be expected due to the absence of steel reinforcement, and through Figure 4.109, we notice that the load-deflection curve has taken a linear path to failure, and this shows the brittle behavior of these slabs without fiber. Also, these slabs do not show any visible cracks before the final failure, where these slabs suddenly failed at maximum load without any noticeable deflection warning during the test.

Table 4.12 The ultimate deflection of concrete slabs containing sand dunes

Slab remark	Pu (kN) Ultimate failure load	Ultimate deflection (mm) Δu	Δu / Δu Reference slab %	Change in deflection %
DSC0%	26.4	22.685	100	0
DSC20%	27.3	20.881	92.05	-7.95
DSC40%	28	20.396	89.91	-10.09
DSC60%	26.1	20.325	89.59	-10.40
DSC80%	21.8	18.52	81.64	-18.36
DSC100%	20.3	19.94	87.89	-12.10

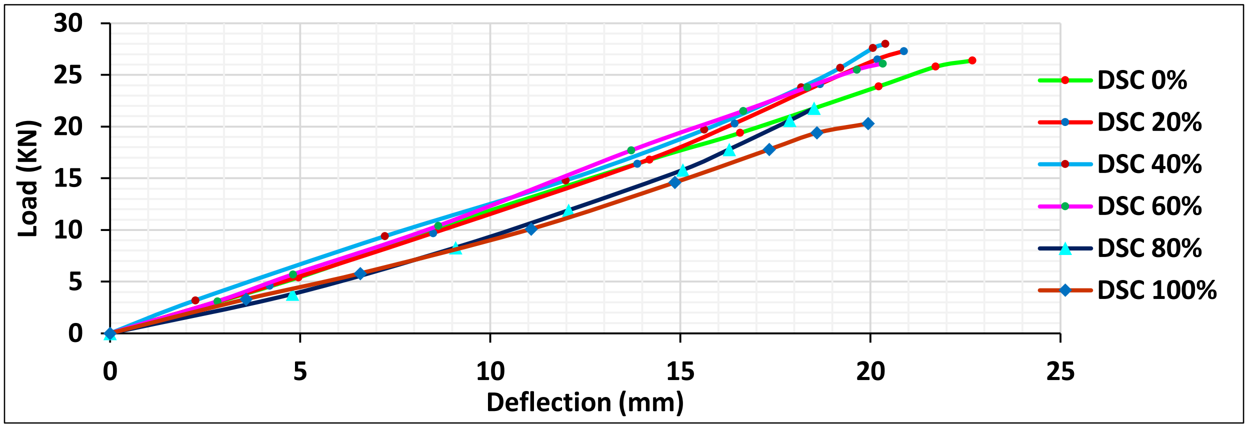


Figure 4.109 Load - deflection curves for concrete slabs containing D.S without fiber.

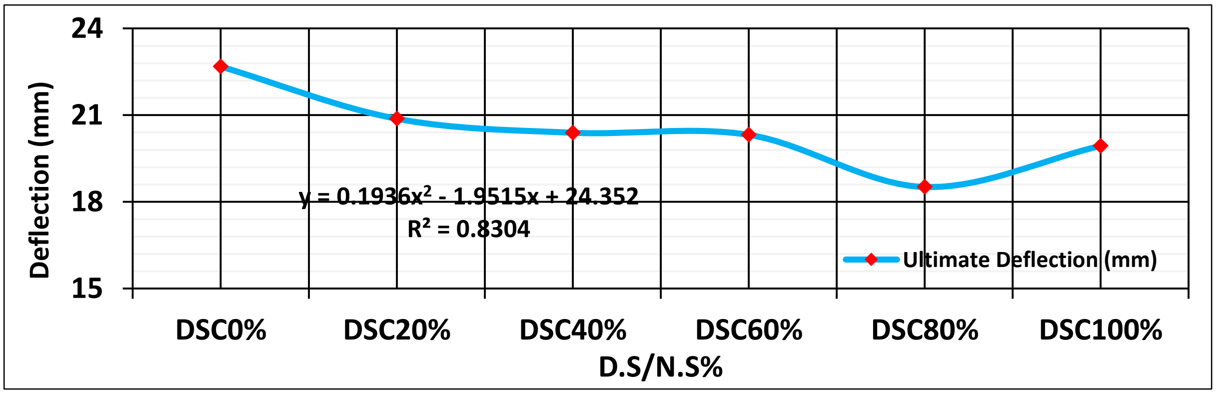


Figure 4.110 The curve of maximum deflections for concrete slabs without fibers.

4.2.2.4.2 Load – deflections behavior for slabs reinforced with steel fiber

The maximum deflection of all concrete slabs containing sand dunes as a partial and total replacement for sand and reinforced with steel fibers was listed in Table 4.13 and the load-deflection curve was plotted for each major replacement group separately.

Table 4.13 The ultimate deflection of concrete slabs containing D.S with fiber

Slab remark	Pu (kN) Ultimate failure load	Ultimate deflection Δu (mm)	Δu / Δu without fiber %	Change in deflection %
FRDC0%-S	30.4	25.146	110.8	10.8
FRDC0%-L	32.1	19.337	85.2	-14.7
FRDC0%-HY	41.9	23.744	104.7	4.67
FRDC20%-S	30.8	24.094	115.4	15.38
FRDC20%-L	31.6	20.808	99.65	-0.35
FRDC20%-HY	32.7	21.817	104.48	4.5
FRDC40%-S	32.6	22.457	110.10	10.1
FRDC40%-L	33.9	16.673	81.7	-18.25
FRDC40%-HY	35.1	22.306	109.4	9.36
FRDC60%-S	28.2	19.903	97.9	-2.07
FRDC60%-L	29.6	19.196	94.4	-5.55
FRDC60%-HY	29	22.911	112.7	12.7
FRDC80%-S	23.3	18.502	99.90	-0.097
FRDC80%-L	25.8	20.467	110.51	10.51
FRDC80%-HY	25.6	20.614	111.31	11.31
FRDC100%-S	22.1	19.693	98.76	-1.24
FRDC100%-L	22.8	18.129	90.92	-9.08
FRDC100%-HY	22.5	20.969	105.16	5.16

The results of the slabs reinforced with short steel fibers and replacement ratios (0%-100%), showed that the slab (FRDC0%-S) achieved the highest value of the maximum deflection compared to all the slabs reinforced with short fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of (4.3%, 11.9%, 26.3%, 35.9%, and 27.6%), respectively. As shown in Figure 4.111.

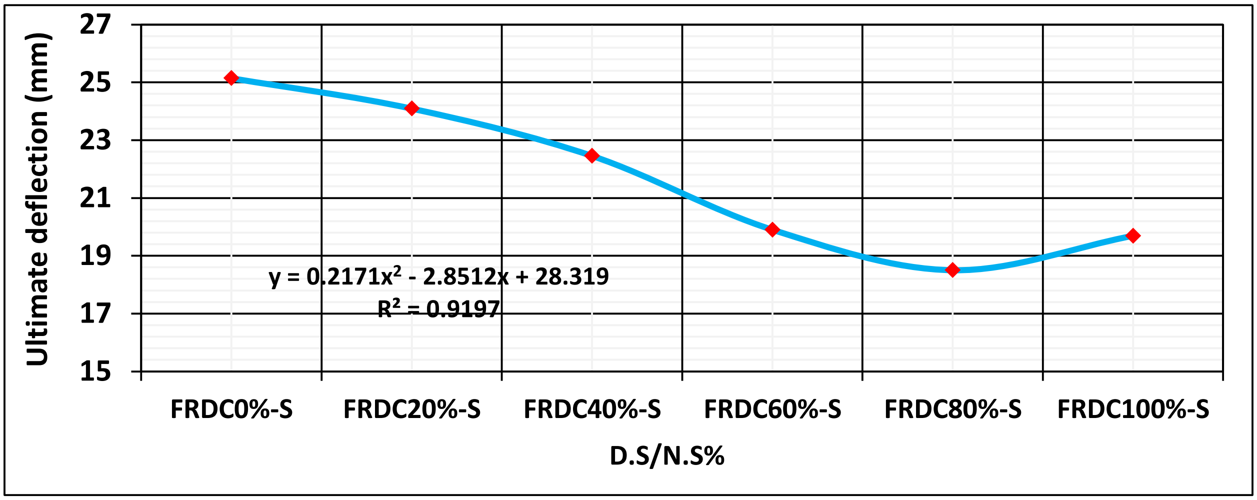


Figure 4.111 The curve of ultimate deflection for slabs reinforced with S.F.S.

The results of the slabs reinforced with long steel fibers showed that the slab (FRDC20%-L) achieved the highest value of the maximum deflection compared to all slabs reinforced with long steel fibers and replacement ratios (0%, 40%, 60%, 80%, 100%) with an increase of about (7.6%, 24.8%, 8.4%, 1.6%, and 14.7%), respectively, as shown in Figure 4.112.

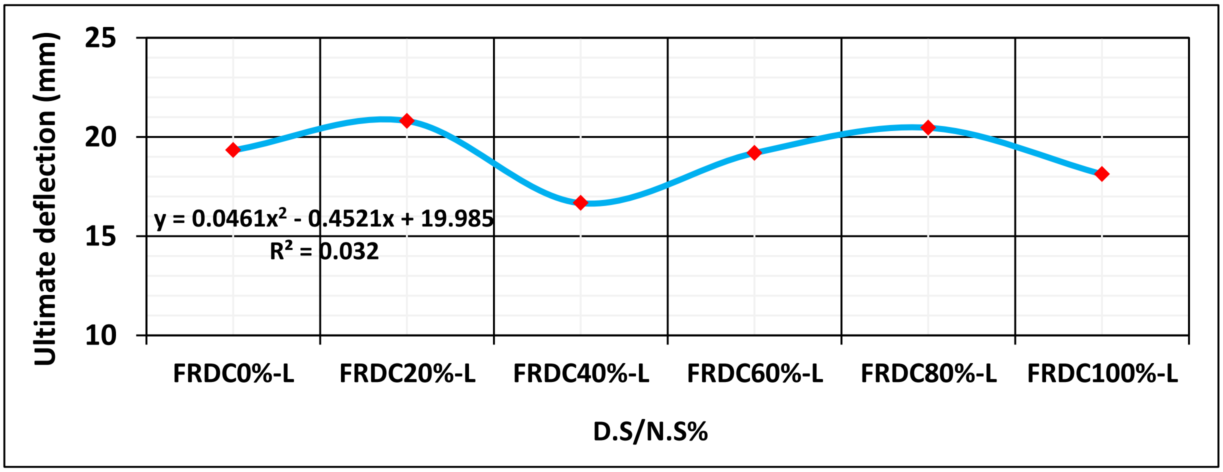


Figure 4.112 The curve of ultimate deflection for slabs reinforced with S.F.L.

The results of the slabs reinforced with hybrid steel fibers showed that the hybrid slab (FRDC0%-HY) achieved the highest value of the maximum deflection compared to all slabs reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (8.8%, 6.4%, 3.6%, 15.1%, and 13.2%) respectively, as shown in Figure 4.113.

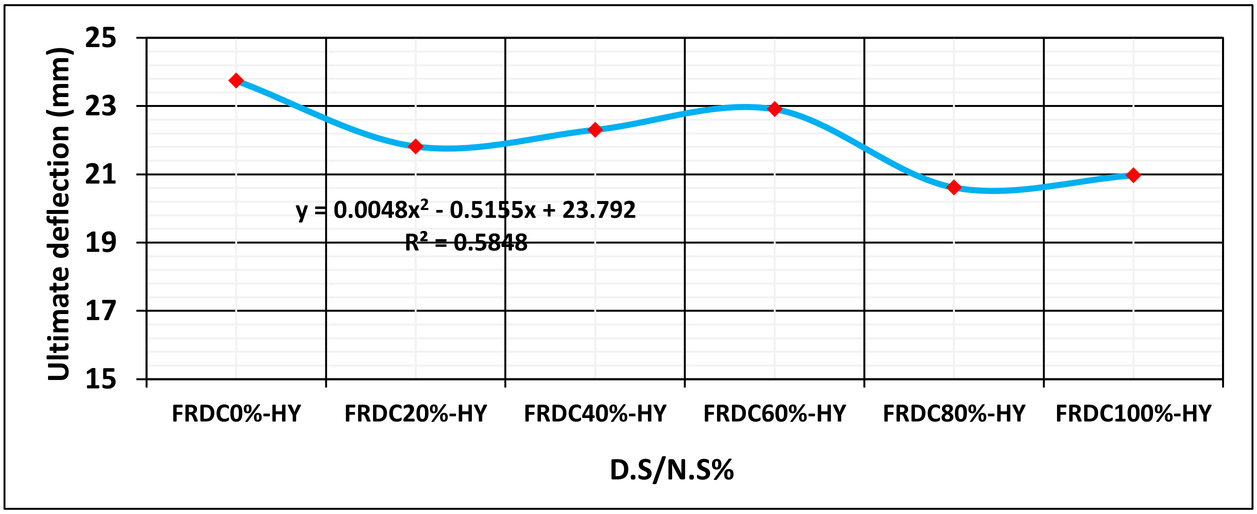


Figure 4.113 The curve of ultimate deflection for slabs reinforced with H.S.F.

The results showed that the FRDC0%-S concrete slab without sand dunes achieved a maximum deflection of 25.146mm, which is higher than the maximum deflection of all slabs, with an increase of about 10.8% compared to the DSC0% slab without fibers. Then the maximum deflection of the slabs decreases when using long steel fibers without dunes sand, where the FRDC0%-L slab recorded a maximum deflection of 19.337mm (with a decrease of 14.7% compared to the DSC0% slab without fibers). While the slab FRDC0%-HY containing hybrid steel fibers achieved a maximum deflection of 23.744mm (4.6% greater than the DSC0% slab without the fibers), It is also less than the slab FRDC0%-S by about 5.6% and greater than the slab FRDC0%-L by about 22.8%, as shown in Figure 4.114 and Figure 4.115.

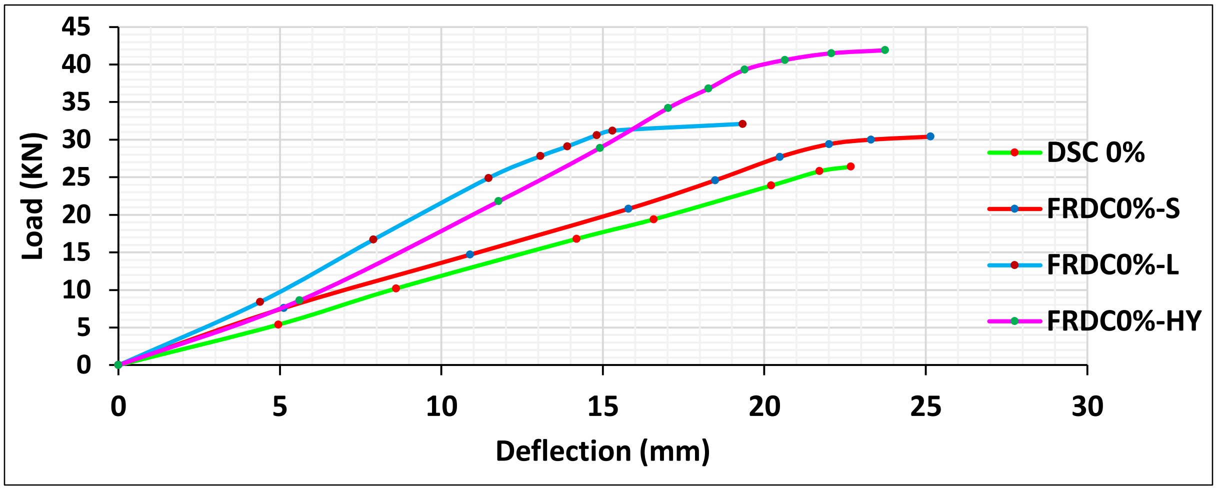


Figure 4.114 Load - deflection curves for slabs containing sand dunes 0%.

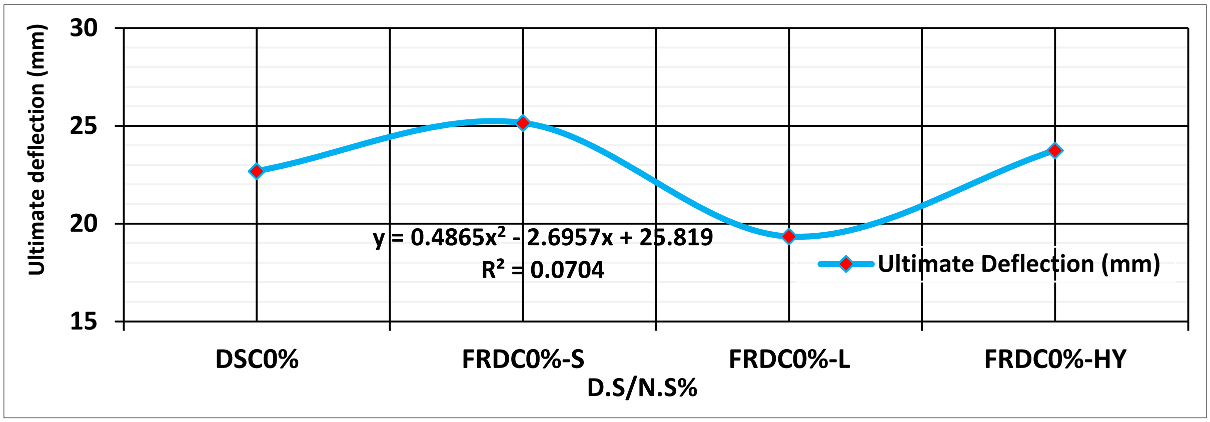


Figure 4.115 The curve of ultimate deflection for slabs containing (0%D.S).

When sand dunes is alternative for the sand of ratio 20%, the maximum deflection of FRDC20%-S is increased by 24.094mm (15.4% higher than that of DSC20% without fibers), while the slabFRDC20%-L recorded a maximum deflection of 20.808mm with a small decrease of 0.3%. Less than the slab DSC 20% without fibers. While the slab FRDC20%-HY containing the hybrid steel fiber achieved an increase in the maximum deflection of 21.817mm (4.5% increase compared to the slab DSC20 % without the fibers). Also, It is less than the slab FRDC20%-S by 9.4% and higher than the slab FRDC20%-L by about 4.8%, as shown in Figure 4.116 and Figure 4.117.

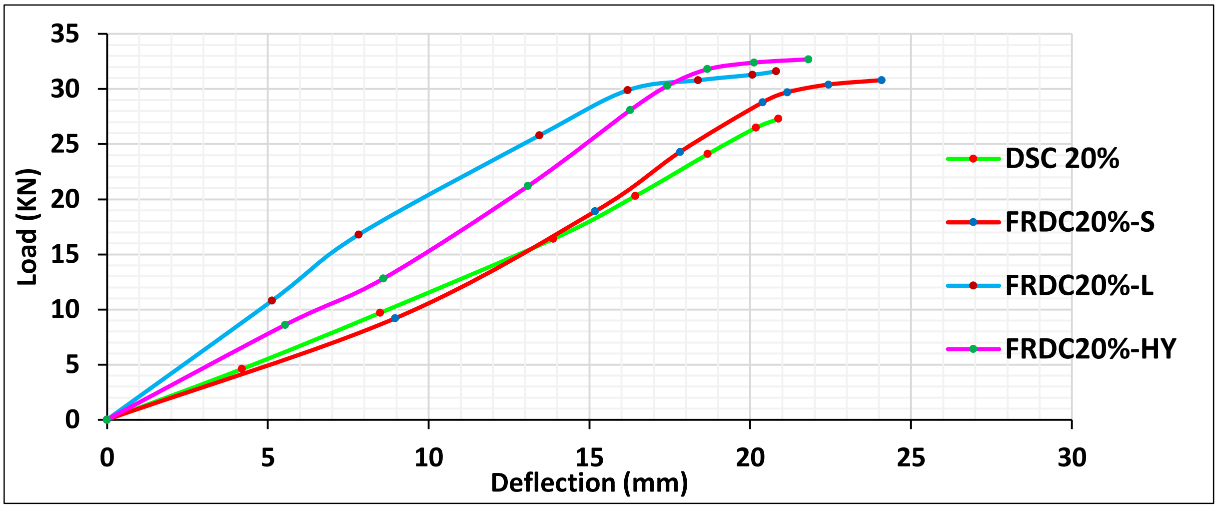


Figure 4.116 Load - deflection curves for slabs containing sand dunes 20%.

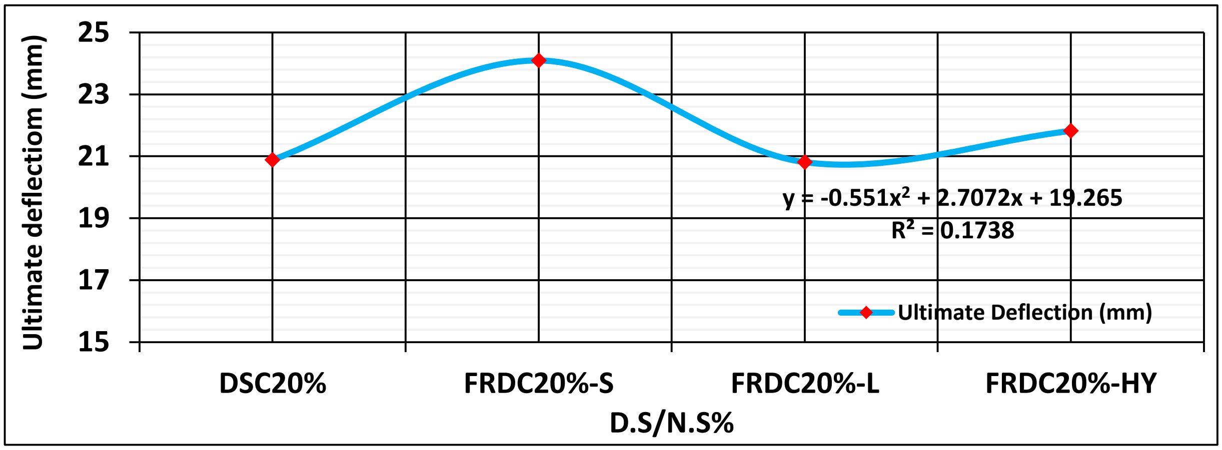


Figure 4.117 The curve of ultimate deflection for slabs containing (20%D.S).

For the FRDC40%-L concrete slab containing short steel fibers with 40% sand dunes, the maximum deflection was 22.457mm (10.1% greater than the slab DSC40% without fibers), while the slab FRDC40%-L recorded a maximum deflection of 16.673mm (With a decrease by about 18.2% less than the slab DSC 40% without fibers). While the slab FRDC40%-HY containing hybrid steel fibers achieved a maximum deflection of 22.306mm (i.e. 9.36% higher than the slab DSC40 % without the fibers), also, It is lower than the slab FRDC40%-S by about 0.67% and higher than the slab FRDC40%-L by about 33.7%, as shown in Figure 4.118 and Figure 4.119.

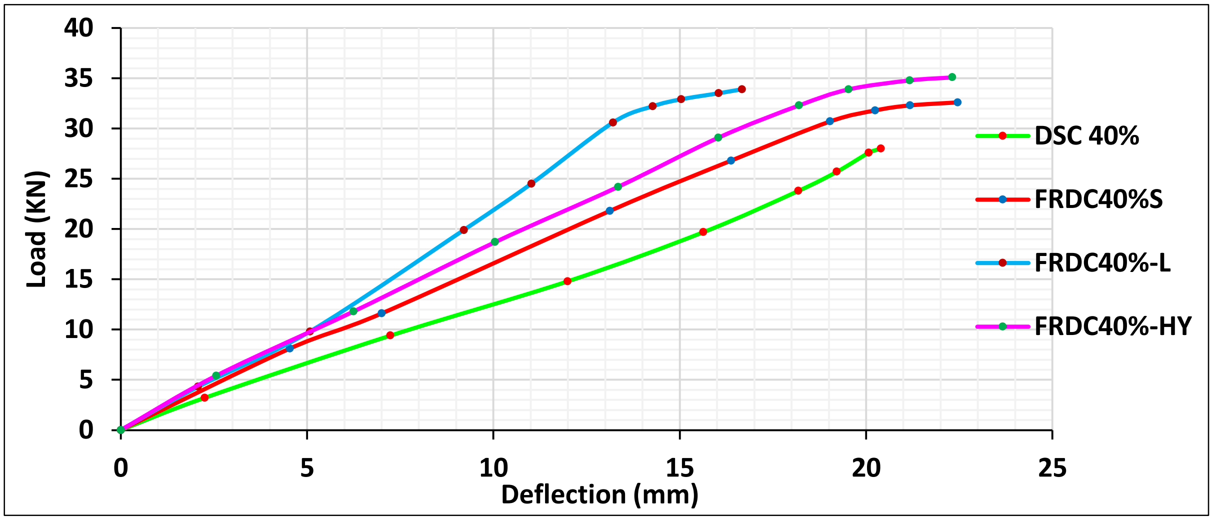


Figure 4.118 Load - deflection curves for slabs containing sand dunes 40%.

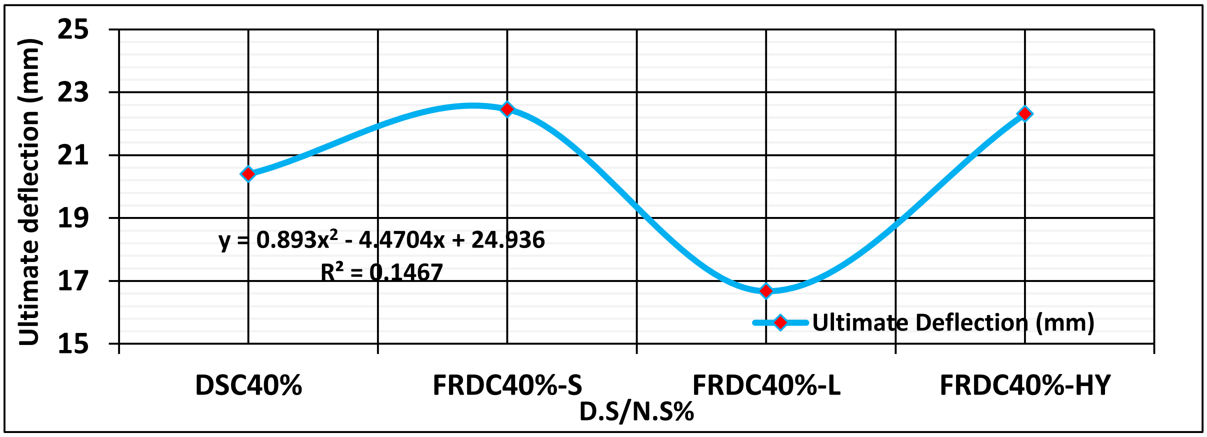


Figure 4.119 The curve of ultimate deflection for slabs containing (40%D.S).

When the sand dunes content is increased by 60%, the ultimate deflection of slabs FRDC60%-S and FRDC60%-L was 19.903mm and 19.196mm with a decrease of (2% and 5.5%, respectively less than the slab DSC60% without fibers), while the FRDC60%-HY slab achieved an increase in the maximum deflection of 22.911mm (12.7% higher than the DSC60% slab without fibers). It is also higher than FRDC60%-S and FRDC60%-L slabs with an increase of 15.1% and 19.3%, respectively, and as shown in Figure 4.120 and Figure 4.121.

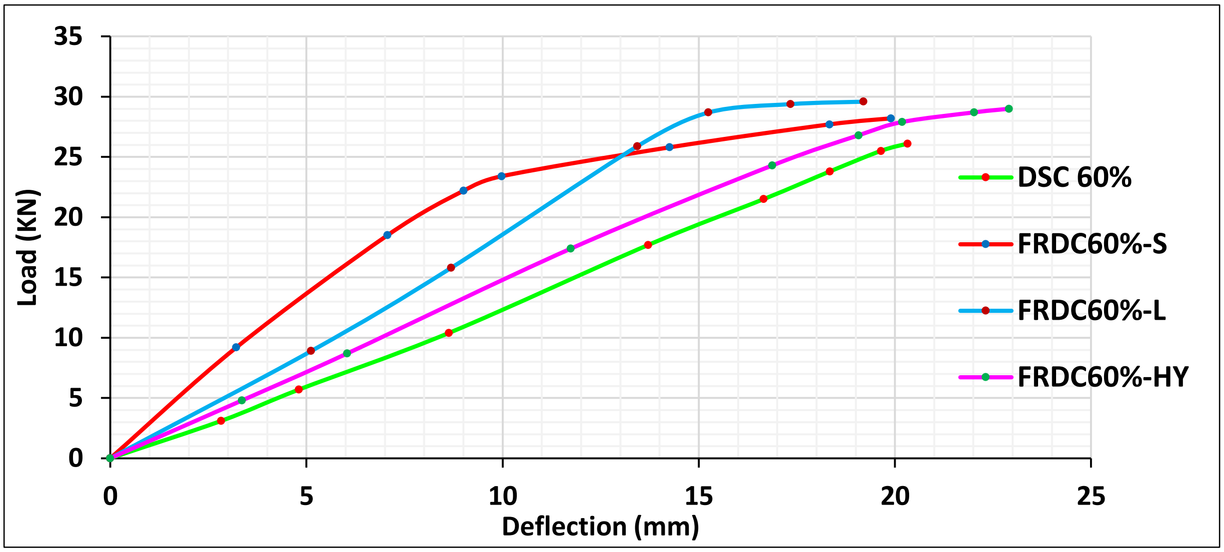


Figure 4.120 Load - deflection curves for slabs containing sand dunes 60%.

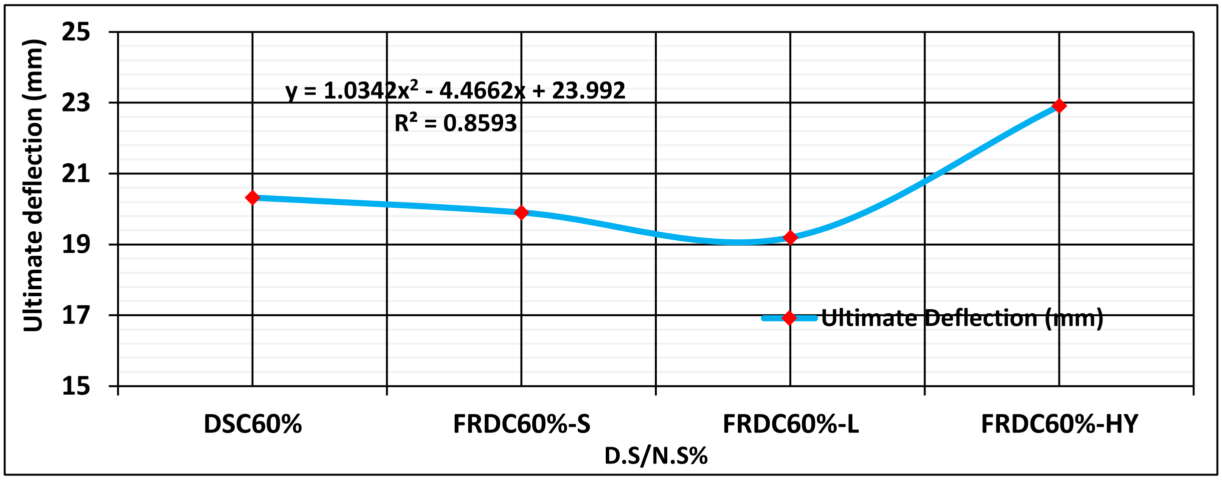


Figure 4.121 The curve of ultimate deflection for slabs containing (60%D.S).

The maximum deflection of the FRDC80%-S slab is 18.502 mm, a slight decrease of 0.09% compared to the DSC80% slab without fibers, while the FRDC80%-L and FRDC80%-HY slabs achieved the maximum deflection of 20.467mm and 20.614mm, an increase of 10.5% and 11.3%, respectively, compared to the slab DSC80% without fibers, also, the FRDC80%-HY slab achieved an increase in ultimate deflection by 11.4% and 0.72% higher than the FRDC80%-S and FRDC80%-L slabs respectively, as shown in Figure 4.122 and Figure 4.123.

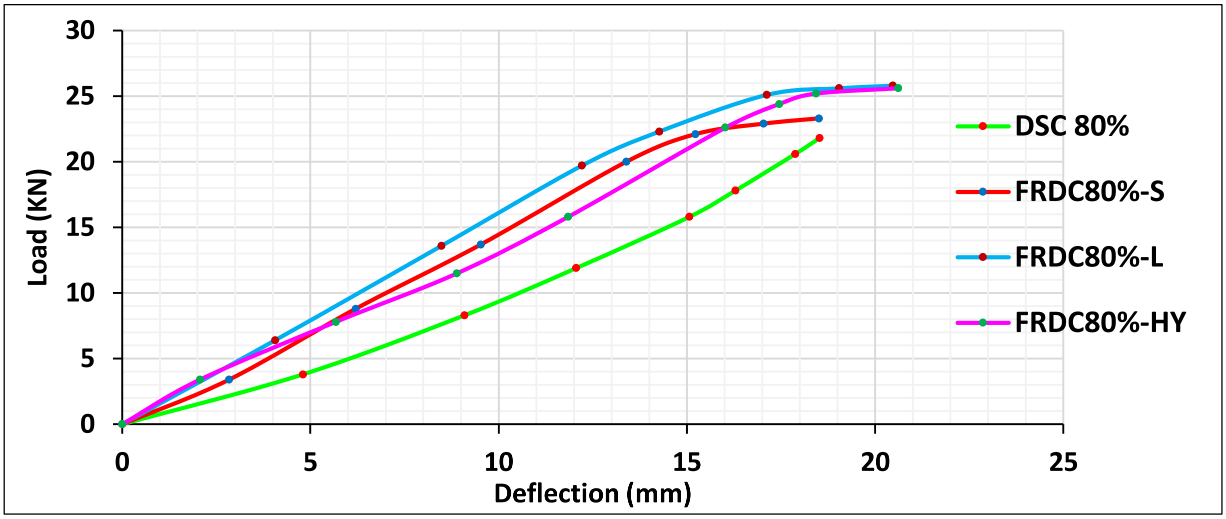


Figure 4.122 Load - deflection curves for slabs containing sand dunes 80%.

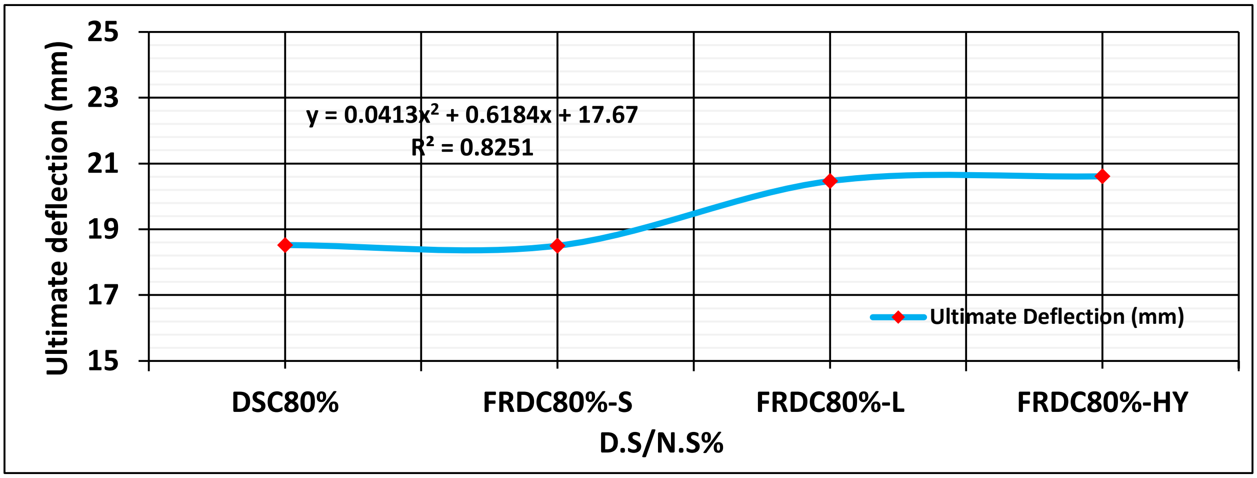


Figure 4.123 The curve of ultimate deflection for slabs containing (80%D.S).

When sand dunes is alternative for the sand of ratio 100%, the FRDC100%-S slab achieved a maximum deflection of 19.693mm (1.2% less than the DSC100% slab without fibers), while the FRDC100%-L slab achieved a maximum deflection of 18.129mm, a decrease of about 9% compared to the slab. DSC100% without fibers. The slab FRDC100%-HY containing hybrid steel fibers recorded a maximum deflection of 20.969mm, an increase of 5.2% higher than the DSC100% slab without the fibers, as well as higher than the FRDC100%-S and FRDC100%-L slabs, with an increase of about 6.5% and 15.6%, respectively. In Figure 4.124 and Figure 4.125.

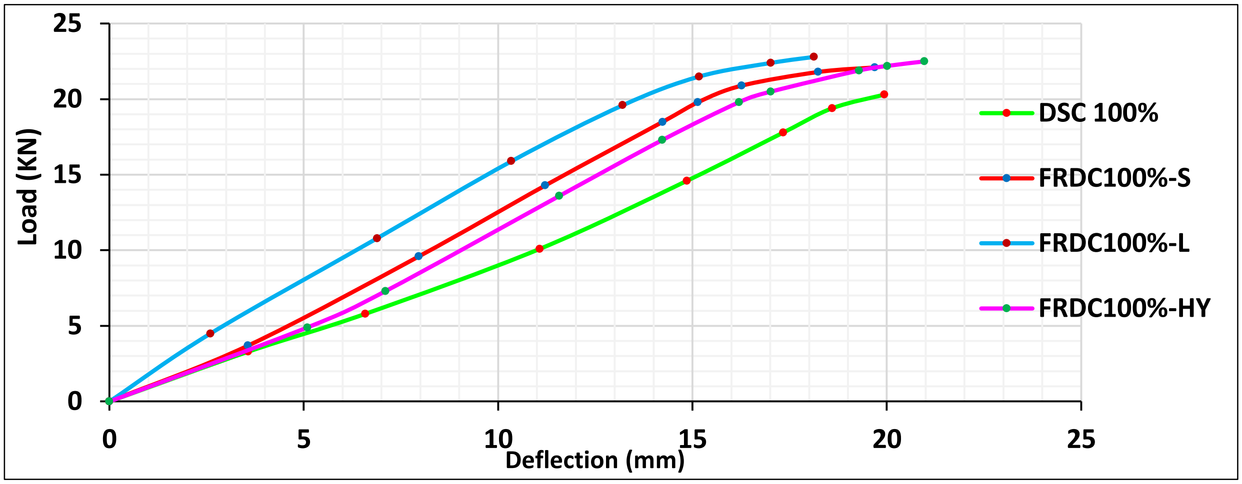


Figure 4.124 Load - deflection curves for slabs containing sand dunes 100%.

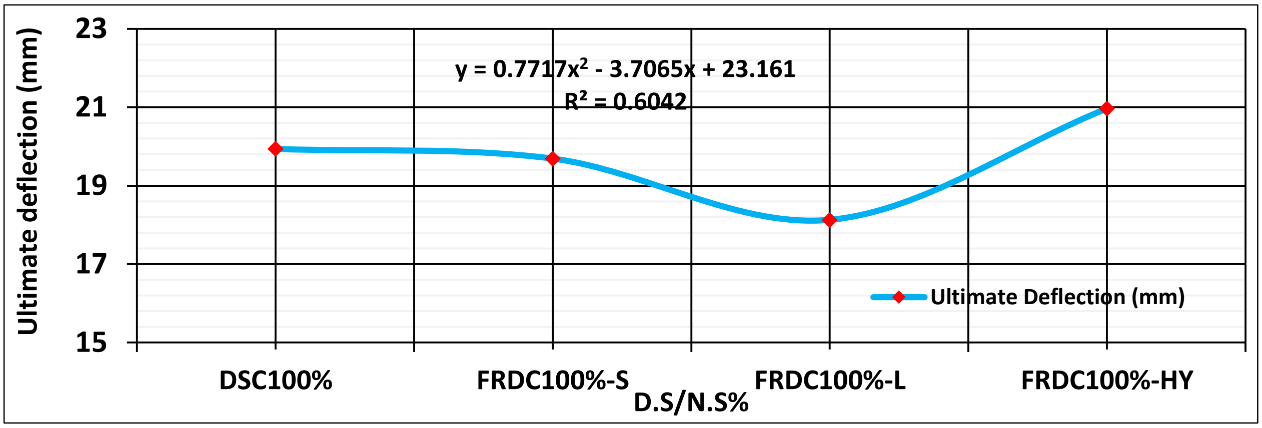


Figure 4.125 The curve of ultimate deflection for slabs containing (100%D.S).

From the analysis of the above results, appears the behavior of the concrete slabs through the maximum deflection path and according to the type of added fibers and the proportion of sand dunes in the slabs, the load-deflection curve of most specimens takes a linear path, and some of them are non-linear to failure, and this shows the elastic behavior of most concrete slabs that contain steel fibers. Also, these slabs containing steel fibers maintained their integrity for a longer time before failure and reached relatively high or low varying deflection after the final load, as in the FRDC0%-S slab, which had the greatest deflection, this indicates a prolongation of the fracture time and gives a warning before failure, especially in earthquake-prone sites.

4.2.2.5 Ductility index

It is the ability of the reinforced concrete structure to face larger deformations before final failure or without a complete collapse. The ductility can get from the load-deflection curve, which is equal to the ratio of the maximum deflection (Δu) to the deflection at yield (Δy). Table 4.14 shows the ductility, albeit low, of slabs containing different percentages of sand dunes reinforced with fibers. From the load-deflection curves of concrete slabs without fibers, the behavior of all these slabs is brittle and there is no ductility, and the curve path takes a linear path until collapse.

Table 4.14 Ductility results for slabs specimens containing D.S with fiber

Slab remark	Ultimate deflection Δu (mm)	Yield deflection Δy (mm)	Ductility index	Change in Ductility%
FRDC0%-S	25.146	22.012	1.14	-
FRDC20%-S	24.094	21.684	1.11	-2.6
FRDC40%-S	22.457	19.031	1.18	3.5
FRDC60%-S	19.903	14.634	1.36	19.3
FRDC80%-S	18.502	15.225	1.22	7.01
FRDC100%-S	19.693	15.699	1.25	9.6
--------------------	------------	------------	---------	---------------
FRDC0%-L	19.337	15.304	1.26	-
FRDC20%-L	20.808	16.198	1.28	1.58
FRDC40%-L	16.673	13.211	1.26	0
FRDC60%-L	19.196	15.245	1.26	0
FRDC80%-L	20.467	17.121	1.19	-5.6
FRDC100%-L	18.129	15.169	1.19	-5.6
--------------------	------------	------------	---------	---------------
FRDC0%-HY	23.744	20.638	1.15	-
FRDC20%-HY	21.817	18.676	1.17	1.74
FRDC40%-HY	22.306	18.195	1.23	6.95
FRDC60%-HY	22.911	20.184	1.14	-0.87
FRDC80%-HY	20.614	17.911	1.15	0
FRDC100%-HY	20.969	19.289	1.09	-5.22

Figure 4.126 show the ductility and replacement ratios of D.S for slabs containing short steel fiber.

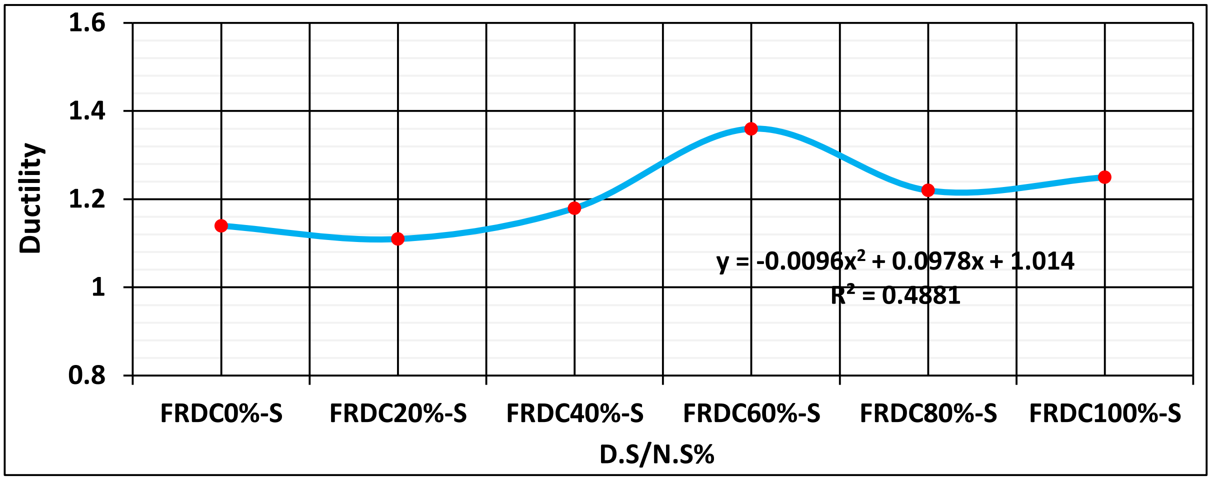


Figure 4.126 The curve of ductility for slabs reinforced with short steel fibers.

It can be seen from Table 4.14 and Figure 4.126 that the ductility index follows a convergent path for all slabs containing short steel fibers, with a variation in ductility, even if it limited to some slabs. The ductility also increased with the increase of the sand dunes content of ratio 60%, where the slab FRDC60%-S achieved the greatest ductility of 1.36 compared to all slabs. This explains the compatibility of the content of dune sand by 60% with the short steel fibers (that is, 19.3% higher than the ductility of the FRDC0%-S slab without sand dunes) due to the effect of the fineness of the grains dunes sand and their interaction with the short steel fibers inside the concrete mix, the ductility of this slab increased, it is also higher by about 22.5%, 15.2%, 11.5% and 8.8% compared to slabs FRDC20%-S, FRDC40%-S, FRDC60%-S, FRDC80%-S, and FRDC100%-S, respectively.

Figure 4.127 shows the ductility path is convergent for all slabs containing long steel fibers, even if the ductility is low. The FRDC20%-L slab achieved the highest ductility compared to slabs containing long fibers, amounting by about 1.28 (namely, 1.58% higher than the ductility of the FRDC 0% -L slab without dunes sand), it is also 1.58% higher compared to FRDC40%-L and FRDC60%-L slabs, also 7.5% larger than FRDC80%-L and FRDC80%-L slabs.

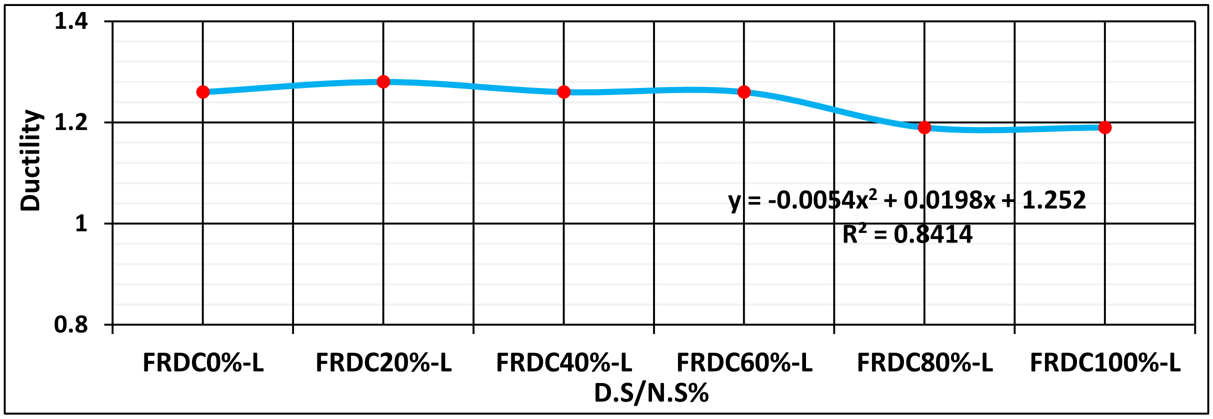


Figure 4.127 The curve of ductility for slabs reinforced with long steel fibers.

From Table 4.14, shows the ductility results of slabs containing hybrid steel fibers are convergent, even if the ductility is low. However, the ductility increased with the increase of the sand dunes content in the slabs of ratio 40%, where the slab FRDC40%-HY achieved the greatest ductility value of 1.23 Compared to other hybrid slabs (i.e. 6.95% greater than FRDC0%-HY slab without dunes sand), it is also higher by about 5.13%, 7.89%, 6.95%, and 12.8%% compared to FRDC20%-HY, FRDC60%-HY, FRDC80%-HY, and FRDC100%-HY slabs respectively. Figure 4.128, explains the compatibility of the dunes sand content of ratio 40% as an alternative for sand with the hybrid steel fibers inside the concrete slab due to the high fineness of the sand dunes granules and their interaction with the hybrid steel fibers within the mixture of this slab.

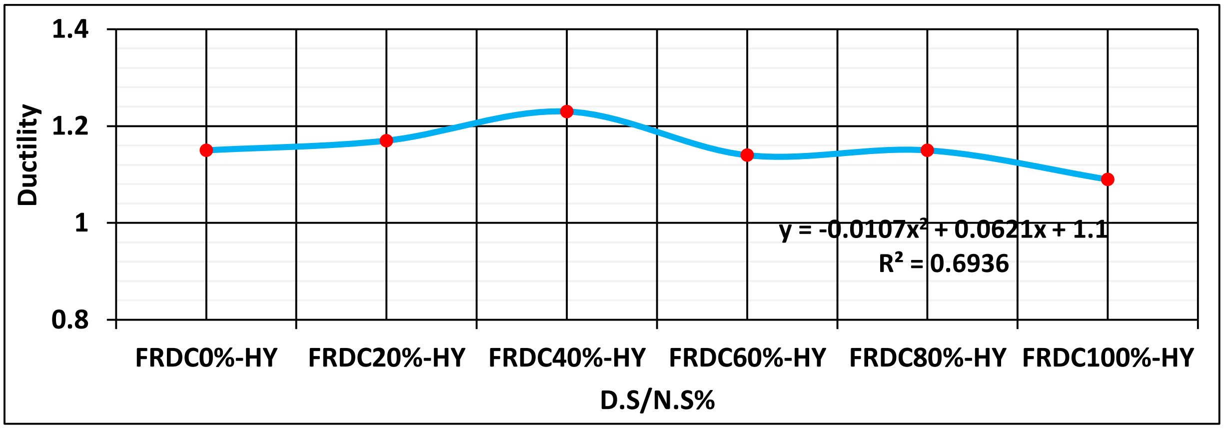


Figure 4.128 The curve of ductility for slabs reinforced with hybrid steel fibers.

4.2.2.6 Flexural Strain at ultimate load

The results of readings flexural compression strain at ultimate load for concrete slabs shown in Table 4.15.

Table 4.15 Strain value for slabs specimens containing sand dunes

Slab remark	(D.S/N.S)+FIBER	Compression strain	Changing %
DSC0%	0%D.S	0.00279	0
DSC20%	20%D.S	0.00257	-7.88
DSC40%	40%D.S	0.00251	-10.04
DSC60%	60%D.S	0.0025	-10.39
DSC80%	80%D.S	0.00228	-18.28
DSC100%	100%D.S	0.00245	-12.18
FRDC0%-S	0%D.S+1%S.F.S	0.00309	10.75
FRDC0%-L	0%D.S+1%S.F.L	0.00238	-14.69
FRDC0%-HY	0%D.S+1%H.S.F	0.00293	5.02
FRDC20%-S	20%D.S+1%S.F.S	0.00297	15.56
FRDC20%-L	20%D.S+1%S.F.L	0.00256	-0.389
FRDC20%-HY	20%D.S+1%H.S.F	0.00268	4.28
FRDC40%-S	40%D.S+1%S.F.S	0.00276	9.96
FRDC40%-L	40%D.S+1%S.F.L	0.00205	-18.33
FRDC40%-HY	40%D.S+1%H.S.F	0.00274	9.16
FRDC60%-S	60%D.S+1%S.F.S	0.00245	-2
FRDC60%-L	60%D.S+1%S.F.L	0.00236	-5.6
FRDC60%-HY	60%D.S+1%H.S.F	0.00282	12.8
FRDC80%-S	80%D.S+1%S.F.S	0.00228	0
FRDC80%-L	80%D.S+1%S.F.L	0.00252	10.53
FRDC80%-HY	80%D.S+1%H.S.F	0.00254	11.40
FRDC100%-S	100%D.S+1%S.F.S	0.00242	-1.22
FRDC100%-L	100%D.S+1%S.F.L	0.00223	-8.98
FRDC100%-HY	100%D.S+1%H.S.F	0.00258	5.31

The results show that the compression strain at the maximum load decreases with the increase in the percentage of dunes sand for concrete slabs without fibers. As shown from the strain-mixtures curve for slabs without fibers in Figure 4.129.

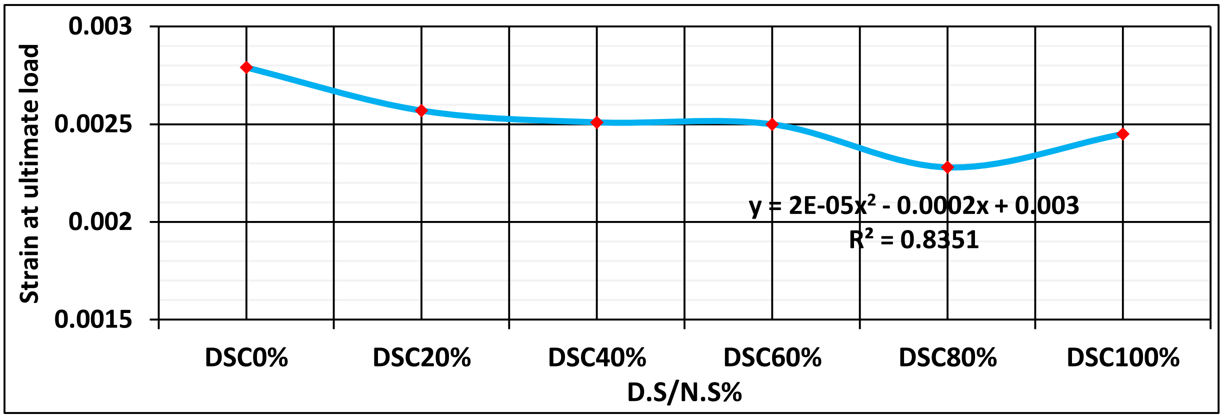


Figure 4.129 The curve of strain for slabs containing D.S without S.F.

The results show that the compression strain for the DSC 0% reference slab is 0.00279, then the strain decreases with the replacement of sand dunes as an alternative for sand in the slabs, whereas, the DSC20%, DSC40% and DSC60% slabs recorded nearly equal strain results of 0.00257, 0.00251 and 0.0025, with a decrease by about 7.88%, 10.03% and 10.39% compared to the DSC0% slab without fibers. While the DSC 80% and DSC100 % slabs achieved strain values of 0.00228 and 0.00245 (i.e. 18.3% and 12.2%, respectively, lower than the DSC 0% slab without fibers). We note that the compression strain values are within the limits of flexural compressive strain, which does not exceed 0.0035. The load-strain curves for all slabs without fiber and containing sand dunes in Figure 4.130 , and which show the difference between the brittle behavior of these slabs.

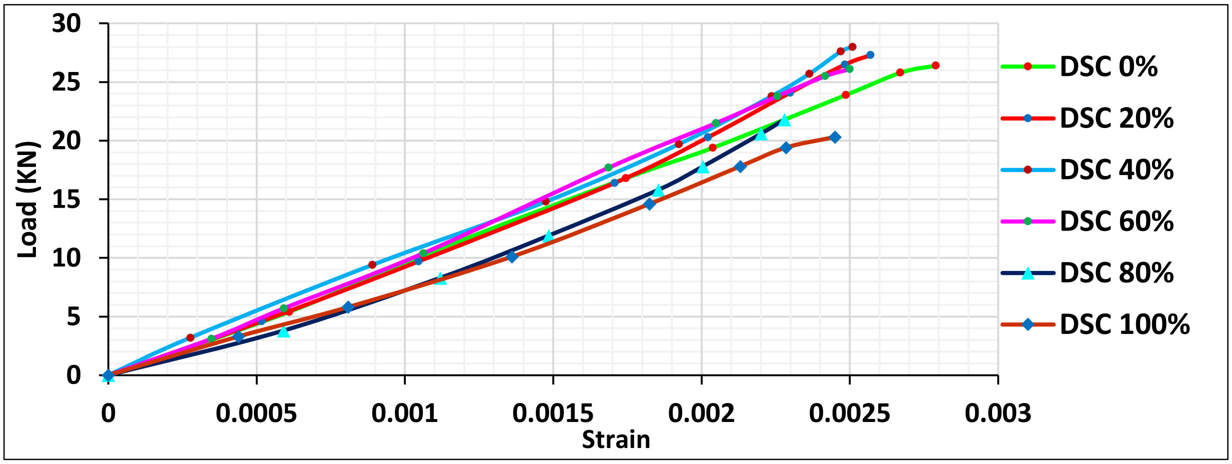


Figure 4.130 Load - strain curves for concrete slabs containing D.S without fiber.

Also, the results showed the strain of slabs containing sand dunes as an alternative for sand in different proportions with steel fibers, that the FRDC0%-S slab containing short steel fibers achieved the greatest strain value of 0.00309 (namely, 10.75% greater than the DSC0% slab without fibers), also the slabs FRDC0%-L and FRDC0%-HY achieved strain values of 0.00238 and 0.00293, respectively. Also, the FRDC0%-HY slab achieved an increase in strain by about 5.02% and 23.1% greater than the DSC 0% and FRDC0%-L slabs, respectively, but less than the slab FRDC0%-S by about 5.2%. As shown in Figure 4.131 for slabs containing natural sand without dunes sand of ratio 0% D.S and reinforced with steel fibers, and which shows the difference between the brittle behavior of the reference slab with slabs containing sand dunes as an alternative to sand and containing long, short and hybrid steel fibers.

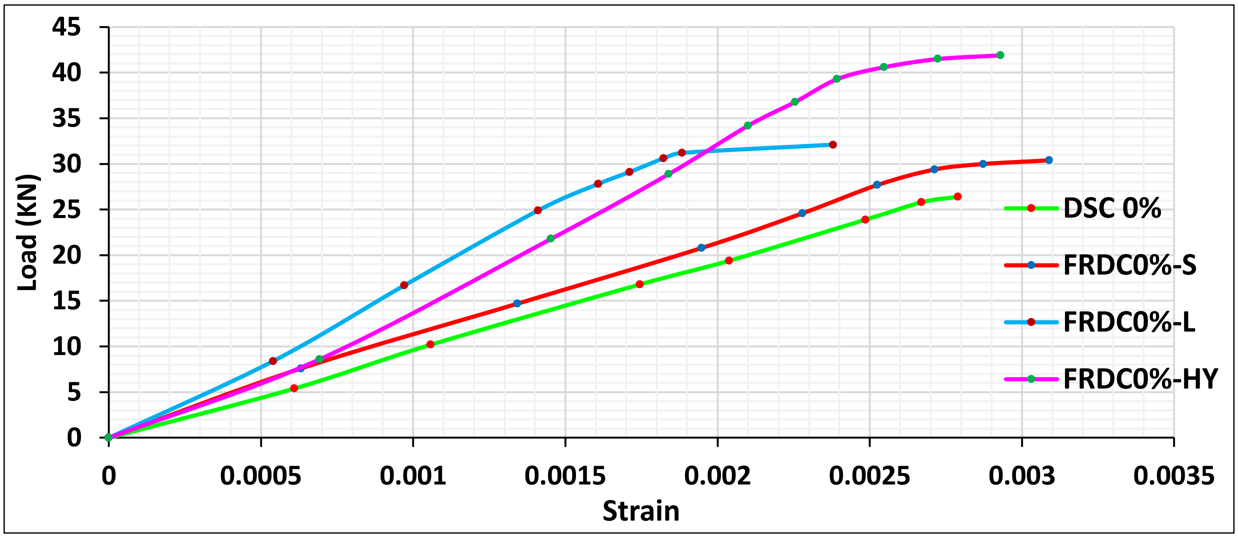


Figure 4.131 Load - strain curves for concrete slabs containing sand dunes (0%).

Also, the strain results of FRDC20%-S slabs were 0.00217 (15.6% higher than DSC20% slabs without fibers) while FRDC20%-L and FRDC20%-HY achieved strain values of 0.00256 and 0.00268, also, the FRDC20%-HY slab achieved an increase of about 4.28% and 4.7% compared to the (DSC20% without fibers) and FRDC20%-L, but it was less than the FRDC20%-S slab by about 9.7%. As in

Figure 4.132 for slabs containing sand dunes as an alternative to the sand of ratio 20% and reinforced with steel fibers, and which shows the difference between the brittle behavior of DSC 20% slab without fibers with slabs containing steel fibers.

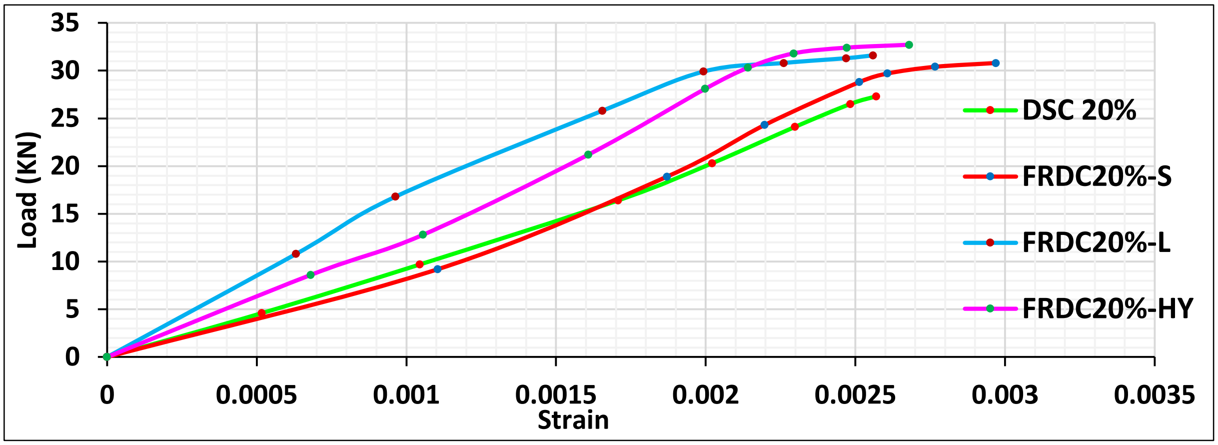


Figure 4.132 Load - strain curves for concrete slabs containing sand dunes (20%).

The slab FRDC40%-L containing steel fibers with sand dunes as an alternative to the sand of ratio 40% showed less strain of 0.00205 (i.e. 18.3% less than the slab DSC40% without fibers), while the FRDC40%-S and FRDC40%-HY slabs achieved a strain of 0.00276 and 0.00274 with an increase of about 9.96% and 9.16%, respectively, compared to DSC40% slab without fibers. Also, the FRDC40%-HY slab achieved an increase in strain by about 33.6% (higher than the FRDC40%-L slab) but less than the slab FRDC40%-S by about 0.72, as in Figure 4.133 for slabs containing sand dunes as an alternative to the sand of ratio 40% and reinforced with steel fibers, and which shows the difference between the brittle behavior of DSC 40% slab without fibers with slabs containing steel fibers.

Also, the slab FRDC60%-HY containing hybrid steel fibers achieved a strain of 0.00282 (increased by about 12.8%, 15.10%, and 19.5% higher than the slabs DSC60 % without fibers, FRDC60%-S and FRDC60%-L, respectively). While the values of the strain decreased for slabs FRDC60%-S and FRDC60%-L, which are 0.00245 and 0.00236 (namely, 2% and 5.6% less than the slab DSC60 % without fibers), as shown in Figure 4.134 for slabs containing dunes sand of ratio 60% and reinforced with steel fibers, and which shows the difference between the brittle behavior of DSC 60% slab without fibers with slabs containing steel fibers.

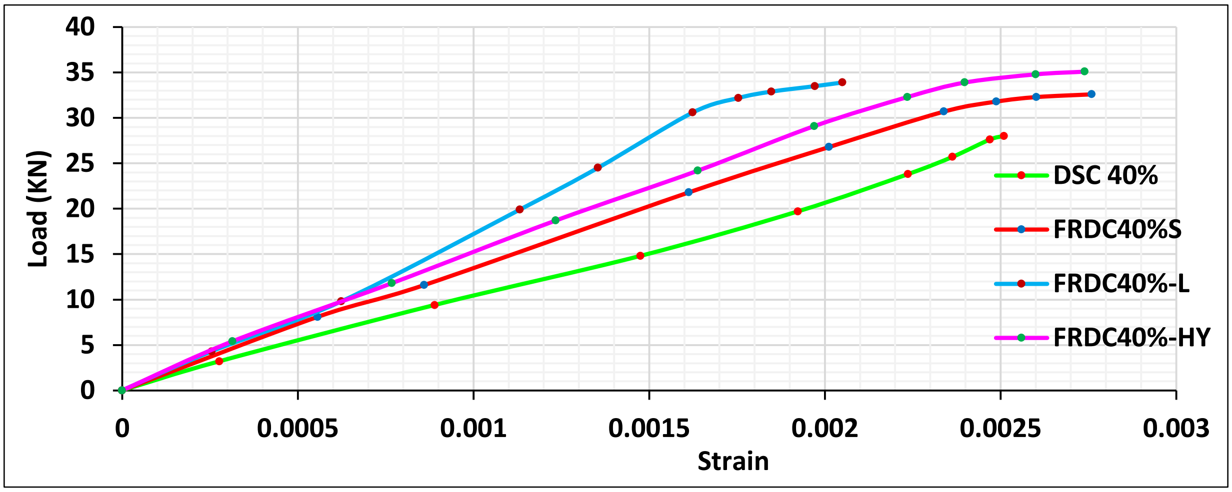


Figure 4.133 Load - strain curves for concrete slabs containing sand dunes (40%).

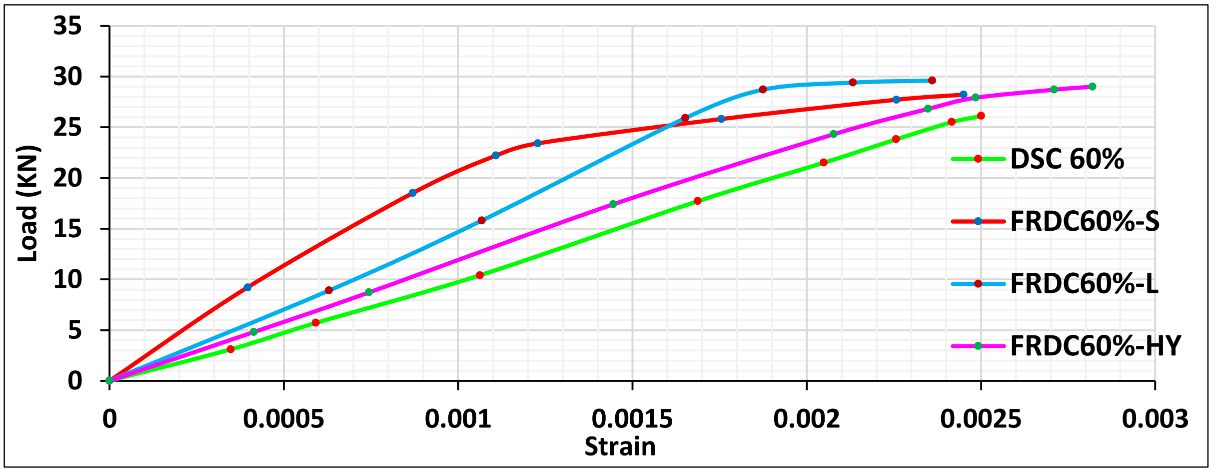


Figure 4.134 Load - strain curves for concrete slabs containing sand dunes (60%).

When sand dunes was replaced as an alternative to the sand of ratio 80%, the strain values of the slab FRDC80%-S were equal to that of the slab DSC80% without fibers 0.00228. While the slab FRDC80%-HY achieved a strain value of 0.00254 (i.e. 11.4% higher than the slabs (DSC80% without fibers) and FRDC80%-S. Also, an increase of about 0.79% is higher than the slab FRDC80%-L, as in Figure 4.135.

for slabs containing sand dunes as an alternative to the sand of ratio 80% and reinforced with steel fibers, and which shows the difference between the brittle behavior of DSC 80% slab without fibers with slabs containing steel fibers.

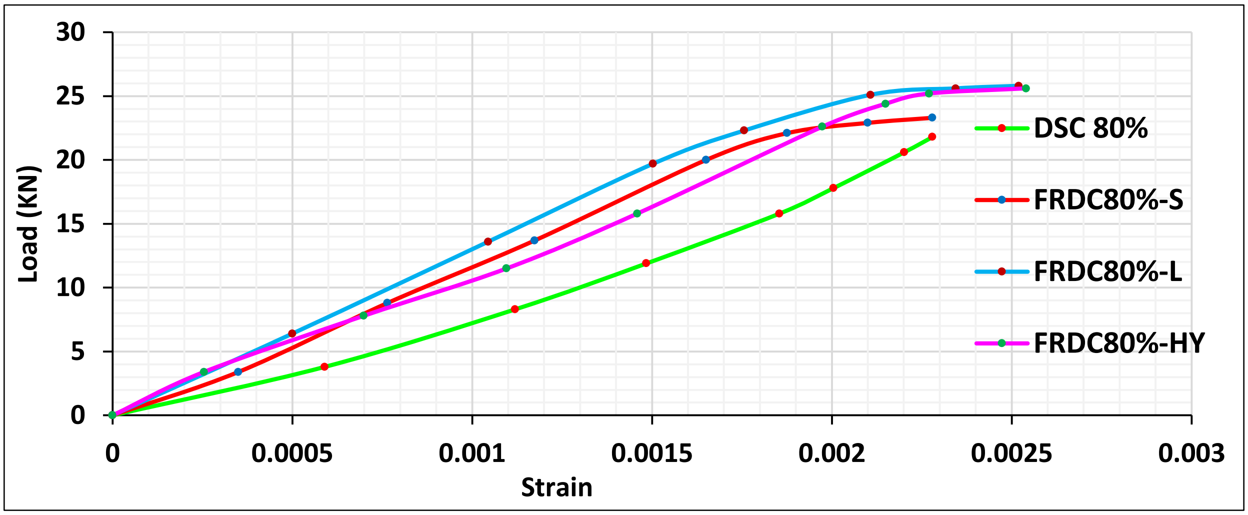


Figure 4.135 Load - strain curves for concrete slabs containing sand dunes (80%).

When sand dunes as an alternative for the sand of ratio 100%, the strain values of FRDC100%-S and FRDC100%-L slabs, which are 0.00242 and 0.00223, decreased by about 1.22% and 8.98%, respectively, compared to DSC100% slabs without fibers. While the FRDC100%HY slab achieved an increase in Strain value of 0.00258 (namely 5.31% highest than of the DSC100% slab without fibers), it is also larger than FRDC100%-S and FRDC100%-L slabs by about 6.61% and 15.7%, respectively, as shown in Figure 4.136 for slabs containing sand dunes as an alternative to the sand of ratio 100% and reinforced with steel fibers, and which shows the difference between the brittle behavior of DSC 100% slab without fibers with slabs containing steel fibers .

Although there is an increase or decrease in the strain values of the slabs, noted all the compression strain values are within the compressive flexural strain limits, which do not exceed 0.0035 according to the Indian code IS: 456-200's stress-strain curves[53].

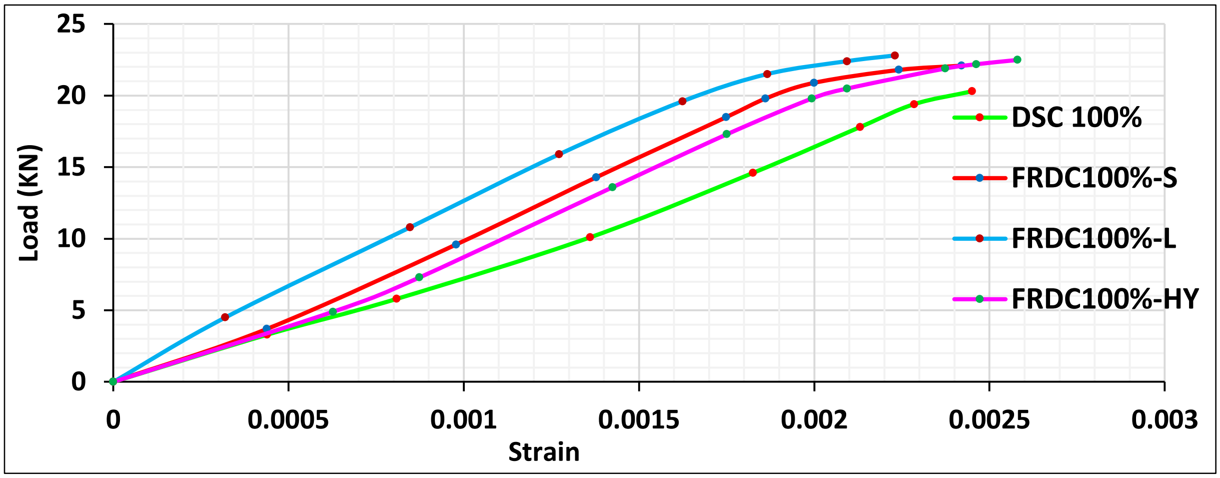


Figure 4.136 Load - strain curves for concrete slabs containing sand dunes (100%).

4.2.2.7 Stiffness

From the load-deflection curve, can get the initial stiffness and secant stiffness, where get the initial stiffness by dividing Yield load (PY) by the deflection at Yield load (Δy). Also, get the secant stiffness by dividing ultimate applied load (Pu) by ultimate deflection (Δu). Where the stiffness is calculated according to T. Sullivan's study et al [54] as shown in Figure 4.137. The following equations:

$$\text{Initial stiffness}=\frac{PY}{\Delta Y} \qquad \text{Eq. 4.3}$$

$$\text{Secant stiffness}=\frac{Pu}{\Delta u} \qquad \text{Eq. 4.4}$$

The results of stiffness are shown in Table 4.16, and Table 4.17. The results show that the initial stiffness of the reference slab DSC 0% without fibers and sand dunes was 1.188kN/mm, while the slabs containing sand dunes as an alternative to sand DSC20%, DSC40%, and DSC60% achieved an increase in the initial stiffness with convergent results of 1.313, 1.338 and 1.298 kN /mm (i.e. 10.5%, 12.6%, and 9.2% higher than DSC 0% slab without fibers).

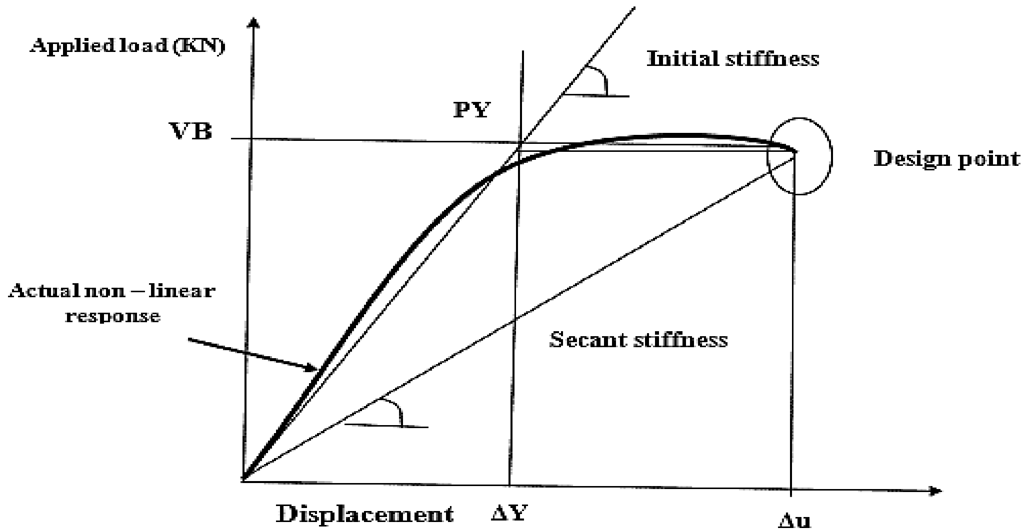


Figure 4.137 The calculation method of the stiffness [54].

Table 4.16 Initial and secant stiffness results for slabs containing sand dunes

Slab remark	(D.S/N.S) +FIBER	Initial stiffness kN/mm	Changing in stiffness %	Secant stiffness kN/mm	Changing in stiffness%
DSC0%	0%D.S	1.188	0	1.164	0
DSC20%	20%D.S	1.313	10.5	1.307	12.3
DSC40%	40%D.S	1.338	12.6	1.373	17.9
DSC60%	60%D.S	1.298	9.2	1.284	10.3
DSC80%	80%D.S	1.192	0.34	1.177	1.12
DSC100%	100%D.S	1.189	0.08	1.168	0.34

The initial stiffness of slabs without fibers DSC 80% and DSC100% increased, and initial stiffness values of 1.192 and 1.189 kN/mm were achieved with a slight increase of about 0.34% and 0.08%, respectively, higher than the DSC0% slabs without fibers). Noted that the initial stiffness increases and improves with the increase in the sand dunes content up to 60% as an alternative to sand, the relationship between initial stiffness and dunes sand ratios as an alternative to sand in slabs without fibers as shown in Figure 4.138.

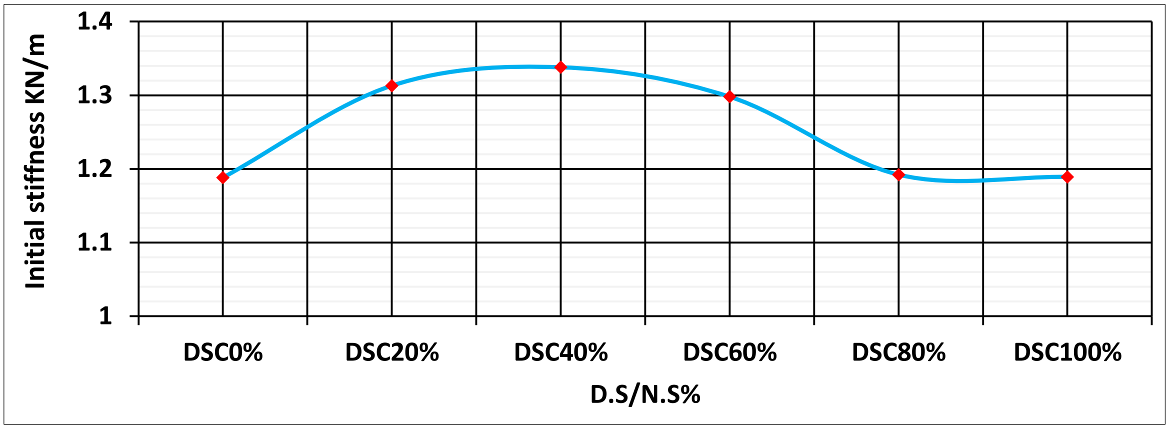


Figure 4.138 The curve of initial stiffness for concrete slabs without fibers.

Table 4.17 Initial and secant stiffness results for slabs containing D.S with fiber

Slab remark	(D.S/N.S)+FIBER	Initial stiffness kN/mm	Changing in stiffness %	Secant stiffness kN/mm	Changing in stiffness %
FRDC0%-S	0%D.S+1%S.F.S	1.335	12.4	1.208	3.7
FRDC0%-L	0%D.S+1%S.F.L	2.038	71.5	1.66	42.6
FRDC0%-HY	0%D.S+1%H.S.F	1.967	65.6	1.765	51.6
FRDC20%-S	20%D.S+1%S.F.S	1.342	2.21	1.378	5.4
FRDC20%-L	20%D.S+1%S.F.L	1.845	40.5	1.518	16.1
FRDC20%-HY	20%D.S+1%H.S.F	1.702	29.6	1.498	14.6
FRDC40%-S	40%D.S+1%S.F.S	1.613	20.5	1.452	5.7
FRDC40%-L	40%D.S+1%S.F.L	2.316	73.1	2.033	48
FRDC40%-HY	40%D.S+1%H.S.F	1.775	32.6	1.573	14.5
FRDC60%-S	60%D.S+1%S.F.S	1.633	25.8	1.417	10.3
FRDC60%-L	60%D.S+1%S.F.L	1.882	44.9	1.542	20
FRDC60%-HY	60%D.S+1%H.S.F	1.382	6.47	1.366	6.4
FRDC80%-S	80%D.S+1%S.F.S	1.452	21.8	1.259	6.9
FRDC80%-L	80%D.S+1%S.F.L	1.466	22.9	1.261	7.1
FRDC80%-HY	80%D.S+1%H.S.F	1.385	16.2	1.242	5.5
FRDC100%-S	100%D.S+1%S.F.S	1.344	13.04	1.222	4.6
FRDC100%-L	100%D.S+1%S.F.L	1.417	19.2	1.258	7.7
FRDC100%-HY	100%D.S+1%H.S.F	1.351	13.6	1.243	6.03

The results of the slabs reinforced with short steel fibers and replacement ratios (0%-100%), showed that the slab (FRDC60%-S) achieved the highest value of the initial stiffness compared to all the slabs reinforced with short fibers and replacement ratios (0%, 20%, 40%, 80%, 100%) with an increase of (22.3%, 21.6%, 1.23%, 12.4%, and 21.5%), respectively. As shown in Figure 4.139.

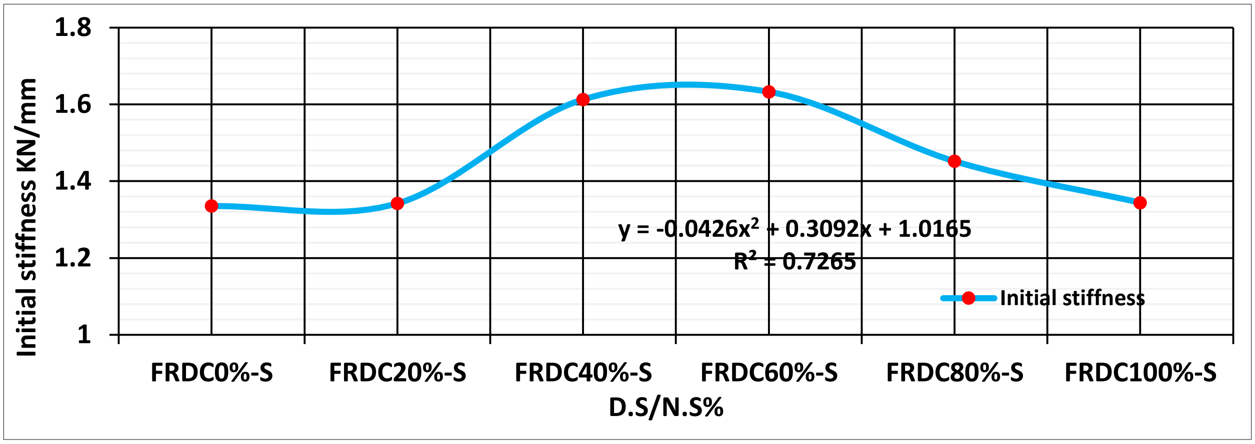


Figure 4.139 The curve of initial stiffness for concrete slabs with short steel fibers.

The results of the slabs reinforced with long steel fibers showed that the slab (FRDC40%-L) achieved the highest value of the initial stiffness compared to all slabs reinforced with long steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of about (13.6%, 25.5%, 23%, 57.9%, and 63.4%), respectively, as shown in Figure 4.140.

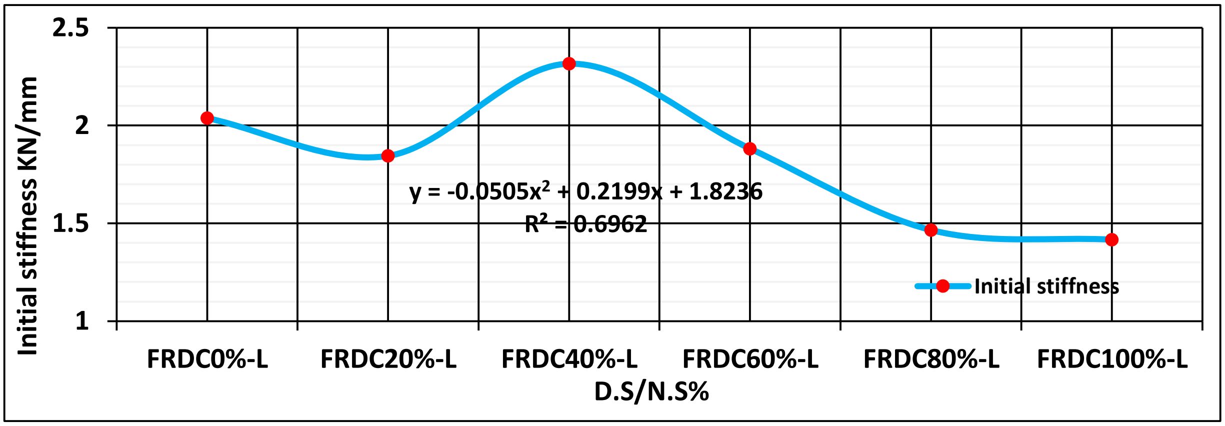


Figure 4.140 The curve of initial stiffness for concrete slabs with long steel fibers.

The results of the slabs reinforced with hybrid steel fibers showed that the hybrid slab (FRDC0%-HY) achieved the highest value of the initial stiffness compared to all slabs reinforced with hybrid steel fibers and replacement ratios

(20%, 40%, 60%, 80%, 100%) with an increase of about (15.5%, 10.8%, 42.3%, 42%, and 45.5%) respectively, as shown in Figure 4.141.

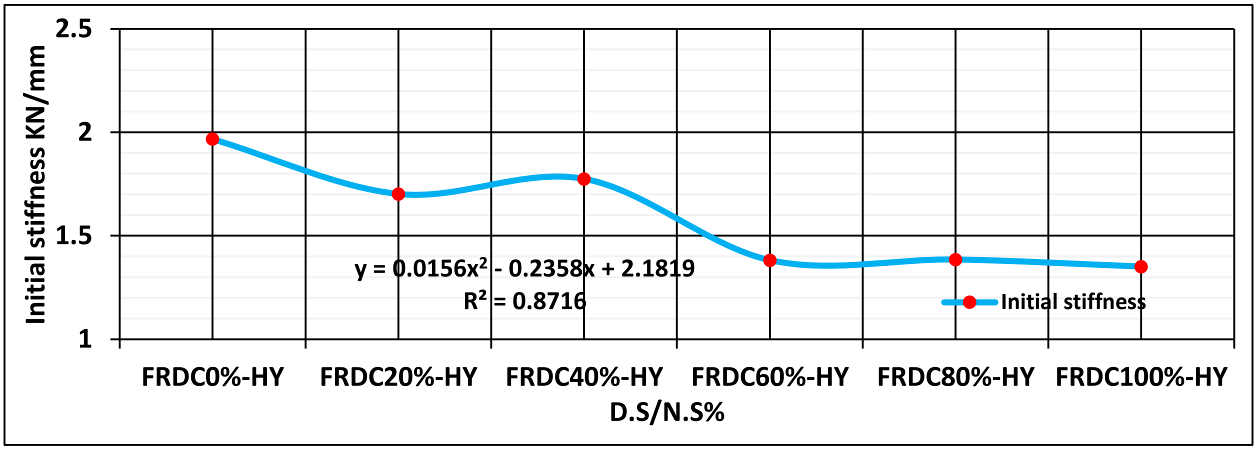


Figure 4.141 The curve of initial stiffness for concrete slabs with hybrid steel fibers.

When fibers are added, the initial stiffness of the slabs increases. As in Table 4.17, the slabs FRDC0%-L, FRDC0%-S, and FRDC0%-HY recorded an initial stiffness of 1.335, 2.038, and 1.967kN/mm, higher than the reference slab DSC0% by about 12.4 %, 71.5%, and 65.6%, respectively. Also, the FRDC0%-L slab recorded an increase in initial stiffness by about 52.3% and 3.6% compared to FRDC0%-S and FRDC0%-HY slabs, respectively. While it was the lowest stiffness for the FRDC0%-S slab compared to all slabs. The relationship between the initial stiffness and slabs containing natural sand without D.S, as shown in Figure 4.142.

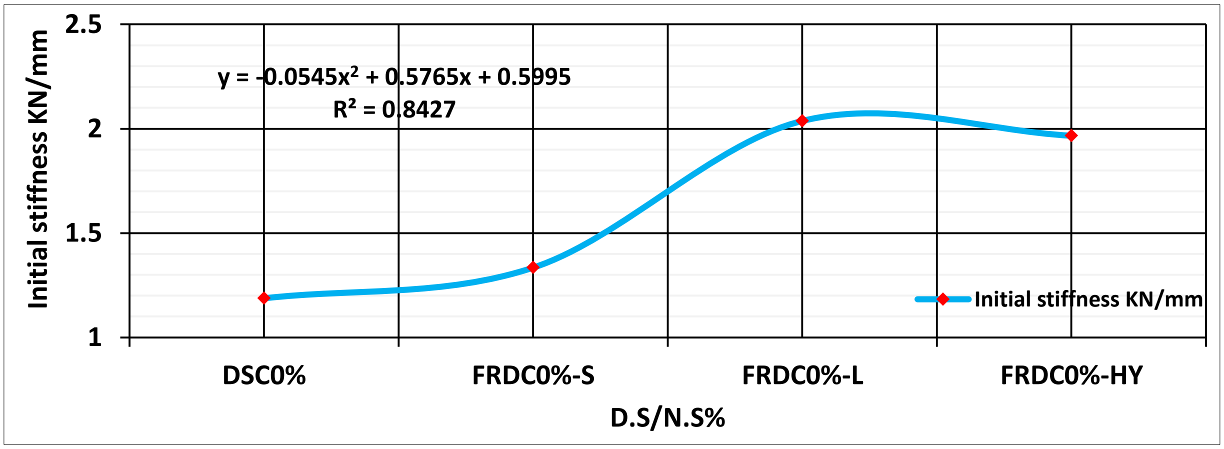


Figure 4.142 The curve of initial stiffness for slabs containing (0%D.S).

The slabs containing sand dunes as an alternative to sand for slabs FRDC20%-S, FRDC20%-L and FRDC20%-HY recorded an initial stiffness of 1.342, 1.845 and 1.702 kN/mm, with an increase of about 2.21%, 40.5% and 29.6% compared to DSC 20% without fibers. also, the slab containing long steel fiber FRDC20%-L achieved an increase in the initial stiffness by about 37.5% and 8.4% compared to slabs FRDC20%-S and FRDC20%-HY, respectively, as shown in Figure 4.143.

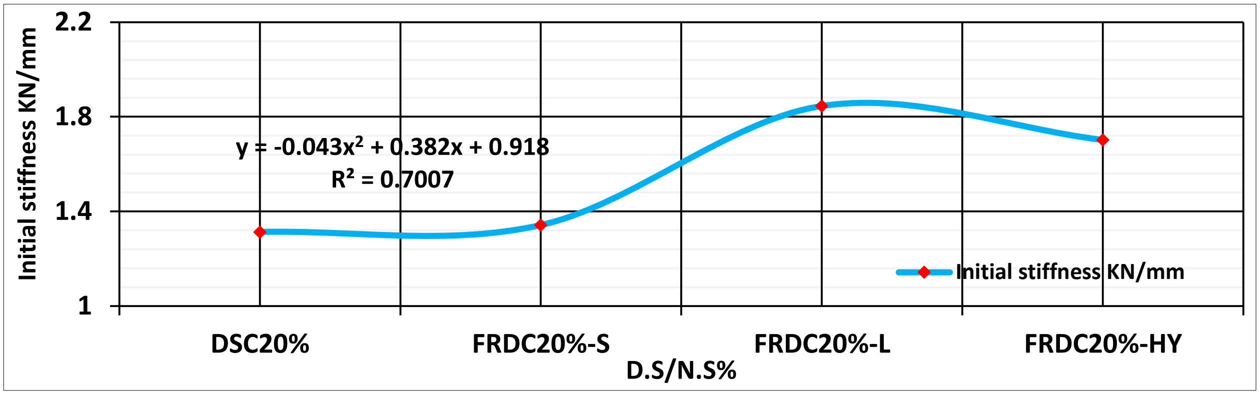


Figure 4.143 The curve of initial stiffness for slabs containing (20%D.S).

The FRDC40%-S and FRDC40%-HY slabs recorded an initial stiffness of 1.613 and 1.775 kN/mm (namely 20.5% and 32.6% higher than the slab DSC40% without fibers). While FRDC40%-L slab achieved the greatest initial stiffness of 2.316kN/mm, an increase of about 73.1% compared to slab DSC40% without fibers, as well as higher than FRDC40%-S and FRDC40%-HY slabs by 43.5% and 30.5%, respectively, as shown in Figure 4.144.

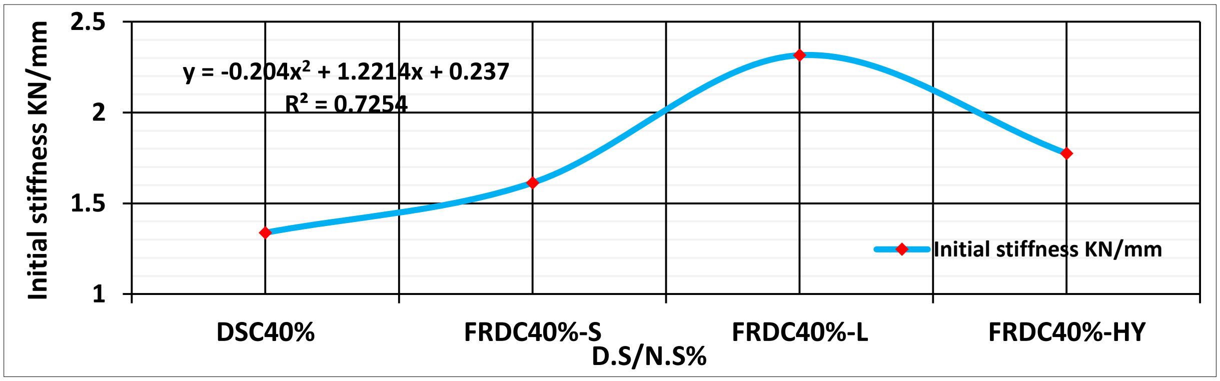


Figure 4.144 The curve of initial stiffness for slabs containing (40%D.S).

Also, FRDC60%-S, FRDC60%-L and FRDC60%-HY slabs recorded an increase in initial stiffness of 1.633, 1.882 and 1.382kN/mm, with an increase of about 25.8%, 44.9% and 6.47% higher than DSC60% without fibers, as shown in Figure 4.145.

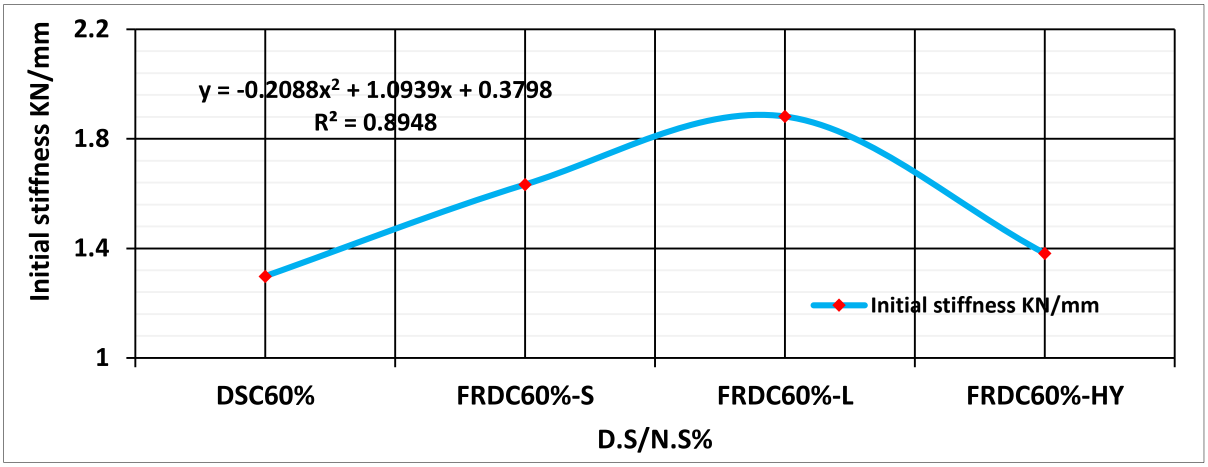


Figure 4.145 The curve of initial stiffness for slabs containing (60%D.S).

The slabs containing 80% dunes sand, FRDC80%-S, FRDC80%-L, and FRDC80%-HY, achieved convergent initial stiffness values of 1.452, 1.466, and 1.385kN/mm, with an increase of 21.8%, 22.9%, and 16.2% compared to the slab DSC80% without fibers, as shown in Figure 4.146.

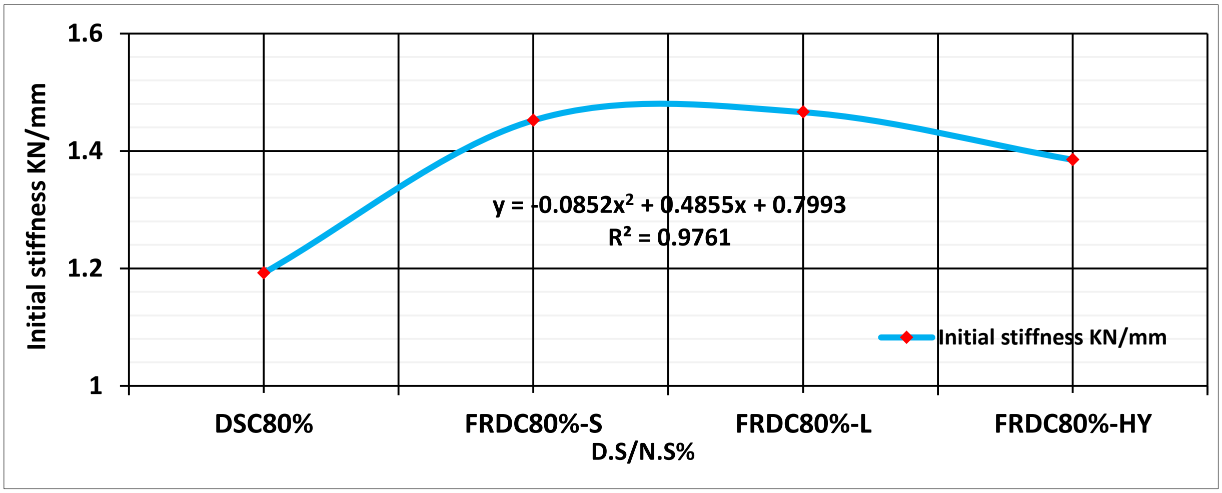


Figure 4.146 The curve of initial stiffness for slabs containing (80%D.S).

When sand dunes is replaced by 100% as an alternative to sand in the slabs containing fibers, we notice a decrease in the initial stiffness values, as the FRDC100%-HY slab achieved an initial stiffness of 1.351kN/mm, but it is greater than the slab DSC100% without fibers by about 13.6%. Also, the FRDC100%-L slab achieved an increase in initial stiffness by about 5.4% and 4.9% higher than the FRDC100%-S and FRDC100%-HY slabs, respectively. The relationship between the initial stiffness and slabs containing sand dunes as an alternative to sand, as shown in Figure 4.147. In general, the initial stiffness increases in slabs containing steel fibers, especially long steel fibers.

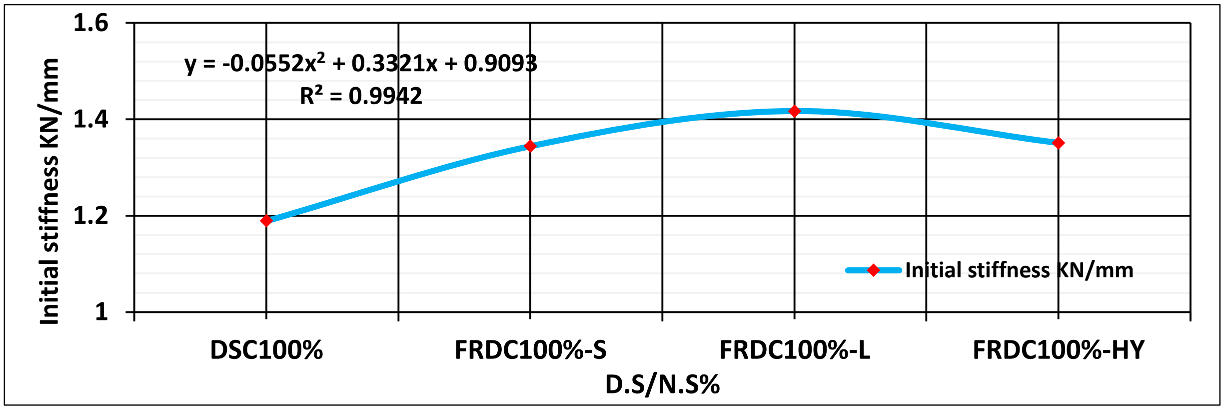


Figure 4.147 The curve of initial stiffness for slabs containing (100%D.S).

Secant stiffness increases with increasing sand dunes content in slabs without fibers, as shown in Table 4.16 and Figure 4.148. The reference slab DSC0% recorded an effective stiffness of 1.164kN/mm, then the effective stiffness gradually increased with the increase of the dunes sand content in the slabs, where the DSC20%, DSC40%, DSC60%, and DSC80% slabs recorded an effective stiffness of 1.307, 1.373, 1.284 and 1.177 kN. /mm with an increase of 12.3%, 17.9%, 10.3% and 1.12%, respectively, compared to the DSC0% slab without fibers. While there was a slight increase in the value of the effective stiffness when dunes sand was replaced as an alternative to the sand of ratio 100%, where the DSC100 % slab without fibers recorded an effective stiffness of 1.168kN/mm, 0.34% higher than the reference DSC 0% slab without fibers.

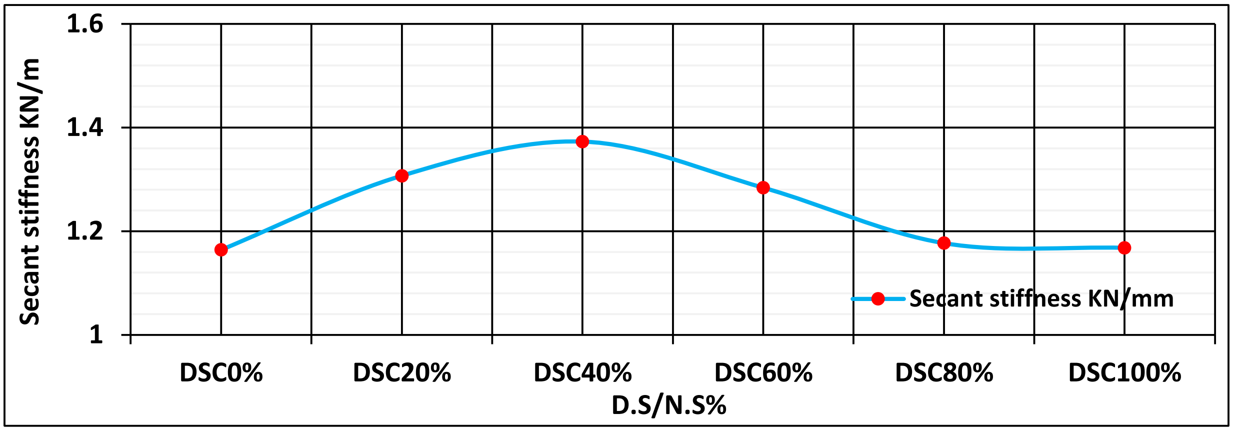


Figure 4.148 The curve of secant stiffness for concrete slabs without fibers.

The results of the slabs reinforced with short steel fibers and replacement ratios (0%-100%), showed that the slab (FRDC40%-S) achieved the highest value of the secant stiffness compared to all the slabs reinforced with short fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of (20.1%, 5.3%, 2.4%, 15.3%, and 18.8%), respectively. As shown in Figure 4.149.

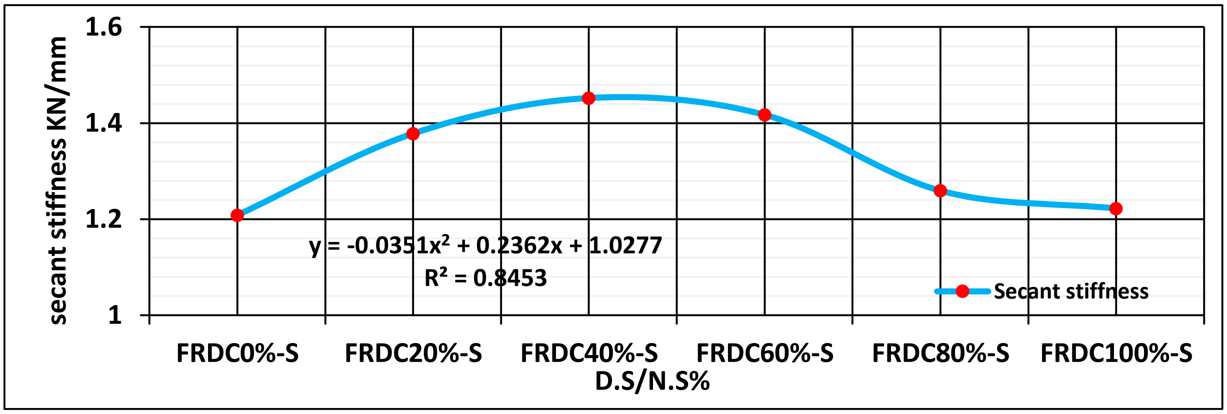


Figure 4.149 The curve of secant stiffness for concrete slabs with short steel fibers.

The results of the slabs reinforced with long steel fibers showed that the slab (FRDC40%-L) achieved the highest value of the secant stiffness compared to all slabs reinforced with long steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of about (22.4%, 33.9%, 31.8%, 61.2%, and 61.6%), respectively, as shown in Figure 4.150.

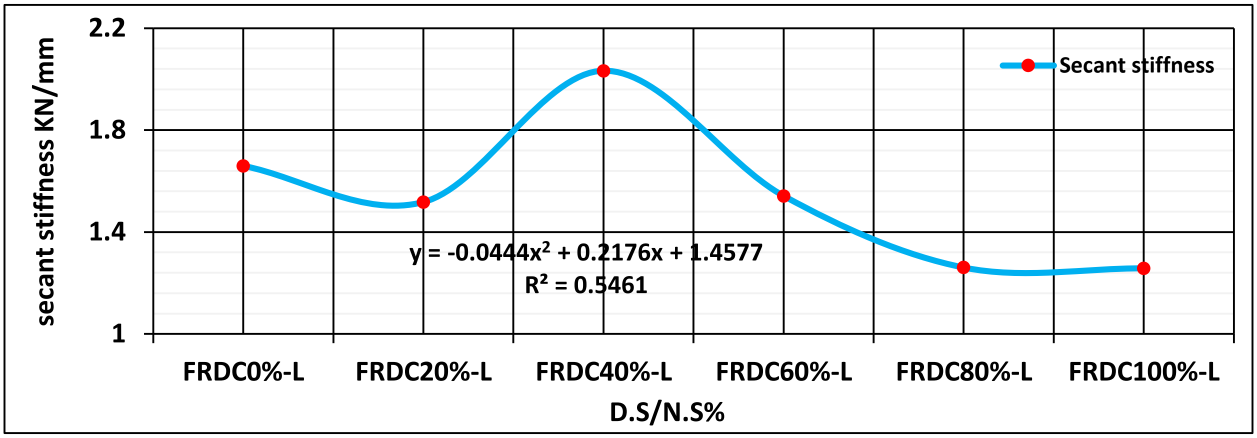


Figure 4.150 The curve of secant stiffness for concrete slabs with long steel fibers.

The results of the slabs reinforced with hybrid steel fibers showed that the hybrid slab (FRDC0%-HY) achieved the highest value of the secant stiffness compared to all slabs reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (17.8%, 12.2%, 29.2%, 42.1%, and 41.9%) respectively, as shown in Figure 4.151.

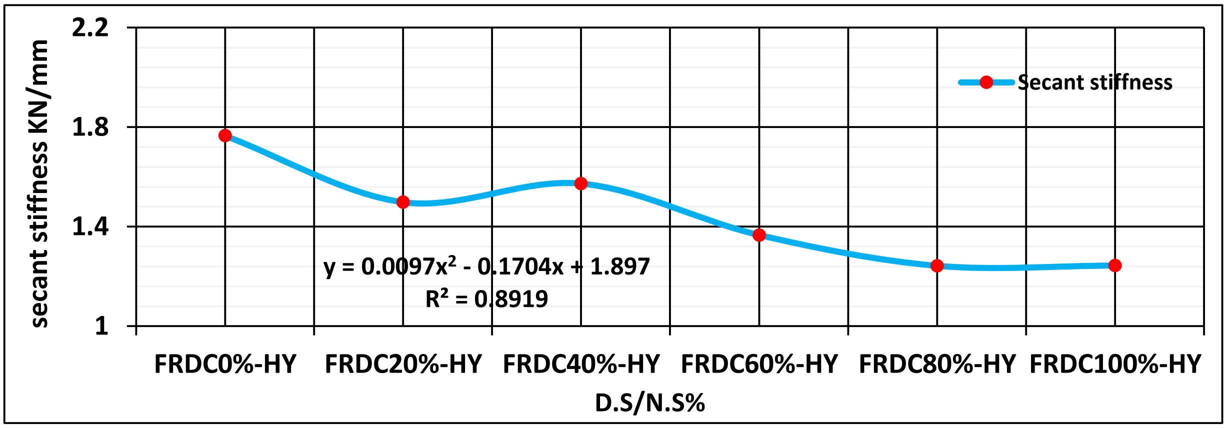


Figure 4.151 The curve of secant stiffness for concrete slabs with hybrid steel fibers.

When adding steel fibers to the slabs, the effective stiffness increases, as in Table 4.17 the slabs FRDC0%-S, FRDC0%-L, and FRDC0%-HY recorded an effective stiffness of 1.208, 1.66, and 1.765kN/mm, with an increase of about 3.7%, 42.6 %, and 51.6%, respectively, compared to the slab DSC 0% without fibers. Also, the FRDC0%-HY slab recorded an increase in effective stiffness (i.e., 46.1% and 6.33% higher than the slabs FRDC0%-S and FRDC0%-L, respectively. While the lowest effective stiffness was 1.208 kN/mm for the slab FRDC0%-S, as shown in Figure 4.152.

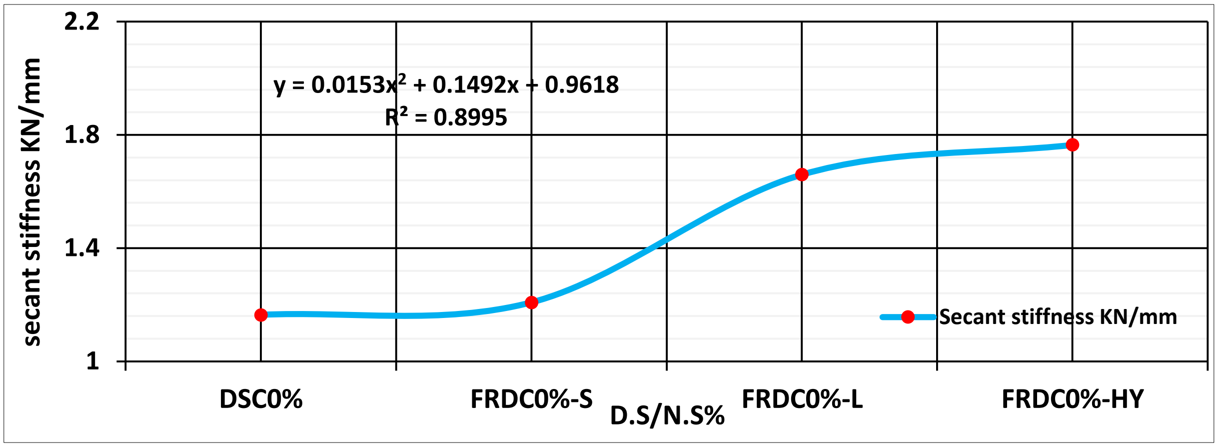


Figure 4.152 The curve of secant stiffness for slabs containing (0%D.S).

The slabs containing sand dunes as an alternative to sand FRDC20%-S, FRDC20%-L, and FRDC20%-HY recorded an increase in effective stiffness of 1.378, 1.518, and 1.498kN/mm higher than the slab DSC20% without fibers by about 5.4%, 16.1%, and 14 6%, respectively. Also, the FRDC20%-L slab achieved an increase in effective stiffness by about 10.2%, 1.33% compared to the slabs FRDC20%-S and FRDC20%-HY, respectively, as shown in Figure 4.153.

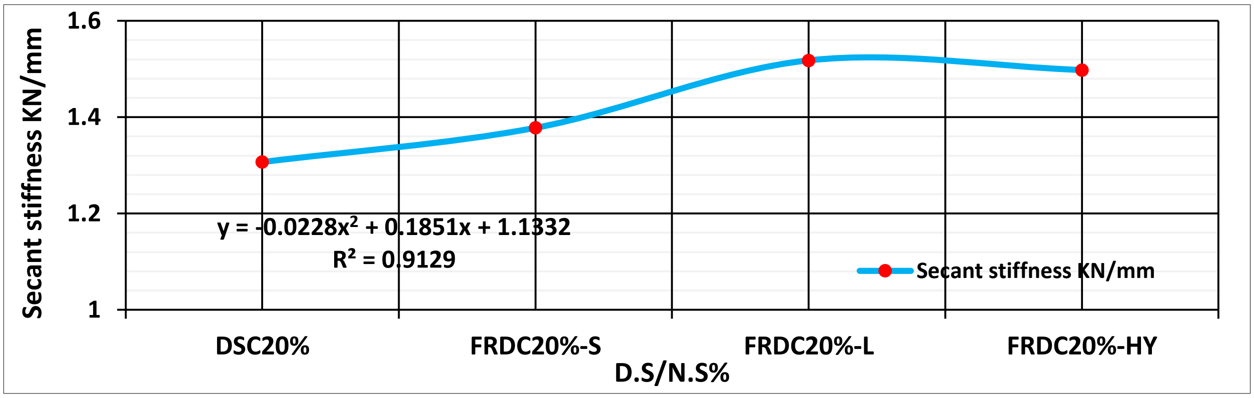


Figure 4.153 The curve of secant stiffness for slabs containing (20%D.S).

While FRDC40%-S and FRDC40%-HY slabs achieved effective stiffness of 1.452 and 1.573 kN/mm, an increase of 5.7% and 14.5% compared to the slab DSC 40% without fibers. While FRDC40%-L slab achieved the greatest effective stiffness of 2.033 kN/mm with an increase of about 48%, 40%, and 29.2% compared to the slabs DSC40% without fibers, FRDC40%-S and FRDC40%-HY, respectively, and as in Figure 4.154.

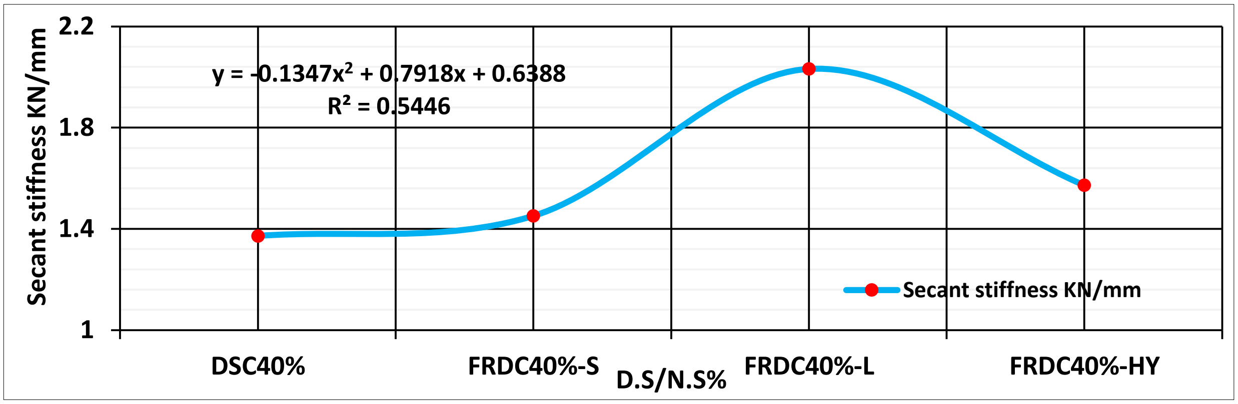


Figure 4.154 The curve of secant stiffness for slabs containing (40%D.S).

Also, FRDC60%-S and FRDC60%-HY slabs recorded an increase in effective stiffness of 1.417 and 1.366kN/mm higher than the slab DSC60% without fibers by about 10.3% and 6.4%, respectively. While the FRDC60%-L slab achieved an effective stiffness of 1.542kN/mm with an increase of about 20%, 8.8%, and 12.9% greater than the slabs DSC60% without fibers, FRDC60%-S and FRDC60%-HY respectively, as shown in Figure 4.155.

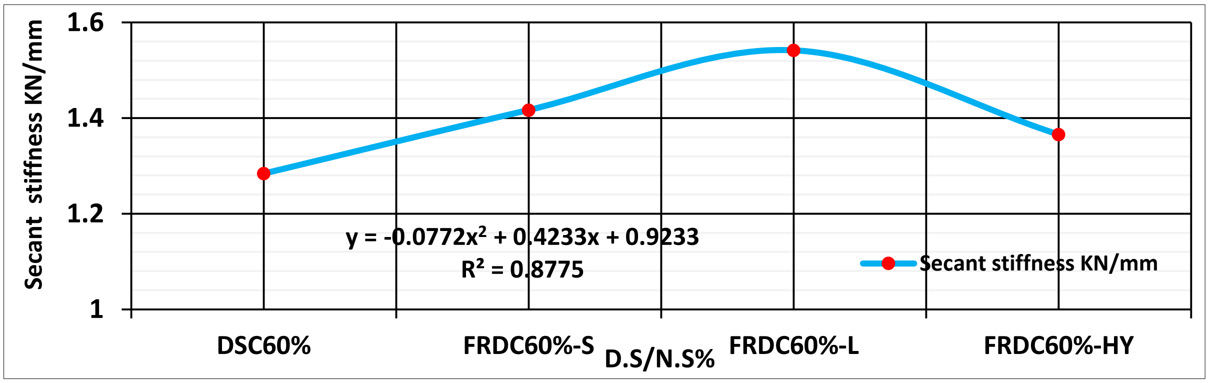


Figure 4.155 The curve of secant stiffness for slabs containing (60%D.S).

The FRDC80%-S, FRDC80%-L and FRDC80%-HY slabs recorded a convergent effective stiffness of 1.259, 1.261, and 1.242 kN/mm with an increase of about 6.9%, 7.1% and 5.5% compared to the slab DSC80% without fibers. Also, slab FRDC80%-L achieved an increase of about 0.16% and 1.5% compared to slabs FRDC80%-S and FRDC80%-HY, respectively, as shown in Figure 4.156.

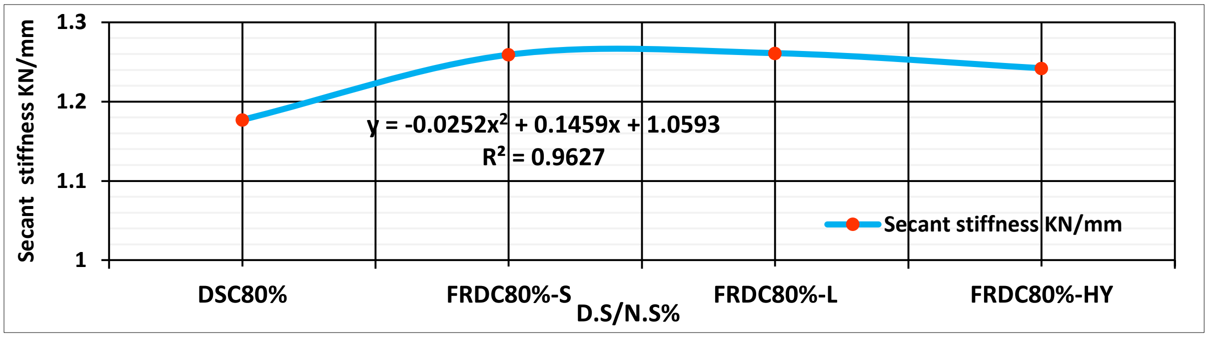


Figure 4.156 The curve of secant stiffness for slabs containing (80%D.S).

When sand dunes as an alternative for the sand of ratio 100%, we notice an increase in the effective stiffness of slabs containing dunes sand, where the slabs FRDC100%-S, FRDC100%-L, and FRDC100%-HY recorded effective stiffness of 1.222, 1.258, and 1.243kN/mm (namely 4.6%, 7.7%, and 6.03% higher than the slab DSC100% without fibers , also, the FRDC100%-L slab achieved an increase of about 2.9% and 1.21% compared to the slabs FRDC100%-S and FRDC100%-HY, respectively, as shown in Figure 4.157. In general, increasing the content of sand dunes in the slabs up to 80% increases the initial stiffness and the effective stiffness of these slabs, especially when they contain long steel fibers.

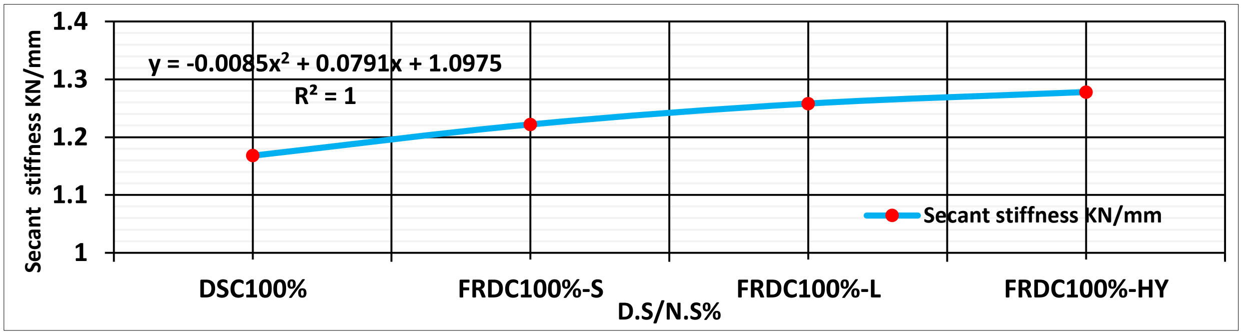


Figure 4.157 The curve of secant stiffness for slabs containing (100%D.S).

4.2.2.8 Absorption Energy

The absorption energy, or toughness, is the area under the load-deflection curve. The results of absorption energy for all slabs without fibers containing sand dunes as an alternative to sand, as well as those containing fibers are in Table 4.18.

Table 4.18 Absorption energy results for slabs concrete containing sand dunes

Slab remark	(D.S/N.S)+FIBER	Absorption Energy kN.mm	Changing in energy absorption%
DSC0%	0%D.S	288.44	0
DSC20%	20%D.S	254.5339	-11.75
DSC40%	40%D.S	264.671	-8.24
DSC60%	60%D.S	256.3658	-11.12
DSC80%	80%D.S	162.2791	-43.74
DSC100%	100%D.S	186.3836	-35.38
FRDC0%-S	0%D.S+1%S.F.S	342.6358	18.78
FRDC0%-L	0%D.S+1%S.F.L	354.2867	22.83
FRDC0%-HY	0%D.S+1%H.S.F	505.1655	75.14
FRDC20%-S	20%D.S+1%S.F.S	324.1633	27.35
FRDC20%-L	20%D.S+1%S.F.L	375.2958	47.44
FRDC20%-HY	20%D.S+1%H.S.F	361.5898	42.06
FRDC40%-S	40%D.S+1%S.F.S	391.3078	47.8
FRDC40%-L	40%D.S+1%S.F.L	386.0162	45.8
FRDC40%-HY	40%D.S+1%H.S.F	438.6695	65.7
FRDC60%-S	60%D.S+1%S.F.S	373.1727	45.5
FRDC60%-L	60%D.S+1%S.F.L	358.0803	39.7
FRDC60%-HY	60%D.S+1%H.S.F	363.7203	41.8
FRDC80%-S	80%D.S+1%S.F.S	236.1983	45.55
FRDC80%-L	80%D.S+1%S.F.L	302.4461	86.37
FRDC80%-HY	80%D.S+1%H.S.F	285.1325	75.71
FRDC100%-S	100%D.S+1%S.F.S	231.9516	24.45
FRDC100%-L	100%D.S+1%S.F.L	235.8068	26.52
FRDC100%-HY	100%D.S+1%H.S.F	238.558	27.99

The results for slabs without fibers show that the absorption energy decreases with the increase of the sand dunes content as an alternative to sand in the slabs. The reference slab DSC 0% without fibers recorded absorption energy of 288.44kN.mm. While the absorption energy decreases with the increase in the content of sand dunes as a partial and total alternative for sand in the slabs DSC20%, DSC40%, DSC60%, DSC80%, and DSC100%, where these slabs achieved absorption energy of 254.534, 264.671, 256.366, 162.279 and 186.384kN.mm with a decrease of about 11.75%, 8.24%, 11.12%, 43.74%, and 35.38%, respectively, compared to the slab DSC0% without fibers.as shown in Figure 4.158.

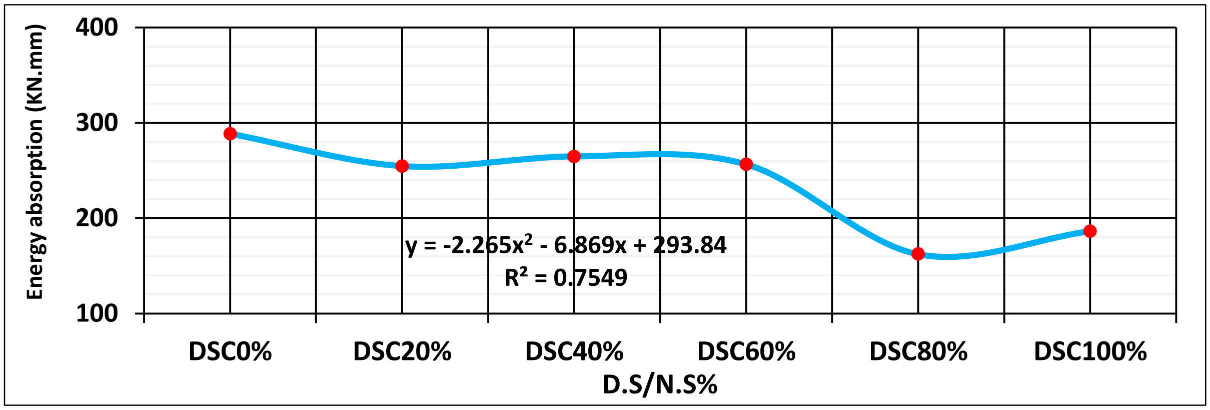


Figure 4.158 The curve of absorption energy for concrete slabs without fibers.

The results of the slabs reinforced with short steel fibers and replacement ratios (0%-100%), showed that the slab (FRDC40%-S) achieved the highest value of the absorption energy compared to all the slabs reinforced with short fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of (14.2%, 20.7%, 4.8%, 65.6%, and 68.7%), respectively. As shown in Figure 4.159.

The results of the slabs reinforced with long steel fibers showed that the slab (FRDC40%-L) achieved the highest value of the absorption energy compared to all slabs reinforced with long steel fibers and replacement ratios (0%, 20%, 60%, 80%, 100%) with an increase of about (8.9%, 2.8%, 7.8%, 27.6%, and 63.7%), respectively, as shown in Figure 4.160.

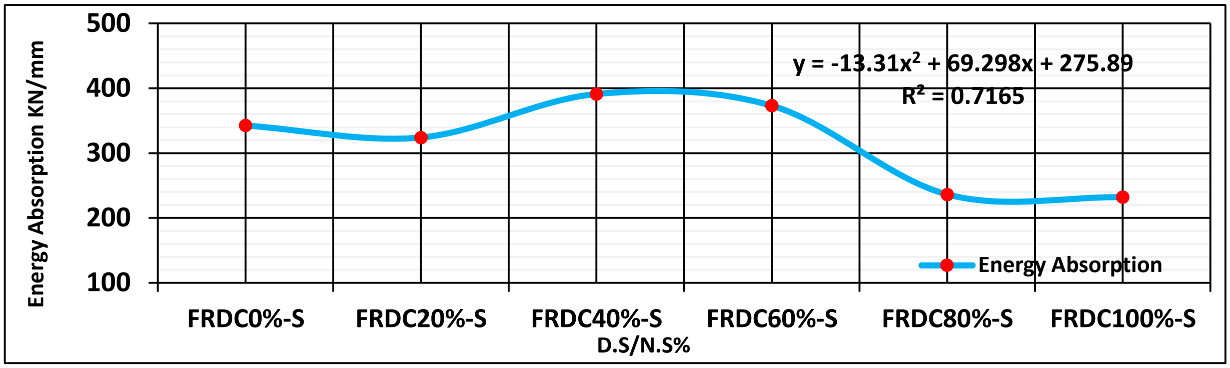


Figure 4.159 The curve of absorption energy for concrete slabs with S.F.S.

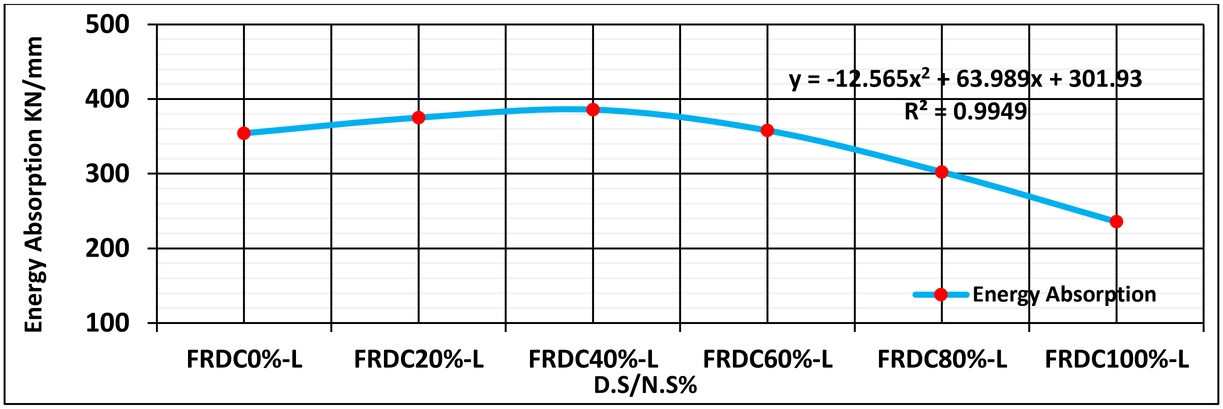


Figure 4.160 The curve of absorption energy for concrete slabs with S.F.L.

The results of the slabs reinforced with hybrid steel fibers showed that the hybrid slab (FRDC0%-HY) achieved the highest value of the absorption energy compared to all slabs reinforced with hybrid steel fibers and replacement ratios (20%, 40%, 60%, 80%, 100%) with an increase of about (39.7%, 15.1%, 38.8%, 77.1%, and 112%) respectively, as shown in Figure 4.161.

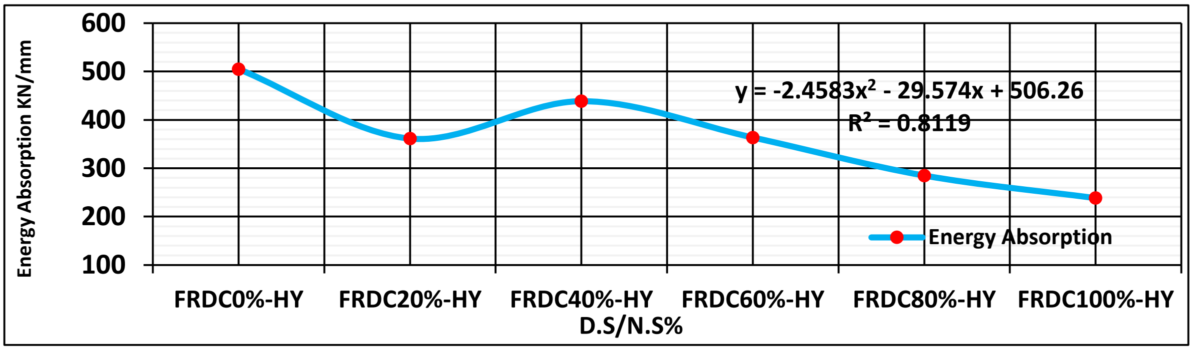


Figure 4.161 The curve of absorption energy for concrete slabs with H.S.F.

When adding steel fibers, the absorption energy of the slabs increases, where the FRDC0%-S and FRDC0%-L slabs achieved an absorption energy of 342.6358 and 354.2867 KN.mm, an increase of about 18.78% and 22.83%, respectively, compared to the slab DSC0% without the fibers. While the FRDC0%-HY slab achieved the greatest increase in absorption energy of 505.1655KN.mm, with an increase of about 75.14%, 47.4%, and 42.6% compared to the slabs DSC0%, FRDC0%-S, and FRDC0%-L, respectively, as shown in Figure 4.162. The relationship between the absorption energy and the replacement ratios of sand dunes as an alternative to the sand of ratio 0% for these slabs.

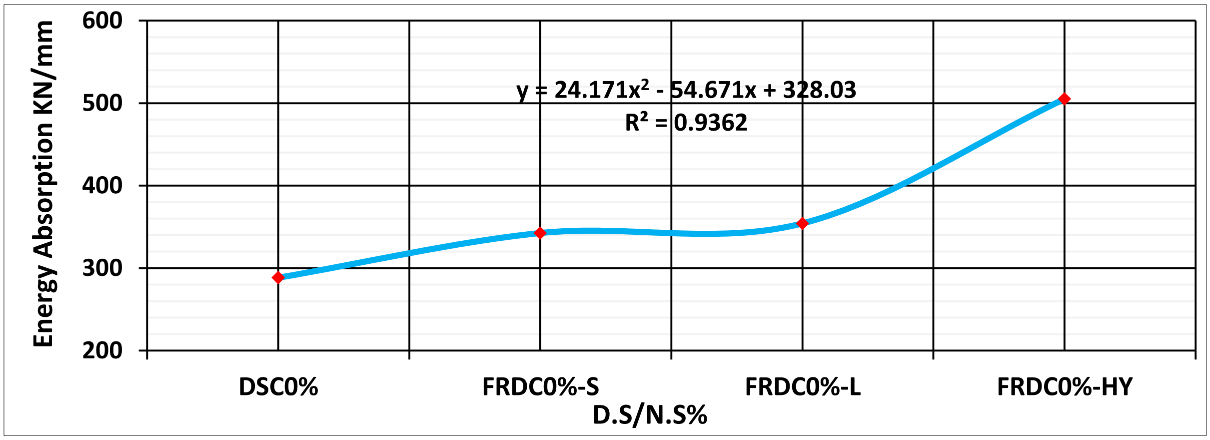


Figure 4.162 The curve of absorption energy for slabs containing (0%D.S).

When sand dunes is replaced as an alternative to sand in the slabs, the absorption energy increases, where the slabs FRDC20%-S, FRDC20%-HY achieved absorption energy of 324.1633 and 361.5898 kN.mm, with an increase of about 27.35% and 40.06% compared to the slab DSC20% without fibers. Also, the slab containing long steel fiber and dunes sand FRDC20%-L achieved absorption energy of 375.2958kN.mm (increased by about 47.4%, 15.7%, and 3.79% compared to the slabs DSC20% without fiber, FRDC20%-S, and FRDC20%- HY, respectively and as shown in Figure 4.163.

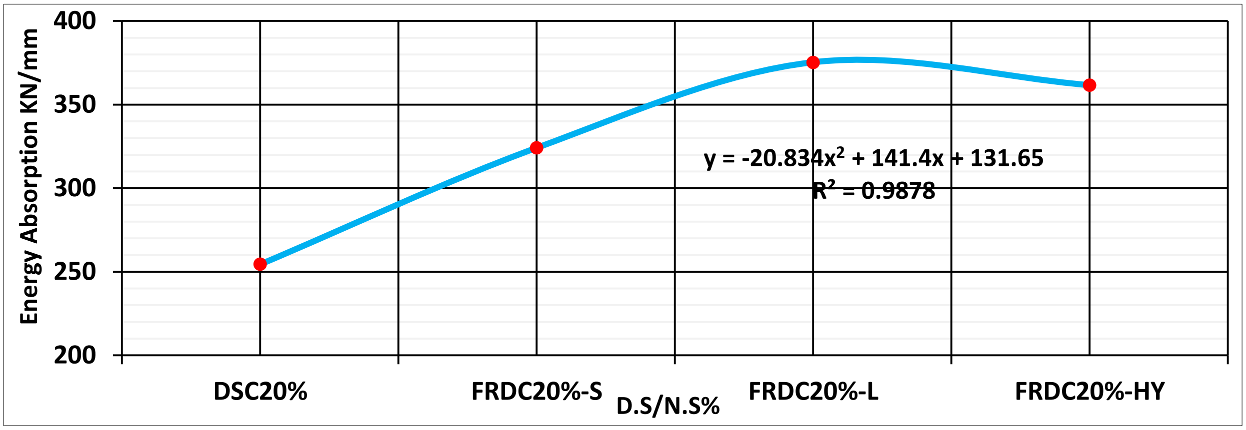


Figure 4.163 The curve of absorption energy for slabs containing (20%D.S).

When sand dunes as an alternative to the sand of ratio 40%, the slabs FRDC40%-S, FRDC40%-L, and FRDC40%-HY recorded a higher absorption capacity of 391.3078, 296.0162, and 438.6695kN.mm (i.e. 47.8%, 11.8%, and 65.79%, respectively, greater than the slab DSC 40% without fibers). Also, the FRDC40%-HY slab achieved an increase in the absorption energy by about 12.1% and 48.2% compared to the slabs FRDC40%-S and FRDC40%-L, as shown in Figure 4.164.

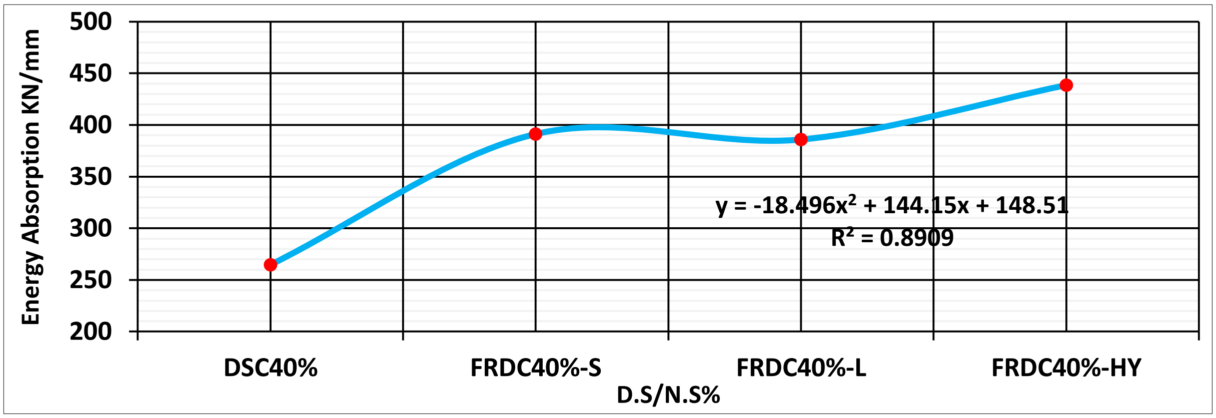


Figure 4.164 The curve of absorption energy for slabs containing (40%D.S).

The slabs FRDC60%-S, FRDC60%-L, and FRDC60%-HY recorded 373.1727, 308.0803, and 363.7203 kN.mm absorption energy with an increase of about 45.5%, 20.17%, and 41.8% higher than the slab DSC60% without fibers.

Where we notice an increase in the absorption energy of slab FRDC60%-S by about 21.1% and 2.6% compared to the slabs FRDC60%-L and FRDC60%-HY, respectively, as shown in Figure 4.165.

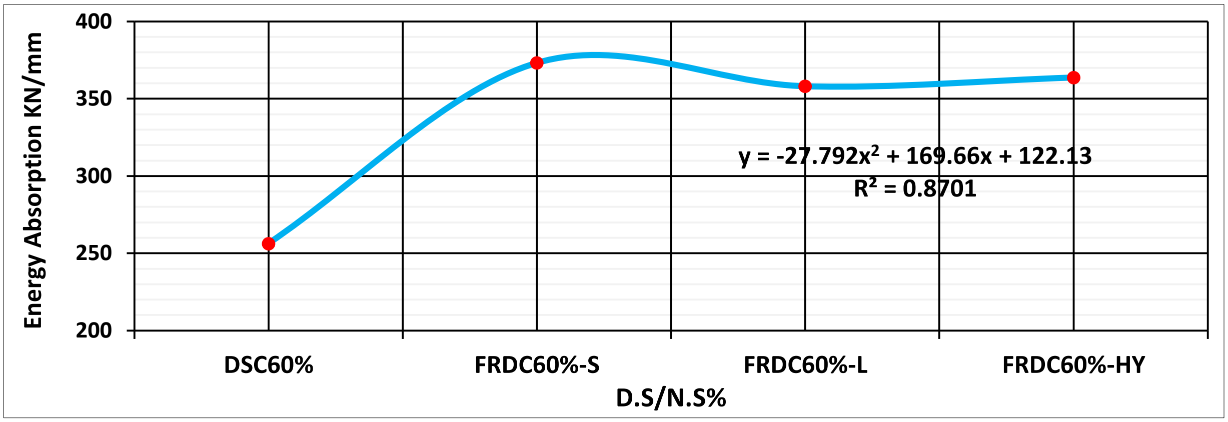


Figure 4.165 The curve of absorption energy for slabs containing (60%D.S).

When sand dunes as an alternative to the sand of ratio 80%, the slabs FRDC80%-S, FRDC80%-L, and FRDC80%-HY recorded absorption energies of 236.1983, 302.4461, and 285.1325 kN.mm, with an increase of 45.55%, 86.37%, and 75.71%, respectively. Compared to the slab DSC 80% without fibers. While the slab FRDC80%-L achieved an increase in absorption energy by about 28.05% and 6.07% compared to the slabs FRDC80%-S and FRDC80%-HY, respectively, as shown in Figure 4.166.

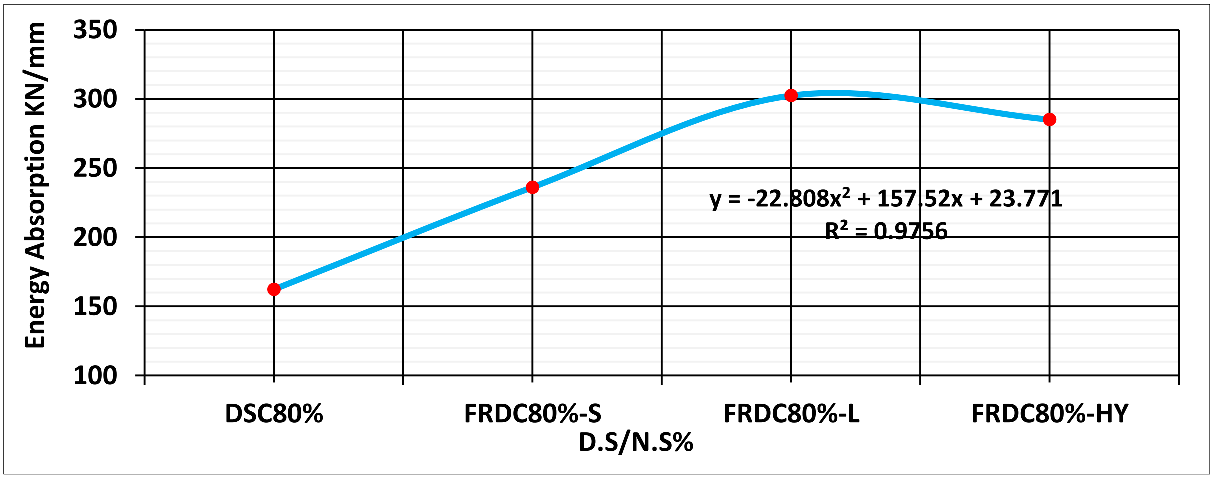


Figure 4.166 The curve of absorption energy for slabs containing (80%D.S).

When sand dunes as an alternative to the sand of ratio 100%, the absorption energy of slabs containing steel fibers FRDC100%-S, FRDC100%-L, and FRDC100%-HY decreased, and the results were recorded as 231.9516, 235.8068, and 238.558 kN.mm, respectively. But it is higher than the slab DSC100% without fibers by about 24.45%, 26.52%, and 27.99%, respectively. The relationship between absorption energy and the percentage of replacement of dunes sand as an alternative to sand by 100%, as shown in Figure 4.167. In general, the absorption capacity of slabs that contain dunes sand as a partial alternative to sand increases with the addition of steel fibers to them, especially hybrid steel fibers, with varying increases according to the type of added fiber and the proportions of replacement of dunes sand as an alternative to sand in concrete slabs.

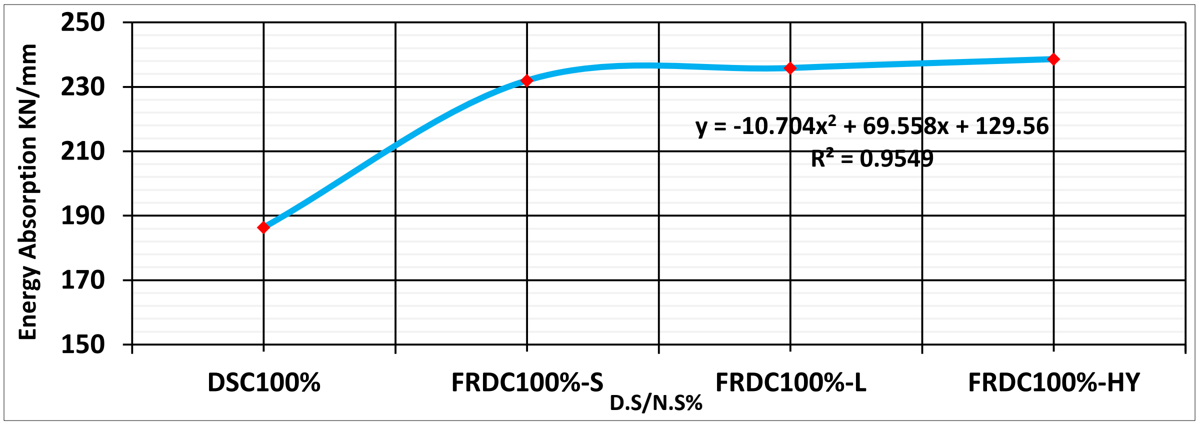


Figure 4.167 The curve of absorption energy for slabs containing (100%D.S).

4.2.2.9 Crack pattern for concrete slabs

Through the testing of slabs specimens, we note that there are no initial cracks for slabs without fibers, as no visible cracks appear before the final failure. Also, these slabs suddenly failed without any appreciable deflection warning. The failure of slabs containing fibers was gradual, where these slabs containing sand dunes as an alternative to sand and reinforced with steel fibers fail gradually but quickly and without warning, and the cracking starts from the tension zone and goes directly to the compression zone. As for the crack pattern, all slabs had a linear crack pattern, that is, in the form of a straight line between the north and south direction of the slab as shown in Figure 4.168. Where these the slabs without fibers completely broke into two pieces at maximum load. While the slabs containing the fibers maintained their integrity during the applied load for a longer time before the final failure occurred compared to the slabs without fibers. Where despite the crack in the middle of the slab containing the fibers, the two pieces did not separate from each other and remained connected due to the role of the connecting fibers between the two pieces. Where the steel fibers connect the two ends of the crack and transfer the cracking stress through the crack from one side to the other. Which leads to a reduction in stress concentration on the two ends of the crack and thus prevents the two pieces from separating. Unlike slabs without fibers, which break into two pieces when the maximum failure load is reached during the test, as shown in Figure 4.169 which show the failure pattern of slabs without fibers that broken into two pieces after the test, as well as the failure pattern of slabs that containing steel fibers that did not separate into two pieces after the test.

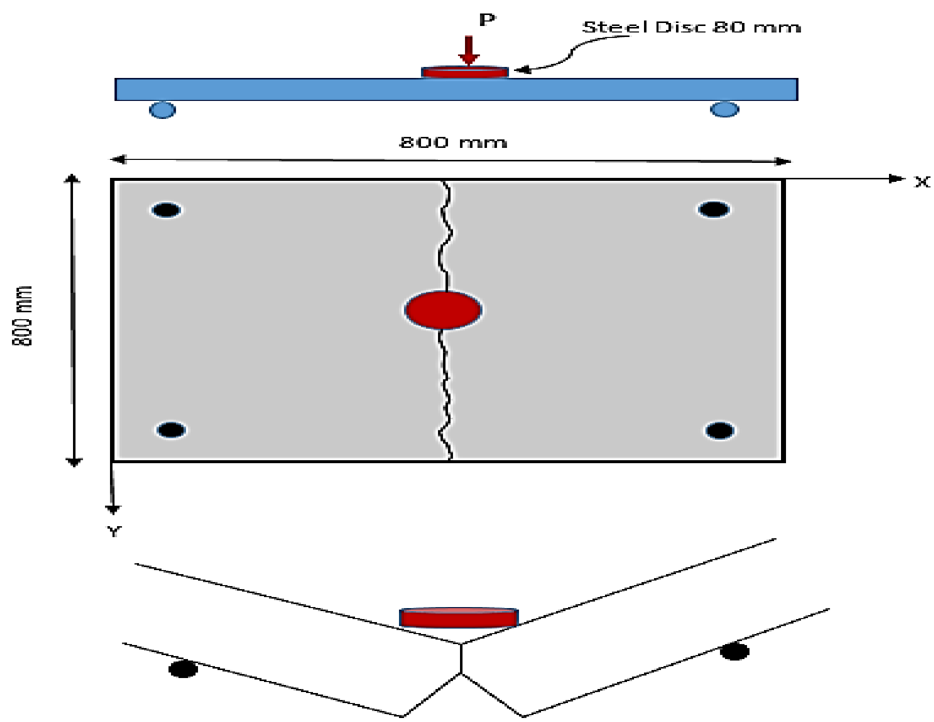
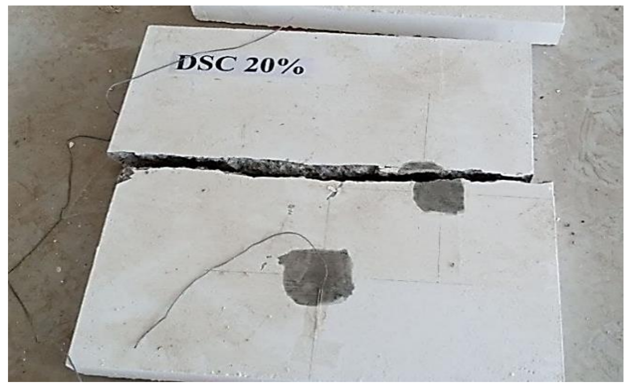


Figure 4.168 Illustration of failure pattern for slabs.

DSC0%

DSC0%

DSC20%

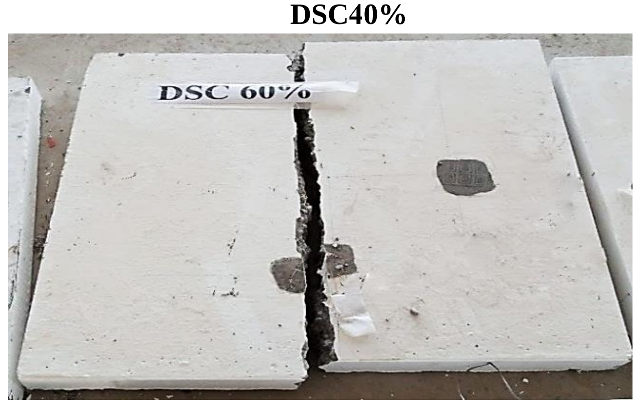


DSC20%

DSC40%

DSC40%

DSC60%



DSC60%

Figure 4.169 The crack pattern for slabs containing D.S as a sand replacement.

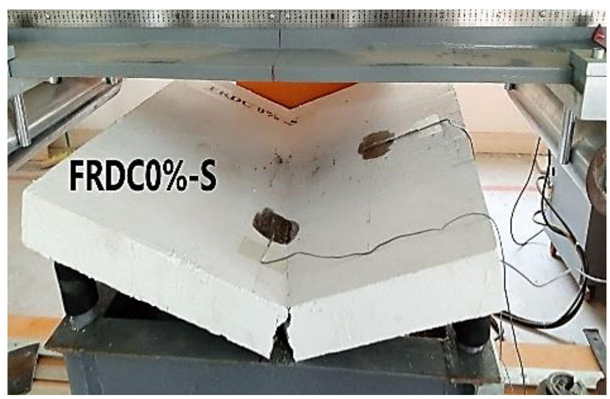
DSC80%

DSC80%

DSC100%

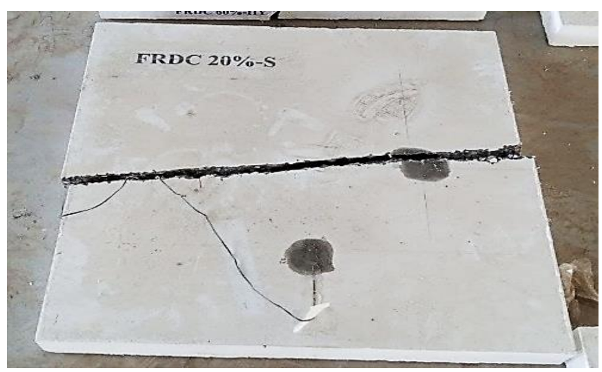
DSC100%

FRDC0%-S



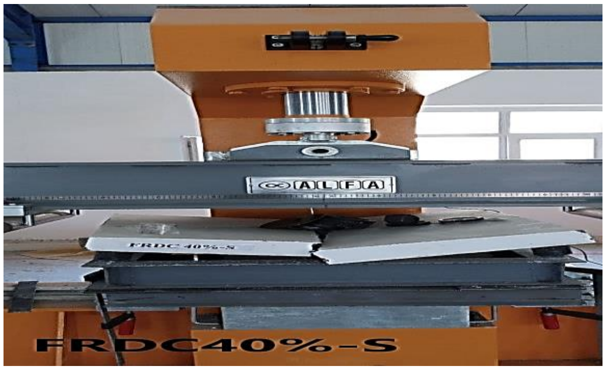
FRDC0%-S

FRDC20%-S

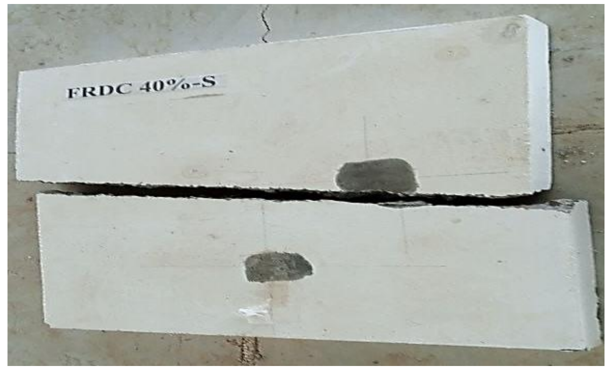


FRDC20%-S

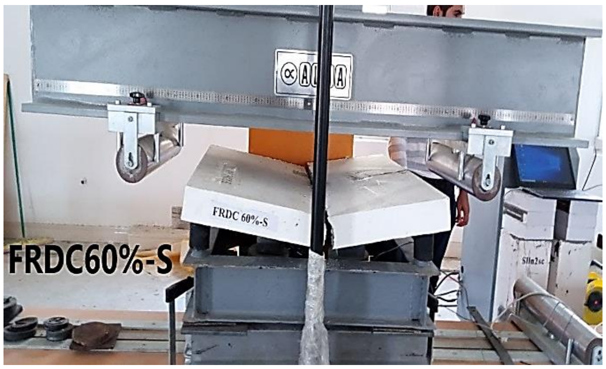
Figure 4.169 Continued.



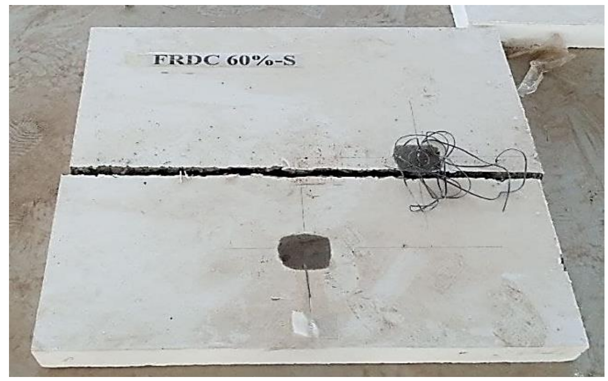
FRDC40%-S



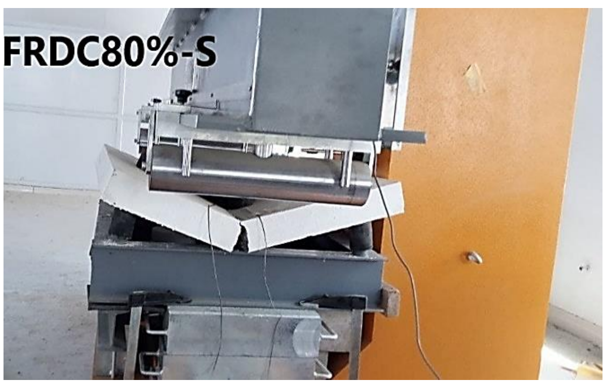
FRDC40%-S



FRDC60%-S



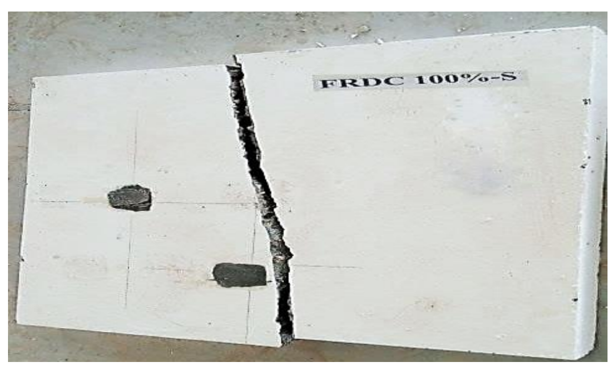
FRDC60%-S



FRDC80%-S

FRDC80%-S

FRDC100%-S



FRDC100%-S

Figure 4.169 Continued.

FRDC0%-L

FRDC0%-L

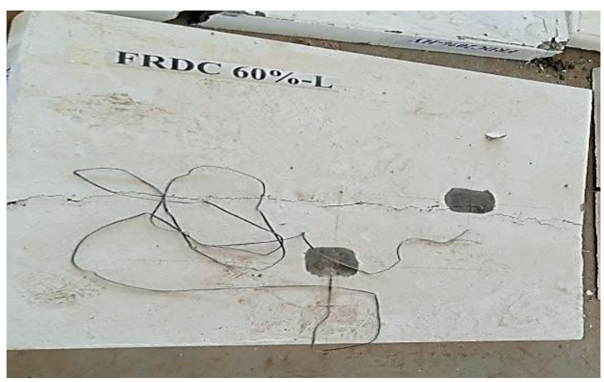
FRDC20%-L

FRDC20%-L

FRDC40%-L

FRDC40%-L

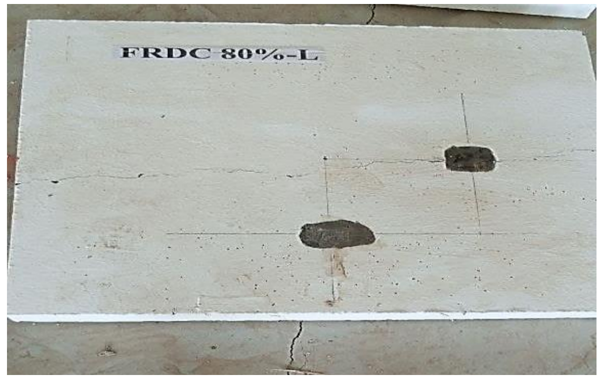
FRDC60%-L



FRDC60%-L

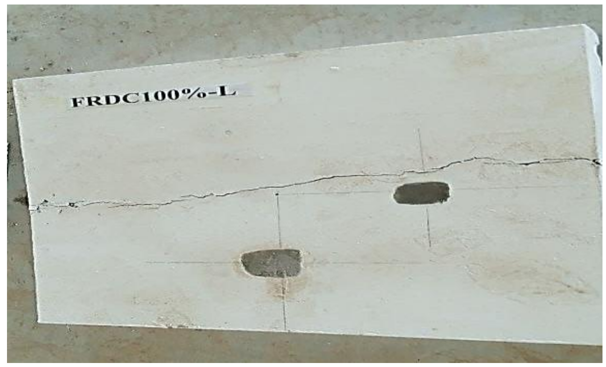
Figure 4.169 Continued.

FRDC80%-L

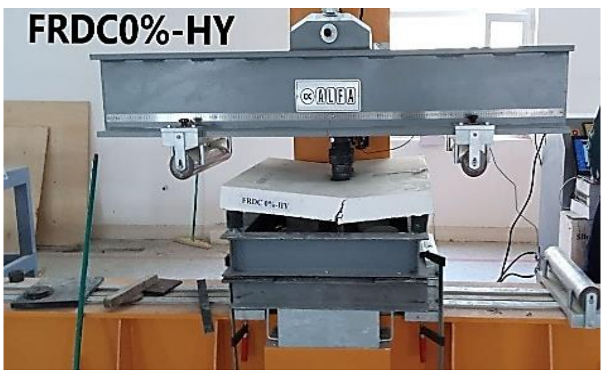


FRDC80%-L

FRDC100%-L



FRDC100%-L



FRDC0%-HY

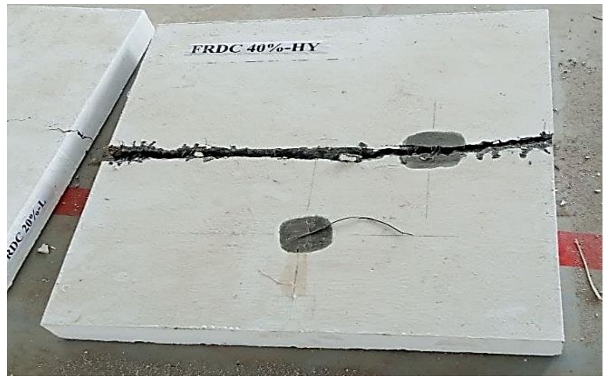
FRDC0%-HY

FRDC20%-HY

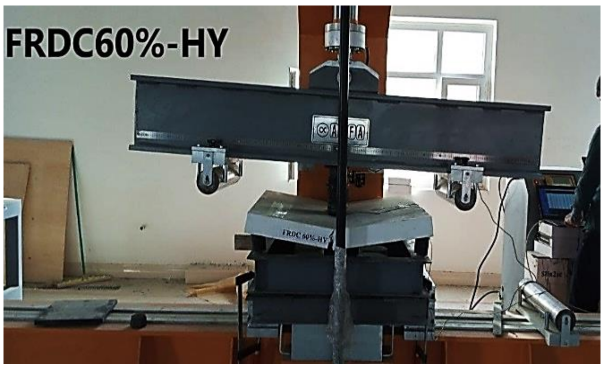
FRDC20%-HY

Figure 4.169 Continued.

FRDC40%-HY



FRDC40%-HY

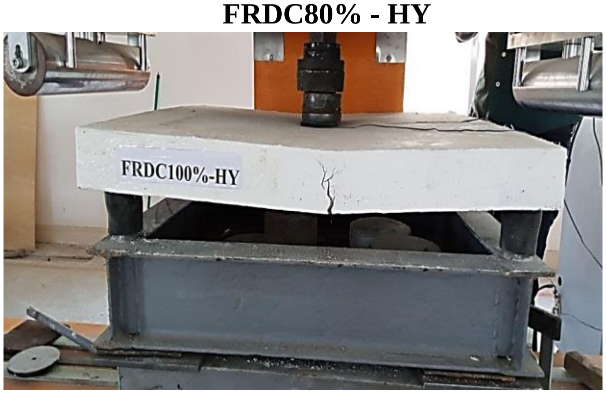


FRDC60%-HY

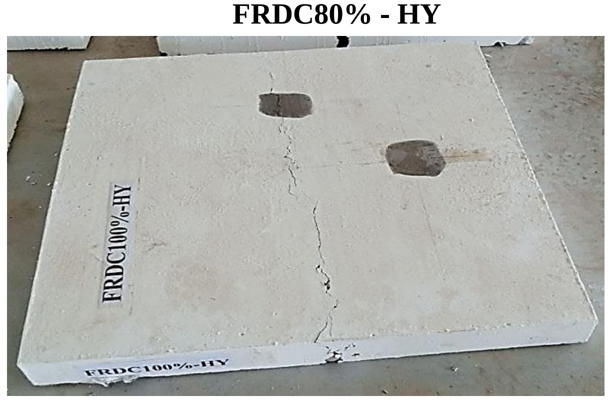
FRDC60%-HY

FRDC80% - HY

FRDC80% - HY



FRDC100%-HY



FRDC100%-HY

Figure 4.169 Continued.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 General

The main conclusions of the results of experimental tests of concrete containing sand dunes as an alternative to sand are presented in this chapter. The conclusions are divided into two parts:

1- Mechanical and physical properties of concrete containing sand dunes as a partial and total alternative for sand and reinforced with single and hybrid steel fibers.

2- Structural behavior of concrete slabs containing sand dunes as a partial and complete alternative for sand and reinforced with single and hybrid steel fibers.

5.2 Conclusions

5.2.1 Physical and mechanical properties of concrete containing sand dunes as sand replacement and reinforced with single and hybrid steel fibers.

1-The workability of concrete mixes decreases with the increase in the content of sand dunes. The reference mixture achieved the highest workability, while recorded the mixtures containing sand dunes as an alternative to the sand for the ratios (20%, 40%, 60%, 80% and 100%) a decrease in the workability by about 15%, 13%, 21% and 26% compared to the reference mixture, respectively. Also, the workability decreases when adding short, long and hybrid steel fibers to concrete mixtures, especially with long steel fibers, where the mixture containing 100% sand dunes and reinforced with long steel fibers (100% D.S + 1% S.F.L) recorded the lowest workability compared with the all mixtures concrete.

2-The compressive strength increases with the increase of the sand dunes content up to the replacement ratio of 60% as an alternative to sand, in specimens reinforced with single and hybrid steel fibers. The specimen (0%D.S+1%S.F.L) achieved the highest compressive strength with an increase of about 46.8% compared to the reference specimen, followed by the hybrid specimen (40%D.S+ 1%H.S.F), an increase of about 26.6% compared to the specimen (40% D.S without fibers). The compressive strength decreases with the increase of the dunes sand content for the replacement ratios of 80% and 100%, where the specimen (100%D.S+1%S.F.S) recorded the lowest compressive strength compared to all specimens that contain steel fibers, but it is higher than the specimens without the fibers.

3- The splitting tensile strength increases with the increase of sand dunes content until the replacement ratio of 80% in specimens reinforced with single and hybrid steel fibers. The tensile strength decreases with the replacement ratio of 100%. The specimen (0%D.S+1%S.F.L) achieved the highest tensile strength with an increase of about 77.4% compared to the reference specimen. The lowest tensile strength of the specimen (100%D.S+1%S.F.S) compared to all specimens reinforced with fibers, but it is higher than the specimen (100%D.S without fibers) by about 31.2%.

4- The flexural strength increases with the increase of sand dunes content until the replacement ratio of 80% in specimens reinforced with single and hybrid steel fibers. The flexural strength decreases with the replacement ratio of 100%. The highest flexural resistance for the specimen (20%D.S+1%S.F.L) with an increase of about 45.3% higher than the specimen (20%D.S without fibers). The least flexural strength of the specimen (100%D.S+1%S.F.S) compared to all specimens reinforced with steel fibers, but it is higher than the specimen (100%D.S without fibers) by about 20.4%.

5- The dry density increases with the increase of sand dunes content until the replacement ratio of 80% in specimens reinforced with single and hybrid steel fibers. The dry density decreases with the replacement ratio of 100%. The highest density for the specimen (0%D.S+1%S.F.L) with an increase of about 7.6% higher than the reference specimen. The least density of the specimen (100%D.S+1%H.S.F) compared to all specimens reinforced with steel fibers, but it is higher than the specimen (100%D.S without fibers) by about 0.17 %.

6- Concrete's water absorption decreases with the increase of sand dunes until the replacement ratio of 40% in specimens reinforced with single and hybrid steel fibers, the absorption increases with the increase in the content of dunes sand for the replacement ratios (60%, 80%, 100%). The specimen (0%D.S+1%S.F.S) recorded the lowest absorption by about 64.9% compared to the reference specimen. While the highest absorption of the specimen (100%D.S+1%S.F.S) compared to all specimens with an increase of about 22.5% higher than the specimen (100%D.S without fibers).

7- The ultrasonic pulse velocity increases with the increase of sand dunes content until the replacement ratio of 40% in specimens reinforced with single and hybrid steel fibers, and decreases with the replacement ratios (60%, 80%, 100%). The highest pulse velocity for the hybrid specimen (0%D.S+1% H.S.F) with an increase of about 26.9% higher than the reference specimen. The lowest pulse velocity of the specimen (100%D.S+1%S.F.L) compared to all specimens reinforced with fibers, but it is higher than the specimen (100%D.S without fibers) by about 0.71%, we note from all the results that a pulse velocity reading of less than 4000m/s was not recorded, and this indicates that the concrete is cohesive and homogeneous for all specimens.

8- The static modulus of elasticity increases with the increase of sand dunes content until the replacement ratio of 60% in specimens reinforced with single and hybrid steel fibers, and decreases with the replacement ratios of 80% and 100%. The specimen (0%D.S+1%S.F.L) achieved the highest modulus of elasticity by about 44.3% higher than the reference specimen. The least elastic modulus of the specimen (100%D.S+1%S.F.S) compared to all specimens containing fibers. , but it is higher than the specimen (100% D.S without fibers) by about 14.6%.

9- The dynamic modulus of elasticity increases with the increase of sand dunes content until the replacement ratio of 60% and decreases with the replacement ratios of 80% and 100%. The specimen (0%D.S+1%S.F.L) achieved the highest dynamic modulus of elasticity depending on the pulse velocity and density, with an increase of about 72.2% higher than the reference specimen. The lowest dynamic modulus of elasticity for the specimen (100%D.S+1%S.F.L) compared to all specimens containing fibers. , but it is higher than the specimen (100% D.S without fibers) by about 2%.

10- Increasing the fineness of sand dunes positively affects the mechanical and physical properties of concrete, especially when using dune sand in partial ratios with natural sand, and the effect decreases when sand dunes is used for total ratios.

11- The addition of steel fibers, especially long and hybrid greatly helped in improving the physical and mechanical properties of concrete and better performance than the properties of concrete without fibers.

5.2.2 Structural behavior of concrete slabs containing sand dunes as sand replacement and reinforced with single and hybrid steel fibers

Based on the results test of concrete slabs reinforced with single and hybrid steel fibers or without fibers and containing replacement ratios of sand dunes as an alternative for sand, we can conclude the following:

1-The ultimate failure load increase with single and hybrid steel fiber reinforced concrete slabs containing sand dunes replacement ratios (0%, 20%, 40%, and 60%). The slabs reinforced with hybrid steel fibers and the replacement ratio (0% and 40%) achieved the highest maximum failure load of about 59% and 25% compared to slabs (DSC0% and DSC40% without the fibers). The lowest maximum load for the slab (FRDC100%-S) compared to the slabs reinforced with fibers, but it is higher than the slab (DSC100% without fibers) by about 8.87%.

2- It is evident from the load-deflection curves that the behavior of concrete slabs without fibers is brittle behavior, the curve takes a linear path until failure, while the slabs containing single and hybrid steel fibers, the curve path for most slabs are nonlinear where the curve starts from the yield region. The slab (FRDC60%-S) achieved the highest ductility compared to slabs containing long and hybrid steel fibers, about 7.9% and 19.3%, respectively. The lowest ductility for hybrid slab (FRDC100%-HY).

3- The ultimate deflection decreases with increasing sand dunes content in the slabs. All slabs containing D.S without fibers recorded a reduction in maximum deflection compared to the reference slab. The slab (FRDC0%-S) recorded the highest value of ultimate deflection with an increase of about 11% higher than the reference slab. While the lowest deflection of the slab (FRDC40%-L).

4- The failure pattern for all slabs is flexural failure, and the crack path is linear between the up and down direction of the slab.

5- The absorption energy decreases with the increase of sand dunes content for all slabs without fibers. The addition of the hybrid steel fibers, and the long single fibers, helped to improve the absorption capacity of concrete slabs. The hybrid slabs (FRDC0%-HY) and (FRDC40%-HY) achieved the highest absorption energy by about 75% and 66% respectively, compared to the slabs without fibers. The lowest absorption energy of the slab (FRDC100%-S).

6- Compressive strain decreases with the increase of the replacement ratios of sand dunes for all slabs without fibers. The slab (FRDC0%-S) recorded the highest value of the strain with an increase of about 10.75% compared to the reference slab. The rest of the slabs achieved strain results with varying percentages of decrease or increase compared to slabs without fibers.

7- The initial stiffness and the effective stiffness increase with the increase of sand dunes content for all slabs without fibers. The initial and effective stiffness increases with the slabs reinforced with the steel fibers. The slab (FRDC40%-L) achieved the highest initial and effective stiffness with an increase of about 73.1%, and 48%, respectively, compared to the slab (DSC 40% without fibers). The lowest initial and effective stiffness of the slab (FRDC0%-S) compared to all the slabs reinforced with fibers, but it is higher than the reference slab by about 12.4% and 3.7%, respectively.

5.3 Recommendations

The recommendations presented below are suggestions for future studies and research:

1- Study of the effect of sand dunes as a partial and total alternative for sand on hollow concrete pipes used in tubular bridges reinforced with polyethylene fibers (polymer).

2- Due to the good effect of sand dunes when used as an alternative for sand in improving the physical and mechanical properties of concrete and the structural behavior of slabs, it is recommended to explore the behavior of other structural parts in the same way of reinforcing such as beam and fiber-reinforced hollow slabs under the influence of flexural as well as under the effect of punching shear.

3- As a result of the positive effect of sand dunes on the behavior of the slabs under the influence of flexural, therefore, we recommend studying its effect when used in partial and total proportions with carbon fibers in the ground slabs to obtain concrete with high strength and evaluating the results in terms of resistance to shrinkage, expansion, heat, and shear at the edges.

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الملخص

يمكن معالجة المشاكل البيئية للكثبان الرملية والتي من اهمها زحف هذه الرمال على الطرق وانتشارها بصورة مفاجئة في الأرض وغيرها، عن طريق استخدامها كركام ناعم في الخرسانة. هدف الرسالة دراسة تأثير استخدام الكثبان الرملية كاستبدال للرمل في البلاطات الخرسانية المسلحة بالألياف. تم تقسيم دراسة الرسالة الى جزأين: يتضمن الجزء الأول دراسة تأثير استخدام الكثبان الرملية كاستبدال جزئي وكلي للرمل على الخواص الميكانيكية والفيزيائية للخلطات الخرسانية المسلحة بألياف فولاذية مفرده وهجينة. يتضمن الجزء الثاني دراسة تأثير استخدام الكثبان الرملية كاستبدال للرمل على السلوك الانشائي للبلاطات الخرسانية المسلحة بالألياف الفولاذية.

تضمن البرنامج التجريبي للرسالة استخدام ست نسب استبدال (وزنية) للكثبان الرملية (0%,20%,40%,60%,80%,100%). تم صب 24خلطة خرسانية , 6 منها بدون الياف و18 خلطة مسلحة بألياف فولاذية. نوعين من الالياف تم استخداما في هذه الدراسة، الياف فولاذية مستقيمة دقيقة بطول 13 ملم والياف فولاذية طويلة (ذي نهايات خطافيه) بطول 50 ملم بصورة (منفردة او هجينة)، بنسبة ثابته 1% من حجم الخرسانة. تشمل الاختبارات الميكانيكية للجزء الأول، الانضغاط وشد الانقسام والانثناء، بينما كانت الاختبارات الفيزيائية التي تم إجراؤها، الكثافة الجافة والامتصاص وسرعة النبض بالموجات فوق الصوتية للخرسانة ومعامل المرونة الساكن والديناميكي، بالإضافة الى اختبار الهطول.

شملت اختبارات الجزء الثاني الذي يتضمن اختبار أربعة وعشرين بلاطة خرسانية ذات اسناد بسيط بأبعاد (80 ×800 ×800) ملم، مع نظام اسناد للبلاطة يحتوي على أربع نقاط أعمدة عند الأركان تجلس عليها البلاطة، تحت نقطة تحميل مركزه واحدة عند منتصف البلاطة. حيث تم الحصول على حمل الأقصى للفشل والانحراف النهائي والانفعال والمطيلية للبلاطات المسلحة بألياف وطاقة الامتصاص والصلابة وكذلك نمط الفشل. أظهرت نتائج اختبارات الجزء الأول ان قابلية التشغيل تنخفض مع جميع نسب الاستبدال للكثبان الرملية في الخرسانة المسلحة بألياف فولاذية، وتحسن في الخواص الميكانيكية مع زيادة محتوى الكثبان الرملية في الخلطات الخرسانية الليفية. حققت الخلطات الخرسانية (40% Sand Dunes +1%Hybrid Fiber)، (20% Sand Dunes +1%Hybrid Fiber) و(20%Dune sand +1% Long Fiber) أعلى مقاومة انضغاط وشد الانقسام والانثناء بزيادة بنحو 26.6% ، 52.9% و45.3% على التوالي للخلطات اعلاه مقارنة بالخلطات بدون ألياف. هذه الزيادة بسبب نعومة حبيبات الكثبان الرملية التي تملئ الفراغات والفجوات بين الحصى والرمل عندما يكون الاستبدال جزئي بالإضافة الى دور الالياف في زيادة التماسك وترابط مكونات

الخليط. تنخفض الخواص الميكانيكية عندما يتجاوز محتوى الكثبان الرملية نسبة 60% لمقاومة الانضغاط و80% لمقاومة الشد والانثناء مقارنة بخلطة التحكم.

كما أظهرت النتائج تحسن في الخواص الفيزيائية مع زيادة محتوى الكثبان الرملية للعينات المسلحة بألياف فولاذية لغاية نسب الاستبدال للكثبان الرملية (80% للكثافة الجافة و40% لسرعة النبض بالموجات فوق الصوتية و60% للامتصاص ومعامل المرونة الساكن والديناميكي).

بينما أظهرت نتائج الاختبار للبلاطات في الجزء الثاني، ان زيادة محتوى الكثبان الرملية تؤدي الى زيادة في حمل الفشل النهائي و طاقة الامتصاص والصلابة الأولية والفعالة لنسب الاستبدال (0%- 40%) لجميع البلاطات المسلحة بألياف فولاذية وخاصة الالياف الأطول بمعدل زيادة بنحو 5.6%,8.9%, 13.6%, و22.4% على التوالي مقارنة بالبلاطات المسلحة بالألياف الطويلة بدون كثبان رملية. بينما انخفض الانحراف النهائي مع زيادة الكثبان الرملية في البلاطات المسلحة بالألياف الطويلة والهجينة عند نسبة الاستبدال 40%.

نمط الفشل لجميع البلاطات هو فشل انثناء، ومسار التشقق خطي بين الاتجاه الأعلى والاسفل للبلاطة.

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تحري البلاطات الخرسانية المسلحة بالألياف المتضمنة كثبان رملية كاستبدال للرمل

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