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EFFECT OF DUNE SAND AS SAND REPLACEMENT ON THE MECHANICAL PROPERTIES OF THE HYBRID FIBER REINFORCED CONCRETE

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Abstract

This paper presents an experimental work to study the effect of dune sand as an alternative to sand on the mechanical properties of hybrid fiber reinforced concrete. 24 concrete mixes were prepared, 6 of them without fibers and containing different proportions of dune sand, and 18 concrete mixes with the same proportions of dune sand but containing long and short single and hybrid steel fibers. For the purpose of studying the properties of hybrid concrete, including measuring the workability of fresh concrete, examining the compressive strength, dry density, split tensile strength, Flexural strength, ultrasonic pulse velocity testing, water absorption of hardened concrete. The main parameters were the proportions of dune sand (20 %, 40 %, 60 %, 80 %, and 100 %) in addition to the ratio 0 % without dune sand. Two types of steel fibers were used: straight steel fibers (short) with a length of 13 mm and hook end steel fibers (long) with a length of 50 mm, It is added to concrete (single or hybrid) with a total volume ratio of 1 % of the concrete volume . The tests that were conducted showed that sand dunes affect the compressive strength, especially when the percentage increased by more than 40 %, where the compressive strength of concrete decreases by 39 % when the replacement ratio reaches 100 %, but it improves with the addition of single or hybrid fibers. Also, the workability from high to medium level decreases by 30 % with increasing dune sand content, the addition of steel fibers along with dune sand significantly reduced the workability. The tensile and flexural strength decreases with the increase in the sand dune rate, but at a lower rate than the compressive strength, which was 29.3 %, 21.1 % for splitting and flexural tensile strength, respectively. The addition of steel fibers improved the mechanical properties of the hybrid concrete, which can compensate for most of the lost strength due to the increase in sand dunes ratios. The study also showed that the use of long fibers (hook end) gives better results than straight fibers. But in the case of using hybrid fibers, we can get an improvement in the mechanical properties more than using one type of fiber.

Keywords:

Hybrid fibers concrete;
Dune sand;
Steel fibres;
Sand replacement;
Long fibers.

1 Introduction

With the increasing demand for building construction and the urgent need to use concrete, the demand for its components has also increased, as repeated use of sand, for example, is increasingly a source of great concern and danger, as it may cause serious environmental effects in addition to the cost resulting from preparing sand [1]. For these and other reasons, researchers sought an alternative to sand, one of the most significant ingredients in concrete. One of these resources is desert sand or sand dunes as a fine aggregate in concrete. Many studies have been done on this subject, but the results are limited and further research is needed to understand how sand dunes affect the mechanical properties of concrete [2]. One of the most important previous studies that dealt with the effect of using sand dunes as an alternative to sand was Al-Harthy, A. S. et al. [3], he added dune

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sand by 10 - 100 % as a percentage of natural sand, he found a remarkable effect of dune sand on the mechanical properties of concrete, especially when the ratio was increased to more than 50 % in which the concrete with good workability and the decrease in concrete strength does not exceed 25 %. Zhang et al. [4] presented an experimental study on the possibility of using dune sand in the production of concrete to improve the workability and concrete strength by using superplasticizers. Their results showed the possibility of using the superplasticizer to improve the workability and compressive resistance of concrete. The mechanical properties of concrete containing dunes sand have been studied by Qin, S. et al. [5], their results showed that sand dunes gave the concrete a higher flexural strength than concrete containing river sand.

The concrete as a result of loadings suffers from cracks and these cracks may extend and grow rapidly as the loading value increases, causing the failure of the entire structure. The fibrous concrete provides a good solution for cracking control. A monofilament kind of steel fibers has been found to successfully suppress cracking due to shrinkage and differential settlements during the fresh condition [6]. Radim, C. and Zuzana, M. [7] have studied the mechanical properties of steel fiber reinforced concrete (hook ends) of 60 mm in length and 0.9 mm in diameter. Three concrete slabs containing different proportions of steel fibers were used which are 25, 50, and 75 kg/m^3. The mechanical properties of fiber reinforced and ordinary concrete were evaluated, including compressive strength, tensile strength, modulus of elasticity. For the purpose of observing the differences in the behavior of fiber concrete, the test results showed the positive effect of the fibers on the load capacity and deformations of the slabs.

The process of assembling fibers is called hybridization and is the process of mixing different fibers in order to increase its efficiency in concrete and to create a new compound with improved concrete properties. Many researchers have worked hard to find synergies by adjusting the proportion of fiber [8]. Hybridization of fibers in concrete is not limited to different fiber lengths, but the difference may be in the shape, type, strength, flexibility, or tensile strength of the fibers, and their effect is shown by studying the mechanical properties of hybrid concrete [9]. Iqbal, K. and Wasim, A. [10] studied the effect of steel fiber hybridization on the mechanical properties of high-strength concrete. They used different proportions of hook-end fibers in lengths 40 mm, 60 mm were hybridized in the concrete mixture while maintaining the total percentage of fibers 1 % of the concrete volume. They observed that the hybridization of 0.65 % of fibers of 60 mm length and 0.35 % of fibers of 40 mm length is the best ratio for improving the compressive and flexural properties. Mohammed, A. et al. [11] studied the mechanical properties of concrete containing hybrid steel fibers (hook end) with different lengths for both states of fresh and hardened concrete and with different percentages of fibers. They found that the workability decreases with an increase in the percentage of fibers 1.5 % in the mixture, while for the same percentage the flexural strength, splitting tensile strength, and compressive strength increase when using hybrid fiber reinforced concrete consisting of 70 % long fibers and 30 % fibers. Leonid, D. et al. [12] studied the effect of adding hybrid steel, basalt, and polypropylene fibers on the mechanical properties of fine-grained concrete; they confirmed that the hybrid steel fibers and basalt fibers achieve good performance for fine-grained concrete compared to the performance of single fibers in concrete. The aim of this work is to study the effect of dune sand as a partial and total alternative to sand on the mechanical properties of hybrid fiber reinforced concrete. Two types of steel fibers were used: hook-end, 50 mm long and 0.75 mm in diameter, and the second type is straight steel fibers, 13 mm long and 0.2 mm in diameter, 24 concrete mixtures consisting of 6 mixtures of different proportions of dune sand as a substitute for sand without steel fibers (0 %, 20 %, 40 %, 60 %, 80 %, 100 %) and 18 concrete mixtures consisting of 6 major proportions of sand dunes, For each major replacement ratio, 3 percentages of steel fibers are added (the proportion of steel fibers is constant at 1 % of the concrete volume). The main proportion of replacement consists of 3 mixtures: The first is to which long steel fibers are added with a hook-end at a rate of 1 %, and the second mixture is to which a short straight steel fiber is added at a rate of 1 %, and the third mixture is to which a hybrid steel fiber is added, consisting of 0.65 % of the long fibers and 0.35 % of the short fibers. 0.5 % plasticizer is added to each mixture, the *W/C* ratio is the same for all mixtures. For each mixture, 6 cubes are casting with dimensions 150 x 150 x 150 mm, 6 cylinders 200 x 100 mm, 6 prisms 500 x 100 x 100 mm. The slump test is conducted for the fresh concrete, as well as the tests for the compressive strength, the splitting tensile strength, the flexural strength, as well as the density test and ultrasonic for the concrete and the absorption test for the hardened concrete. The results of the tests for hybrid concrete are compared with the results of reference concrete and single fiber concrete and their effect on concrete is shown.

2 Experimental work

2.1 Material characteristics

2.1.1 Cement

In this study, ordinary Portland cement was used. Physical and chemical tests of cement were conforms to the Iraqi Standard Specifications No 5/1984 [13], and ASTM C150-04 [14], as shown in Tables 1, 2 and Fig. 1.

2.1.2 Aggregates

Crushed gravel with a gradation of 5 - 19 mm was used as coarse aggregate in this study from the Iraqi-Iran borders in southern Iraq. Natural sand was also used as fine aggregate in partial and total proportions in the mixtures, and the maximum size of sand was 4.75 mm. The examination of the gradation and physical properties of the fine aggregate was conducted according to the Iraqi Standard Specifications No. 45/1984 [15], and ASTM C 33-03 [16], as shown in Table 3 and Fig. 2.

2.1.3. Dunes sand (D.S)

Dune sand was used as an alternative to sand in partial and total proportions in concrete, and this material was brought from the Al-Batira area, in the west of Al-marah city, southern Iraq. Chemical tests for sand dunes and gradation according to the Iraqi Standard Specifications for fine aggregate No. 45/1984 [15], and ASTM C33-03 [16], as shown in Table 4 and Fig. 3.

2.1.4 Admixture

The PC260 superplasticizer was used as a concrete additive to improve workability and reduce water, and it complies with the American Standard ASTM C494_99 Types A and G [17].



Fig. 1: The materials used in the research.

Table 1: Physical properties of cement.

Cement type : Ordinary Portland cement		
Physical properties	**Test result**	**The limits of the Iraqi standard specification No. 5/1984 [13]**
Fineness [kg/m^3]	381	≥ 230
Setting time		
Initial setting time [hrs: min.]	2 : 09	≥ 0.45 min.
Final setting time [hrs: min.]	4 : 20	≤ 10 hrs
The compressive strength of mortar		
3 day [MPa]	19.8	≥ 15
7 day [MPa]	32.1	≥ 23

Table 2: Chemical composition of cement.

Chemical properties [%]	**Test resultby weight [%]**	**The limits of the Iraqi standard specification No. 5/1984 [13]**
Magnesia MgO	3.65	≤ 5 %
Sulphate SO_3	2.23	SO_3 % content is not more than when the proportion of C3A < 5 % > 5 %
Insoluble substances I.S	0.62	≤ 1.5 %
Loss on ignition L.O.I	1.87	≤ 4 %
Tri calcium aluminates C_3Al	3.66	---

Table 3: The results of the properties of graded sand.

	Test	Test result	Limits of Iraqi specification No. 45/1984 [15]
Harmful and fine materials	Material passing through a 75 micron sieve [%]	0.6	≤ 15
	Sulfate content [%]	0.297	≤ 15
Specific gravity		2.65	---
Absorption [%]		0.76	---
Fineness		2.61	---

Table 4: Chemical analysis of the dune sand (Al-Batira).

Oxides compounds	Test results of dune sand samples from Al-Batira / Misan region
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

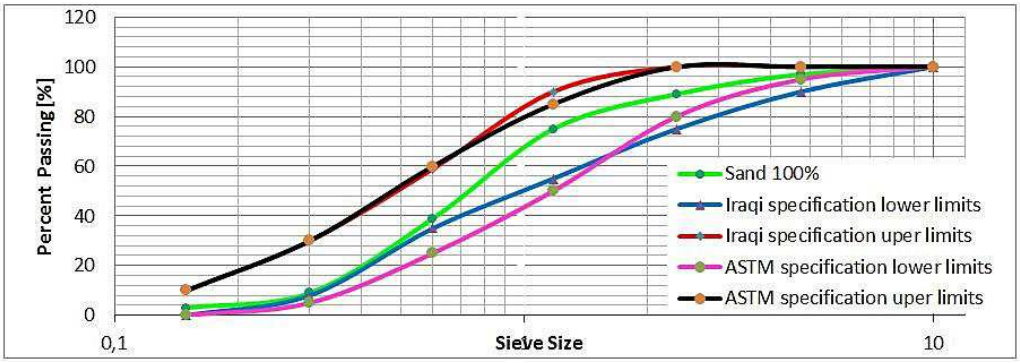


Fig. 2: Gradation curve for sand according to and Iraqi specifications NO. 45/1984 [15] and ASTM C33 [16].

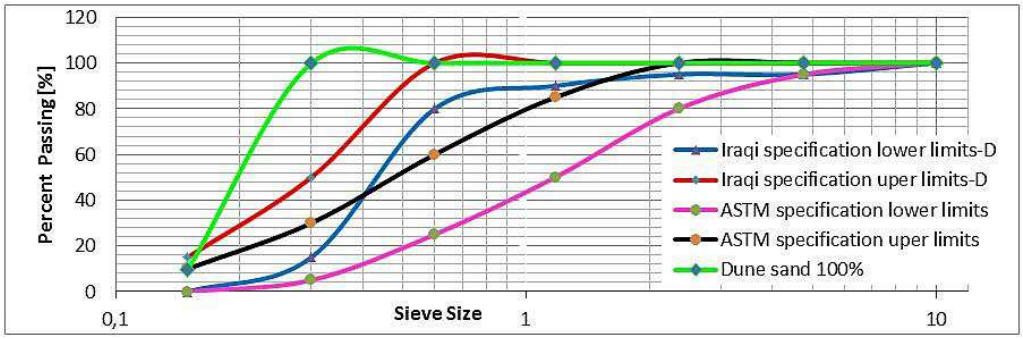


Fig. 3: Gradation curve for 100 % Dune sand according to Iraqi specifications NO. 45/1984 [15] and ASTM C33 [16].

2.1.5 Fibers

Two types of steel fibers are used: straight microfibers with a length of 13 mm and hook-end steel fibers with a length of 50 mm. They are added to the concrete mixture singly or mixed together at a total percentage of 1 % of the concrete volume. The properties of these fibers are shown in Fig. 4 and Tables 5.



Fig. 4: Straight steel fiber and long hook-end fiber.

Table 5: Properties of steel fibers straight and hooked – end.

Description	Shape	Length [mm]	Diameter [mm]	Density [kg/m^3]	Aspect ratio *L/D*	Tensile strength [MPa]	Elastic modulus [GPa]
1	Straight	13	0.2	7800	65	2850	210
2	Hooked-end	50	0.75	7850	67	1100	200

2.2 Gradation of dune sand and natural sand mixtures

In order to obtain good performance of dune sand (D.S) as fine aggregate in concrete mixtures it was mixed with graded natural sand in different proportions to reduce the negative effect of the fineness of dune sand granules. The maximum particle size of dune sand is less than 1.18 mm. From Fig. 3. The results of the dune sieve analysis showed that it conform with the Iraqi Standard No. 45/1984 [15] and ASTM C33-03 [16] specifications for the fine aggregate gradation, except for the sieves 600 μm and 300 μm where a deviation from standard limits were recorded due to the fineness and small size of the sand dune grains. Therefore, a comprehensive proportions of dune sand were used as an alternative to sand in the mixtures by amount of 20 %, 40 %, 60 %, 80 % and 100 % in addition to reference mix 0 % dunes sand. Then fibers are added to above mixtures individually or as hybrid fibers to increase the efficiency and quality of concrete and to study the effect of dune sand as a substitute for natural sand (N.S) on the mechanical properties of hybrid fiber reinforced concrete. Sieve analysis was performed for each percentage of sand dunes as a substitute for sand as shown in the Fig. 5, 6, 7 and 8. The results of the sieve analysis of the mixture of fine aggregates (dunes sand with sand) for different proportions are meet the requirements of zones *D*, *C*, *B* of the Iraqi standard [15] as well as the American standard [16] with some deviations in transit of fine sieves. The size of the granules of these mixtures ranges between medium and fine to very fine granules. In the present study the dune sand is used as sand replacement into three types of fiber reinforced concrete (i.e., single micro-steel fiber mix, single macro-steel fiber mix and hybrid-steel fibers mix) in addition to mix without fibers, as listed below.

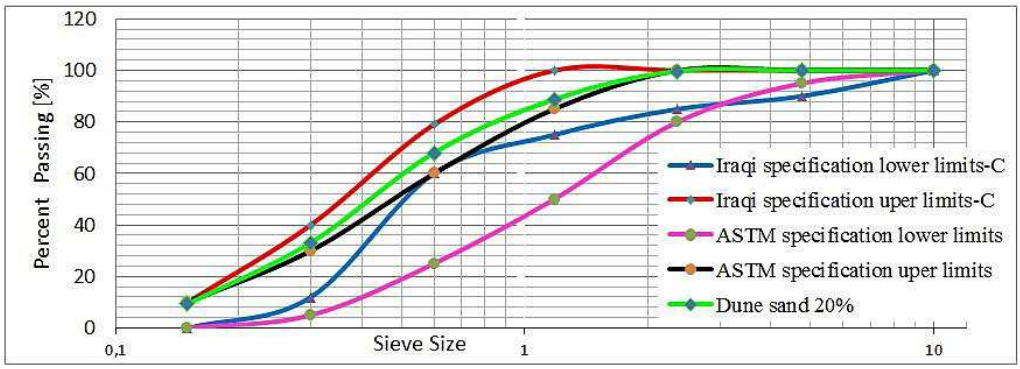


Fig. 5: Gradation curve for fine aggregate (20 % Dune sand + 80 % Natural sand) according to [15] and [16].

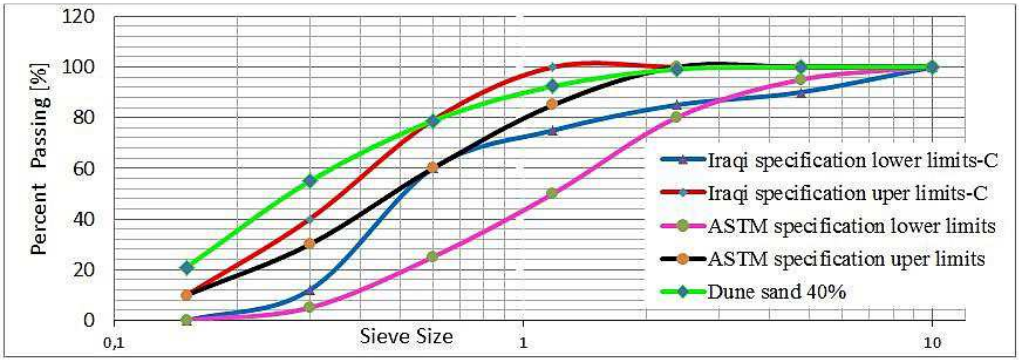


Fig. 6: Gradation curve for fine aggregate (40 % Dune sand + 60 % Natural sand) according to [15] and [16].

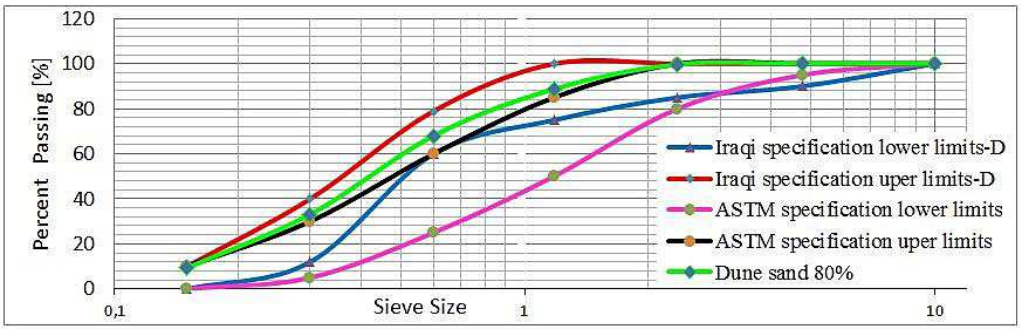


Fig. 7: Gradation curve for fine aggregate (60 % Dune sand + 40 % Natural sand) according to [15] and [16].

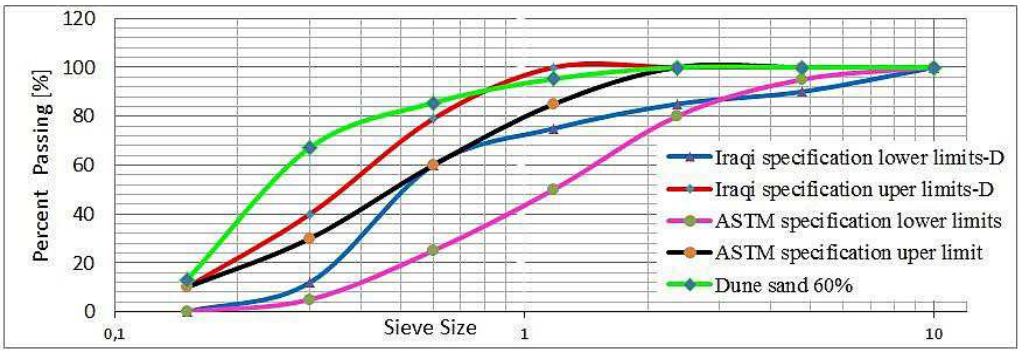


Fig. 8: Gradation curve for fine aggregate (80 % Dune sand + 20 % Natural sand) according to [15] and [16].

2.2.1 Dune sand as sand replacement for mixture without steel fibres

Five mixing ratios of dune sand were used as an alternative to sand, in addition to reference mix without dune sand, for mixtures without adding steel fibers, namely (0 % D.S, 20 % D.S, 40 % D.S, 60 % D.S, 80 % D.S, 100 % D.S). For each casting ratio, 6 cubes 150 x 150 x 150 mm, 6 prisms 500 x 100 x 100 mm, 6 cylinders 200 x 100 mm. as in Fig. 9.

2.2.2 Dune sand as sand replacement for mixture with single micro straight steel fibres

The same percentages of dune sand in section 2.2.1 are added to concrete mixtures containing 1 % of single straight steel fibers with a length of 13 mm and a diameter of 0.2 mm, namely 0 % D.S + 1 % S.F.S (steel fiber short), 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 casting ratio, 6 cubes 150 x 150 x 150 mm, 6 prisms 500 x 100 x100 mm, 6 cylinders 200 x100 mm, as in Fig. 10.

2.2.3 Dune sand as sand replacement for mixture with single macro steel fibres (hooked-end)

The same percentages of dune sand above are added to concrete mixtures containing 1 % hooked-end steel fibers, 50 mm long and 0.75 mm in diameter, namely 0 % D.S + 1 % S.F.L (steel fiber long), 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 casting ratio, 6 cubes 150 x 150 x 150 mm, 6 prisms 500 x 100 x 100 mm, 6 cylinders 200 x 100 mm, as in Fig. 11.

2.2.4 Dune sand as sand replacement for mixture with hybrid steel fibers

The same percentages of dune sand above are added to concrete mixtures containing a total percentage of 1 % of the hybrid steel fibers of the concrete volume (the hybrid fibers consist of 65 % of the long fibers and 35 % of the short fibers), namely 0 % D.S + 1 % H.S.F. (Hybrid steel fiber), 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 casting ratio, 6 cubes 150 x 150 x 150 mm, 6 prisms 500 x 100 x 100 mm, 6 cylinders 200 x 100 mm, as in Fig. 12 .



Fig. 9: Dune sand mixing ratios without steel fiber.



Fig. 10: Dune sand mixing ratios with micro straight steel fiber.



Fig. 11: Dune sand mixing ratios with macro steel fiber (hooked end).



Fig. 12: Dune sand mixing ratios with hybrid steel fiber.

2.3 Mix design and preparation

In this work, the concrete mixing materials included cement, fine aggregate consisting of a mixture of dune sand and natural sand, crushed gravel, water with plasticizer additive, single and hybrid steel fibers. A reference concrete mix was prepared according to the American code ACI.211.1-91 [18]. Table 6 shows the mixing ratios of concrete without fibers while Table 7 the mixing ratios of 1 m^3 with steel fibers. Coarse aggregate and fine aggregate (consisting of a mixture of dune sand and natural sand in different proportions) are added to the bowl of the electric mixer, then the mixer is run for two minutes. Then the cement is added to the mixture and mix the ingredients for another 2 minutes for the purpose of homogeneity of the mixture components while they are dry. Then the water is gradually added with the addition of the plasticizer. Then mix the ingredients for 3 minutes. Then the steel fibers are added, where the fibers are added manually and gradually to the mixing bowl with the continuous rotation of the mixing bowl in order to avoid the fibers being balled and collected in one mass and as in the Fig. 13. Then mix the ingredients for 5 minutes. After the mixing process is completed, the concrete is poured into the concrete transport vehicle, a slump test is conducted, and the concrete is poured into the iron molds as in the Fig. 14.

Table 6: Mixing ratios per cubic meter without steel fibres.

Mix	Dune sand 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]	Dune sand [kg/m^3]	Water to cement ratio *W/C*
M1	0 %	482.93	198	0.5 %	1024	650.07	0	0.41
M2	20 %	482.93	198	0.5 %	1024	520.06	130.01	0.41
M3	40 %	482.93	198	0.5 %	1024	390.04	260.03	0.41
M4	60 %	482.93	198	0.5 %	1024	260.03	390.04	0.41
M5	80 %	482.93	198	0.5 %	1024	130.01	520.06	0.41
M6	100 %	482.93	198	0.5 %	1024	0	650.07	0.41

2.5 Slump test for fresh concrete

A slump test was carried out for fresh concrete for all mixtures according to ASTM C143 [19] to measure the concrete workability. When adding steel fibers to concrete, the workability decreases, and to overcome the low workability, we use plasticizers to improve the workability. Table 8 shows the results of the slump test for concrete**.**



Fig: 13: Manually adding fibers to the mixer.

Table 7: Mixing ratios per cubic meter with the addition of steel fibers**.**

Dune sand [%]	Description of max		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]	Dune sand [kg/m^3]	*W/C*
	Mix	Description of steel fiber									
0 %	M7	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	650.07	0	0.41
	M8	Mono (13 mm)	482.93	0	78.5	198	0.5 %	1024	650.07	0	0.41
	M9	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	650.07	0	0.41
20 %	M10	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	520.06	130.01	0.41
	M11	Mono (13 mm)	482.93	0	78.5	198	0.5 %	1024	520.06	130.01	0.41
	M12	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	520.06	130.01	0.41
40 %	M13	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	390.04	260.03	0.41
	M14	Mono (13 mm)	482.93	0	78.5	198	0.5 %	1024	390.04	260.03	0.41
	M15	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	390.04	260.03	0.41
60 %	M16	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	260.03	390.04	0.41
	M17	Mono (13 mm)	482.93	0	78.5	198	0.5 %	1024	260.03	390.04	0.41
	M18	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	260.03	390.04	0.41
80 %	M19	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	130.01	520.06	0.41
	M20	Mono (13 mm)	482.93	0	78.5	198	0.5 %	1024	130.01	520.06	0.41
	M21	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	130.01	520.06	0.41
100 %	M22	Mono (50 mm)	482.93	78.5	0	198	0.5 %	1024	0	650.07	0.41
	M23	Mono 13 mm)	482.93	0	78.5	198	0.5 %	1024	0	650.07	0.41
	M24	0.65 long + 0.35 short	482.93	51.025	27.475	198	0.5 %	1024	0	650.07	0.41

2.6 Tests on hardened concrete

2.6.1 Density test

The density is calculated for the concrete cubes 150 x 150 x 150 mm at the age of 7 days and 28 days according to ASTM C642 [20] for all concrete mixtures as shown in Fig. 15 and the results are shown in Table 9.

2.6.2 Compressive strength test

Concrete cubes 150 x 150 x 150 mm were used to perform this test according to BS 1881 part 116 - 89 [21] using a compression machine with a capacity of 2000 KN as shown in Fig. 15 The compressive strength results for 7 days and 28 days are shown in Table 9**.**

2.6.3 Splitting tensile strength test

Cylindrical models 100 x 200 mm were used to measure the split tensile strength (indirect tensile test) according to ASTM C496 [22] as shown in Fig. 15 The splitting tensile strength results for 7 days and 28 days are shown in Table 10.



Fig. 14: Preparing the forms, pouring concrete, and curing it with purified water.

2.6.4 Flexural strength test

Prisms 500 x 100 x 100 mm were used to measure the flexural strength of all mixtures (using a simple beam with third-point loading), according to ASTM C78 [23] as shown in Fig. 15. The flexural strength results for 7 days and 28 days are shown in Table 10.

2.6.5 Absorption water test

Water absorption is tested using cubes of dimensions 150 x 150 x 150 mm and according to ASTM C642 [20]. Where the samples are placed in the drying oven for 72 hours at a temperature of 100 °C as shown in Fig. 15, then the samples are weighed while they are dry W_1, then the samples are immersed in water for 24 hours and the samples are weighed after immersion W_2. The water absorption ratio is calculated from the following relationship and listed in Table 11.

$$\text{Water Absorption [\%]} = \left[\frac{\text{weight of specimen after submerged in water } (W_2) - \text{Dry weight } (W_1)}{\text{weight before submerged (Dry weight) } (W_1)}\right] \cdot 100 \ . \quad (1)$$

2.6.6 Ultrasonic pulse velocity test UPV

Ultrasound Pulse Velocity UPV is a non-destructive technique for predicting the strength of a material, calculating the modulus of elasticity of concrete, and detecting internal defects such as cracks, voids and gaps, homogeneity of concrete, depth measurement of the concrete layer, Determining the quality of concrete, and other problems by measuring ultrasonic velocity through materials. This examination is carried out on concrete cubes 150 x 150 x 150 mm aged 28 days before crushing by compression test, This test is carried out using a pundit ultrasonic instrument, according to BS1881-part 116 [24] and the results are listed in the Table 12.

Table 8: Results of workability for concrete mixes.

Mix	D.S / Sand percentage [%]	Slump test [mm]	Workability classification according to European standard ENV 206:1992	Limit of ENV 206:1992 [25]	Reduction in slump [%]
M1	0 % D.S	160	High workability	≥ 160 mm	-
M2	20 % D.S	135	Medium workability	100 - 150 mm	15
M3	40 % D.S	138	Medium workability	100 - 150 mm	13
M4	60 % D.S	125	Medium workability	100 - 150 mm	21
M5	80 % D.S	117	Medium workability	100 - 150 mm	26
M6	100 % D.S	112	Medium workability	100 - 150 mm	30
M7	0 % D.S + 1 % S.F.S	107	Medium workability	100 - 150 mm	33
M8	0 % D.S + 1 % S.F.L	102	Medium workability	100 - 150 mm	36
M9	0 % D.S + 1 % H.S.F	104	Medium workability	100 - 150 mm	35
M10	20 % D.S + 1 % S.F.S	98	Low workability	50 - 90 mm	27
M11	20 % D.S + 1 % S.F.L	90	Low workability	50 - 90 mm	33
M12	20 % D.S + 1 % H.S.F	93	Low workability	50 - 90 mm	31
M13	40 % D.S + 1 % S.F.S	88	Low workability	50 - 90 mm	36
M14	40 % D.S + 1 % S.F.L	83	Low workability	50 - 90 mm	39
M15	40 % D.S + 1 % H.S.F	85	Low workability	50 - 90 mm	38
M16	60 % D.S + 1 % S.F.S	80	Low workability	50 - 90 mm	36
M17	60 % D.S + 1 % S.F.L	70	Low workability	50 - 90 mm	44
M18	60 % D.S + 1 % H.S.F	75	Low workability	50 - 90 mm	40
M19	80 % D.S + 1 % S.F.S	75	Low workability	50 - 90 mm	35
M20	80 % D.S + 1 % S.F.L	70	Low workability	50 - 90 mm	40
M21	80 % D.S + 1 % H.S.F	73	Low workability	50 - 90 mm	37
M22	100 % D.S + 1 % S.F.	70	Low workability	50 - 90 mm	37
M23	100 % D.S + 1 % S.F.L	65	Low workability	50 - 90 mm	41
M24	100 % D.S + 1 % H.S.F	68	Low workability	50 - 90 mm	39



Fig. 15: Concrete samples tests a, b, c, d, e, f.

Table 9: The results of dry density, compressive strength of concrete cubes at the ages of 7 days and 28 days.

Mix	Dune sand / Sand percentage [%]	Average split tensile strength *FS* [MPa]		[%] change in split tensile strength at 28 days	Average flexural strength *fr* [MPa]		[%] change in flexural strength at 28 days
		7 days	28 days		7 days	28 days	
M1	0 % D.S	2.83	3.27	-----	5.98	6.80	----
M2	20 % D.S	3.1	3.4	3.97	6.11	6.93	1.91
M3	40 % D.S	2.8	4	22.32	6.24	7.47	9.85
M4	60 % D.S	3.08	3.3	0.91	6.21	6.75	- 0.73
M5	80 % D.S	2.44	2.7	- 17.43	6.00	6.36	- 6.47
M6	100 % D.S	2.07	2.31	- 29.35	5.16	5.35	- 21.32
M7	0 % D.S + 1 % S.F.S	3.59	4.04	23.54	6.26	7.60	11.76
M8	0 % D.S + 1 % S.F.L	4.59	5.8	77.37	7.45	8.73	28.38
M9	0 % D.S + 1 % H.S.F	4.26	5.6	71.25	7.38	8.56	25.88
M10	20 % D.S + 1% S.F.S	3.36	4	17.64	6.94	7.79	12.40
M11	20 % D.S + 1 % S.F.L	3.88	5	47.05	8.58	10.07	45.31
M12	20 % D.S + 1 % H.S.F	4.03	5.2	52.94	7.27	8.37	20.77
M13	40 % D.S + 1 % S.F.S	3.65	4.2	5.00	6.96	7.98	6.82
M14	40 % D.S + 1 % S.F.L	4.17	5.1	27.50	7.86	8.39	12.31
M15	40 % D.S + 1 % H.S.F	3.2	4.3	7.50	7.81	8.08	8.16
M16	60 % D.S + 1 % S.F.S	3.4	3.8	15.15	6.45	7.15	5.92
M17	60 % D.S + 1 % S.F.L	4.4	4.7	42.42	7.61	7.92	17.33
M18	60 % D.S + 1 % H.S.F	4.25	4.6	39.39	7.56	7.83	16.00
M19	80 % D.S + 1 % S.F.S	2.98	3.3	22.22	6.58	7.29	14.62
M20	80 % D.S + 1 % S.F.L	3.7	4.9	81.48	7.07	7.68	20.75
M21	80 % D.S + 1 % H.S.F	3.4	3.83	41.85	6.90	7.50	17.92
M22	100 % D.S + 1 % S.F.S	2.91	3.03	31.16	5.31	6.44	20.37
M23	100 % D.S + 1 % S.F.L	3.2	3.7	60.17	5.82	6.71	25.42
M24	100 % D.S + 1 % H.S.F	3.01	3.24	40.25	5.69	6.53	22.05

Table 10: The results of the tests of split tensile strength, and flexural for concrete samples aged 7 and 28 days.

Mix	Dune sand / Sand percentage [%]	Average density [kg/m^3]		[%] change in density at 28 days	Average compressive strength *fcu* [MPa]		[%] change in compressive strength at 28 days
		7 days	28 days		7 days	28 days	
M1	0 % D.S	2272.63	2382.41	----	43.05	51.02	------
M2	20 % D.S	2369.92	2371.55	- 0.45	37.6	51.44	0.82
M3	40 % D.S	2411.15	2427.35	1.88	41.06	56.30	10.34
M4	60 % D.S	2398.96	2400.58	0.76	34.20	51.6	1.13
M5	80 % D.S	2351.80	2355.20	- 1.14	28.9	39.51	- 22.55
M6	100 % D.S	2353.3	2348.83	- 1.40	25.8	31.2	- 38.84
M7	0 % D.S + 1 % S.F.S	2487.30	2516.73	5.63	47.93	65.80	28.96
M8	0 % D.S + 1 % S.F.L	2491.55	2564.13	7.62	61.12	74.93	46.86
M9	0 % D.S + 1 % H.S.F	2485.93	2501.92	5.01	48.40	64.90	27.20
M10	20 % D.S + 1 % S.F.S	2432.78	2441.67	2.95	41.8	58.7	14.11
M11	20 % D.S + 1 % S.F.L	2486.50	2522.37	6.35	48	62.8	22.08
M12	20 % D.S + 1 % H.S.F	2498.76	2527.60	6.58	50.7	65.2	26.74

M13	40 % D.S + 1 % S.F.S	2456.98	2463.30	1.48	46.16	59.72	6.07
M14	40 % D.S + 1 % S.F.L	2468.14	2471.99	1.83	48.83	63.3	12.43
M15	40 % D.S + 1 % H.S.F	2426.90	2548.44	4.98	49.6	71.3	26.64
M16	60 % D.S + 1 % S.F.S	2404.04	2443.85	1.80	37.14	53.2	3.10
M17	60 % D.S + 1 % S.F.L	2423.55	2454.41	2.24	38.63	54.5	5.62
M18	60 % D.S + 1 % H.S.F	2441.08	2451.70	2.12	47.5	54.04	4.72
M19	80 % D.S + 1 % S.F.S	2377.92	2391.40	1.53	29.7	41.8	5.79
M20	80 % D.S + 1 % S.F.L	2409.77	2474.17	5.05	37.8	46.8	18.45
M21	80 % D.S + 1 % H.S.F	2399.40	2389.93	1.47	30.2	43.7	10.60
M22	100 % D.S + 1 % S.F.S	2373.52	2378.81	1.27	32.5	34.6	10.89
M23	100 % D.S + 1 % S.F.L	2357.62	2363.25	0.61	30.6	39.1	25.32
M24	100 % D.S + 1 % H.S.F	2341.77	2352.91	0.17	30.1	36.4	16.66

Table 11: Water absorption test results for concrete cubes.

Mix	Dune sand /Sand percentage [%]	Dry weight W_1 [kg]	Weight of specimen after submerged in water w_2 [kg]	$W_2 - W_1$ [kg]	Water absorption [%]	Concrete quality as per CEB 1989;192 [26]	[%] change in water absorption at 28 days
M1	0 % D.S	7.879	8.050	0.171	2.17	Good	----
M2	20 % D.S	7.812	7.985	0.173	2.21	Good	1.84
M3	40 % D.S	7.975	8.090	0.115	1.44	Good	- 33.64
M4	60 % D.S	7.882	8.088	0.206	2.61	Good	20.27
M5	80 % D.S	7.802	8.043	0.241	3.08	Average	41.93
M6	100 % D.S	8.047	8.308	0.261	3.24	Average	49.30
M7	0 % D.S + 1 % S.F.S	8.201	8.264	0.063	0.76	Good	- 64.97
M8	0 % D.S + 1 % S.F.L	8.235	8.361	0.126	1.53	Good	- 29.49
M9	0 % D.S + 1 % H.S.F	8.239	8.306	0.067	0.81	Good	- 62.67
M10	20 % D.S + 1 % S.F.S	7.970	8.180	0.210	2.63	Good	19.00
M11	20 % D.S + 1 % S.F.L	8.045	8.252	0.207	2.57	Good	16.28
M12	20 % D.S + 1 % H.S.F	8.272	8.434	0.162	1.95	Good	- 11.76
M13	40 % D.S + 1 % S.F.S	8.190	8.297	0.107	1.30	Good	- 9.72
M14	40 % D.S + 1 % S.F.L	8.197	8.292	0.095	1.15	Good	- 20.13
M15	40 % D.S + 1 % H.S.F	8.210	8.321	0.111	1.35	Good	- 6.25
M16	60 % D.S + 1 % S.F.S	7.877	8.110	0.233	2.95	Good	13.02
M17	60 % D.S + 1 % S.F.L	7.904	8.132	0.228	2.88	Good	10.34
M18	60 % D.S + 1 % H.S.F	7.962	8.193	0.231	2.90	Good	11.11
M19	80 % D.S + 1 % S.F.S	7.837	8.110	0.273	3.48	Average	12.98
M20	80 % D.S + 1 % S.F.L	7.620	7.874	0.254	3.33	Average	8.11
M21	80 % D.S + 1 % H.S.F	7.924	8.193	0.269	3.39	Average	10.06
M22	100 % D.S + 1 % S.F.S	7.580	7.881	0.301	3.97	Average	22.53
M23	100 % D.S + 1 % S.F.L	7.621	7.915	0.294	3.85	Average	18.83
M24	100 % D.S + 1 % H.S.F	7.638	7.936	0.298	3.90	Average	20.37

Table 12: Ultrasonic test results of concrete cubes samples *UPV*.

Mix	Dune sand/Sand percentage [%]	Average *UPV* [m/s]	Concrete quality according to BS 1881 [24]	Limits of IS code, BS 1881,1983, pulse velocity [km/s]	[%] change in UPV at 28 days
		28 days			
M1	0 % D.S	4894	Very good	Above 4.0	---
M2	20 % D.S	4991	Very good	Above 4.0	1.98
M3	40 % D.S	4855	Very good	Above 4.0	- 0.79
M4	60 % D.S	4715	Very good	Above 4.0	- 3.65
M5	80 % D.S	4559	Very good	Above 4.0	- 6.84
M6	100 % D.S	4482	Very good	Above 4.0	- 8.41
M7	0 % D.S + 1 % S.F.S	5017	Very good	Above 4.0	2.51
M8	0 % D.S + 1 % S.F.L	6191	Very good	Above 4.0	26.50
M9	0 % D.S + 1 % H.S.F	6212	Very good	Above 4.0	26.93
M10	20 % D.S + 1 % S.F.S	5423	Very good	Above 4.0	8.65
M11	20 % D.S + 1 % S.F.L	6068	Very good	Above 4.0	21.57
M12	20 % D.S + 1 % H.S.F	5969	Very good	Above 4.0	19.59
M13	40 % D.S + 1 % S.F.S	4907	Very good	Above 4.0	1.07
M14	40 % D.S + 1 % S.F.L	4894	Very good	Above 4.0	0.80
M15	40 % D.S + 1 % H.S.F	4934	Very good	Above 4.0	1.63
M16	60 % D.S + 1 % S.F.S	4834	Very good	Above 4.0	2.52
M17	60 % D.S + 1 % S.F.L	4921	Very good	Above 4.0	4.36
M18	60 % D.S + 1 % H.S.F	4728	Very good	Above 4.0	0.27
M19	80 % D.S + 1 % S.F.S	4596	Very good	Above 4.0	0.81
M20	80 % D.S + 1 % S.F.L	4703	Very good	Above 4.0	3.15
M21	80 % D.S + 1 % H.S.F	4753	Very good	Above 4.0	4.25
M22	100 % D.S + 1 % S.F.S	4703	Very good	Above 4.0	4.93
M23	100 % D.S + 1 % S.F.L	4514	Very good	Above 4.0	0.71
M24	100 % D.S + 1 %H.S.F	4630	Very good	Above 4.0	3.30

3 Discussion of results

3.1 Slump results

A slump test was carried out on fresh concrete during pouring concrete mixtures that contain different proportions of dune sand as an alternative to sand as well as steel fibers. The examination was carried out according to the specification to ASTM C143 [19]. The relationship between slump and replacement rates of dune sand as percentages without steel fibres is shown in Fig. 16 and Table 8. We note that the workability of mixtures without steel fibers decreases with the increase of the dune sand content, where workability of mixtures with sand dunes ratios of 20 %, 40 %, 60 %, 80 % and 100 % are decreased by 15.6 %, 13.7 %, 21.8 %, 26.8 % and 30 % compared to the reference mixture, respectively. This is consistent with the conclusion of previous studies [3], the reason for the slump decrease is due to the particle size of natural sand is replaced by finer dune sand particles with higher surface area and more consuming for water. Also, the very fine dune sand absorbs a greater amount of mixing water, due to the increase in the activity of the specific surface area of the fine aggregate, the interlocking of fine aggregate particles and reducing the freedom of movement of the particles in fresh concrete, knowing that the *W/C* ratio is constant.

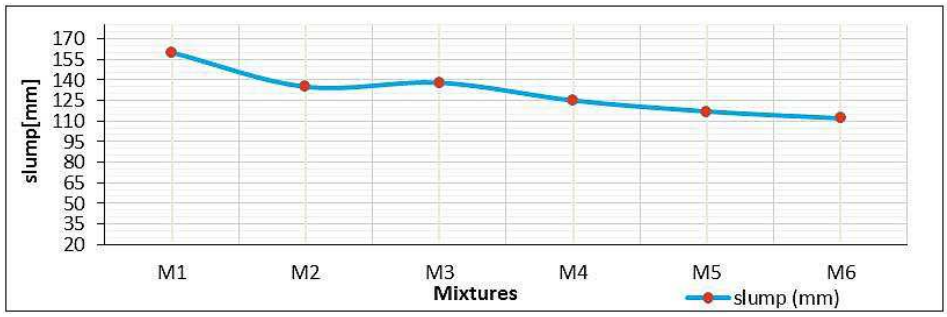


Fig. 16: Relationship between slump and replacement ratios of dune sand without steel fibers.

The relationship between the slump and replacement percentages of dune sand of mixtures containing steel fibers is shown in Fig. 17. We note that the workability decreases with the addition of 1 % of short or long steel fibers or hybrids to concrete mixtures, where the highest workability was recorded for the mixture that contains natural sand with short steel fibers (0 % D.S + 1 % S.F.S), which is higher than the mixtures Which contain natural sand with long and hybrid steel fibers with increased percentages 4.9 % and 2.8 %, respectively. While it is less than the reference mixture without fibers (0 % D.S) with a decrease of 33.1 %, as the steel fibers reduce the workability.

Also, the workability decreases with the increase of the dune sand content as an alternative to sand for the proportions (20 %, 40 %, 60 %, 80 %, 100 %), which contain short, long, and hybrid steel fibers. Where the lowest workability was recorded for the percentage that contains sand dunes 100 % with long steel fibers (100 % D.S + 1 % S.F.L) with a decrease of (41.9 %) compared to (0 % D.S without fibers), Followed by the hybrid percentage (100 % D.S + 1 % H.S.F) and a decrease of 39.2 % compared to (0 % D.S without fibers) which is consistent with previous studies [11]. 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 the lowest workability of the 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 soft concrete fall easily during the inspection process. Also, the length of the fiber plays a role in decreasing the operability, as the operability decreases as the length of the fiber increases.

By adding a plasticizer to mixtures that contain dune sand and steel fibers, we found an increase in the level of workability. The diameter of the sand dunes is fine and is less than 1.18 mm, so the specific surface is larger, which makes the concrete mixture less workable, which requires adding a larger amount of water. However, in this study the *W/C* ratio is constant, so it becomes necessary to add a plasticizer to the mixtures to improve the workability.

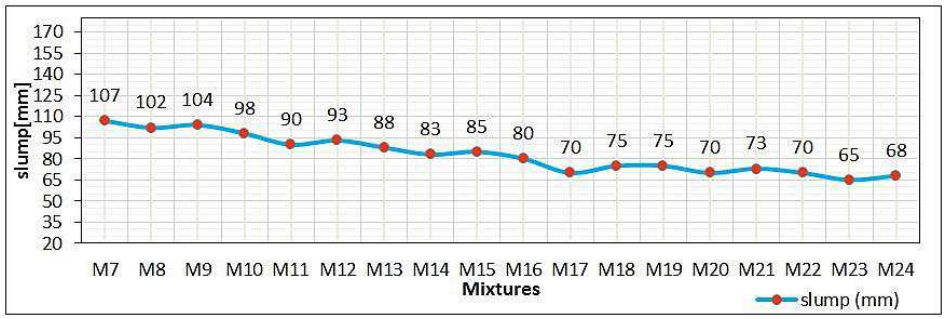


Fig. 17: Relationship between slump and replacement ratios of dune sand with steel fibers.

3.2 Density results

The dry density test was conducted on concrete cubes 150 x 150 x 150 mm, according to the American specification ASTM - C642 [20]. Six cubes for each concrete mix, 3 cubes at 7 days age and 3 at 28 days age. Density results are plotted in Fig. 18. For ages 7 days and 28 days of all mixes. From Table 9, the results of dry density at 7 days of age for all mixes containing steel fibers are higher than the density for mixtures that do not contain steel fibers, but the density decreases with the increase in the dune sand content in the mixture. Where the highest density of 2498.76 kg/m^3 was recorded at the age of 7 days for the hybrid mixture (20 % D.S + 1 % H.S.F) with an increase of 6.58 % greater than the mixture (20 % D.S without fibers), while the density decreases when dune

sand is used as an alternative to sand for the replacement ratio 100 %, where a density of 2341.77 kg/m^3 was recorded for hybrid concrete (100 % D.S + 1 % H.S.F) with a decrease of 1.33 %, and 0.67 % less than the mixtures (100 % D.S + 1 % S.F.S) and (100 % D.S + 1 % S.F.L) respectively.

At the age of 28 days for mixtures without fiber, The dry density measurement results showed that the addition of dune sand to the concrete mixture recorded an increment in the concrete density at the replacement ratios 40 % and 60 %, where the replacement ratio without fiber 40 % D.S recorded the highest density of 2427.35 kg/m^3 with an increase of its amount 1.88 % greater than the reference mixture, followed by the percentage 60 % D.S without steel fibers with an increase by about 0.76 %. The use of dune sand in a partial proportion with the natural sand contributed in the increasing the density of the concrete due to the softness of the sand dunes, their spherical shape, and their overlapping between gravel and sand granules, which helped fill all the gaps and pores inside the concrete. But the density decreases when the sand dune content is increased to 80 % and 100 %. Density results of the age 28-day concrete mixtures containing single and mixed steel fibers with different replacement ratios of sand dunes are shown in Table 9 and Fig. 19. The concrete mix (0 % D.S + 1 % S.F.L) achieved the highest concrete density of 2564.13 kg/m^3 with an increase of 7.62 % greater than the reference mix, followed by the hybrid concrete mix (40 % D.S + 1 % H.S.F), which achieved an increase in density of 2548.44 kg/m^3 with an increase of 4.98 % greater than the mixture 40 % D.S without fibers.

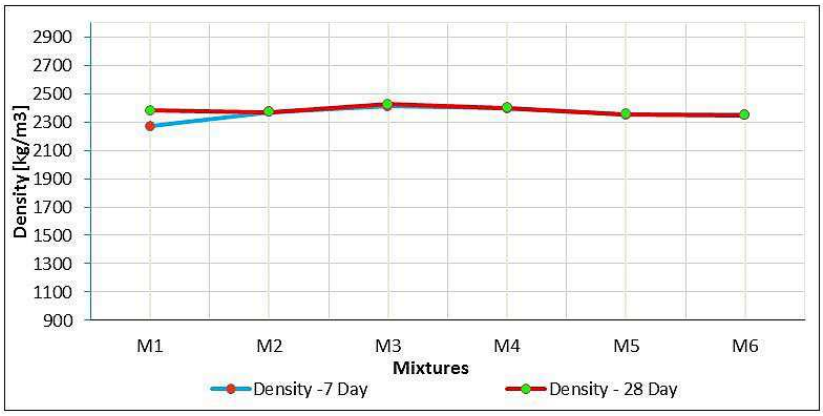


Fig. 18: Relationship between density and replacement ratios of dune sand without steel fibers.

Also, the density of this mixture is higher than the density of mixtures (40 % D.S + 1 % S.F.S) and (40 % D.S + 1 % S.F.L) with an increase of 3.45 % and 3.09 % respectively, this increase in the dry density of concrete is due to the high density of steel fibers. the density of the hybrid concrete decreases when dune sand is used by 100 % as an alternative to sand for the mixture (100 % D.S + 1 % H.S.F) where the density of 2352.91 kg/m^3 was recorded, with a decrease of 1.08 %,and 0.43 % less than the mixtures (100 % D.S + 1 % S.F.S), and (100 % D.S + 1 % S.F.L) respectively, where the role of single steel fibers is better than hybrids at this ratio, while this density is higher than the mixture 100 % D.S without fibers with an increase of 0.17 %.

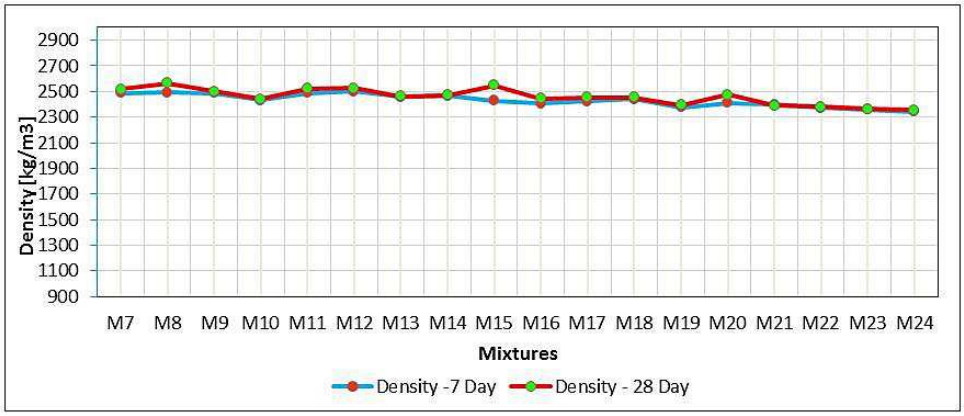


Fig. 19: Relationship between density and replacement ratios of dune sand with steel fibers.

3.3 Compression strength results

The results of samples at 7 days age indicated that the reference specimen 0 % D.S achieved the highest value of compressive strength of 43.05 MPa. Followed by the replacement ratio 40 % D.S, which achieved a resistance of 41.06 MPa (4.8 % less than reference specimen). While for fully sand replacement by dune sand 100 % D.S the compressive strength decreased by 40.06 % compared to the reference specimen as shown in Fig. 20. The results of compressive strength of fiber reinforced concrete at 7- days of age show an increase in compressive strength in varying proportions according to the type of fibers, where the highest compressive strength 61.1 MPa for the mixture (0 % D.S + 1 % S.F. L), namely 41.9 % higher than reference mix. Followed by the hybrid fiber reinforced concrete mixture (20 % D.S + 1 % H.S.F), which consists of fibers (0.65 % long + 0.35 % short) that achieved a compressive strength of 50.7 MPa, namely 34.8 % greater than the mixture (20 % D.S without fibers). The hybrid mixture (40 % D.S + 1 % H.S.F), also achieved an increase in compressive strength by about 20.7 % greater than the mixture (40 % D.S without fibers). When replacing dune sand 100 % as an alternative to sand in concrete containing hybrid steel fibers, we notice a decrease in the compressive strength at the age of 7 days by about (37.8 %, 40.6 %, 39 %, 36.6 %, 0.3 %) less than the hybrid mixtures that contain dunes sand for the percentages (0 %, 20 %, 40 %, 60 %, 80 %) respectively, but still higher than the mixture (100 % D.S without fibers) by 16.6 %. as shown in Fig. 21 and Table 9. The results of the compressive strength at the age of 28-days indicate that the ratio (40 % D.S without fibers) achieved the highest compressive strength of 56.3 MPa (10.3 % greater than reference specimen). Followed by the mixture (60 % D.S without fibers) with an increment of 1.13 % greater than the reference specimen.

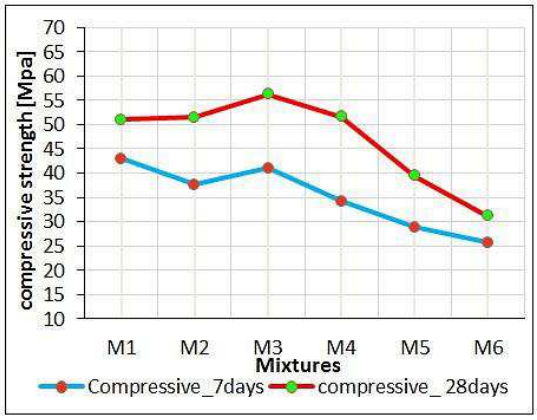


Fig. 20: Relationship between compressive strength of S.F and replacement ratios of dune sand without steel fibers.

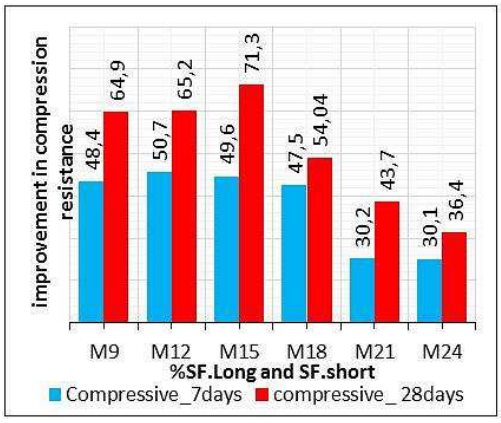


Fig. 22: Improvement in compressive strength (hook end) 0.65 % + S.F (straight) 0.35 % hybrid fibers reinforced concrete [SHFRC] mixes.

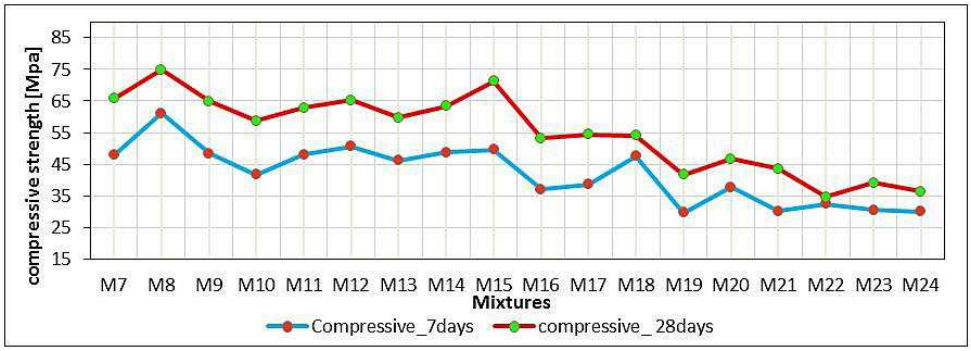


Fig. 21: Relationship between compressive strength and replacement ratios of dune sand with steel fibers.

The compressive strength decreases with the increase in the dunes sand content, where at 100 % replacement ratio (100 % D.S), the compressive strength decreased by 38.8 % compared to reference mixture. The reason for the decrease in the resistance is due to the increase in the surface area of the fine aggregate, which required higher water amount to achieve workable concrete but at the same time it weakens the concrete strength, this conclusion is consistent with previous studies

[3, 4]. The results of the compressive strength at the age of 28 days for mixtures that contain steel fibers showed that the concrete mixture (0 % D.S + 1 % S.F.L) has achieved the highest compressive strength of 74.9 MPa (46.8 % greater than reference specimen), and it also higher than the mixtures (0 % D.S + 1 % S.F.S) and (0 % D.S + 1 % H.S.F) by 13.8 %, 15.4 %, respectively, these results are in agreement with other studies [6, 10, 11, 12].

Hybrid concrete (40 % D.S + 1 % H.S.F) achieved a compressive strength of 71.3 MPa, namely greater than the mixtures (40 % D.S without fibers), (40 % D.S + 1 % S.F.S) and (40 % D.S + 1 % S.F.L) by 26.6 %, 19.4 % and 12.6 %, respectively. This increase in the compressive strength of hybrid concrete is attributed to the positive effect of the fibers hybridization on the concrete characteristics, where the short type of fiber (straight) added by 0.35 % be active at micro cracking stage, and the long type is (hook end) added by 0.65 % at the macro cracking stage, and also the fineness of the dune sand is able to fill all the spaces between the crushed gravel and the graded sand particles in presence of fibers, thus the concrete will be more cohesive and without gaps. Compressive strength decreases at the age of 28 days for the hybrid concrete mixes as well as the mixes containing single fibers at higher dune sand ratios of 60 %, 80 %, and 100 %. When dune sand is replaced by 100 % as an alternative to sand, the compressive strength of the hybrid mixture (100 % D.S + 1 % H.S.F) of 36.4 MPa, namely 16.6 % greater than (100 % D.S without fibers), 5.2 % greater than (100 % D.S + 1 % S.F.S) but 6.9 % less than the mixture (100 % D.S + 1 % S.F.L).

It is clear that all the hybrid concrete mixes SHFRC numbered (M9, M12, M15, M18, M21, M24), which contain percentages of steel fibers in a total percentage 1 % of the concrete volume, showed a positive effect in terms of compressive resistance as shown in Fig. 22, where the best compressive resistance was achieved for the mixture that contain (0.35 % short fibers + 0.65 % long fibers) and with 40 % dune sand as sand replacement.

3.4 Splitting tensile strength results

The results of samples at 7-days age indicated that the specimen (60 % D.S without fibers) achieved the highest value of splitting tensile strength of 3.08 MPa (8.83 % greater than the reference specimen). While for fully sand replacement by dune sand (100 % D.S without fibers) the splitting tensile strength decreased by 26.8 % compared to the reference specimen as shown in Fig. 23. The results of tensile strength of fibrous concrete at 7 days of age show an increase in tensile strength in varying proportions according to the type of fibers, Where the highest tensile strength is 4.59 MPa for the mixture (0 % D.S + 1 % S.F.L), namely 62.1 % higher than the reference mix. Followed by the fiber reinforced concrete mixture (60 % D.S + 1 % S.F.L), that achieved a tensile strength of 4.4 MPa, namely 42.8 % greater than the mixture (60 % D.S without fibers). When replacing dune sand 100 % as an alternative to sand in concrete containing hybrid steel fibers, we notice a decrease in the splitting tensile strength at the age of 7 days by about (29.3 %, 25.3 %, 5.9 %, 29.1 %, 11.4 %) less than the hybrid mixtures that contain dune sand for the percentages (0 %, 20 %, 40 %, 60 %, 80 %) respectively, but still higher than the mixture (100 % D.S without fibers) by 45.4 % as in Fig. 24 and Table 10.

The results of the splitting tensile strength at the age of 28 days indicate that the ratio (40 % D.S without fibers) achieved the highest tensile strength of 4 MPa] (22.3 % greater than the reference specimen). Followed by the mixture (60 % D.S without fibers) with an increase of about 0.91 % greater than the reference mixture. This conclusion is consistent with previous studies [3, 4].

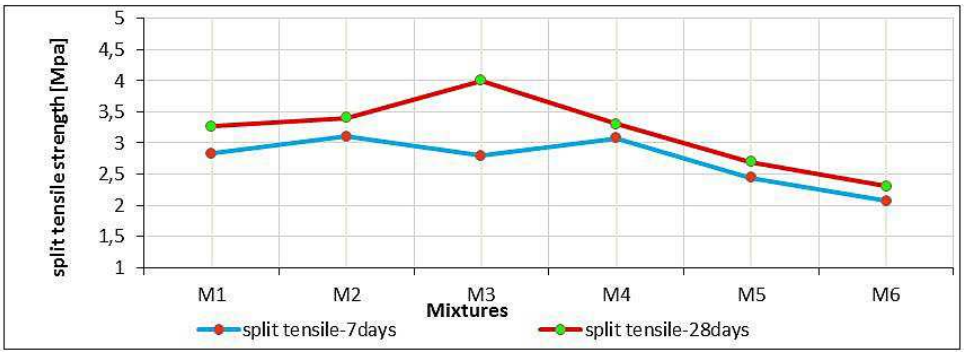


Fig. 23: Relationship between split tensile strength and replacement ratios of dune sand without steel fibers.

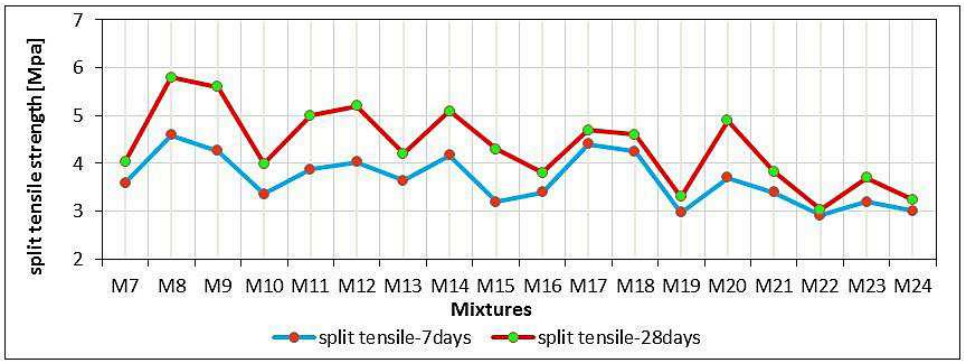


Fig. 24: Relationship between split tensile strength and replacement ratios of dune sand with steel fibers.

Splitting tensile strength decreases at high dunes sand content, when the tensile strength decreasing 29.3 % less than the reference mixture at the replacement ratio 100 % D.S. The results of tensile strength at the age of 28 days for mixtures that contain steel fibers showed that the concrete mixture (0 % D.S + 1 % S.F.L) has achieved the highest tensile strength of 5.8 MPa (77.3 % greater than the reference specimen), and it is also higher than the mixtures (0 % D.S + 1 % S.F.S) and (0 % D.S + 1 % H.S.F) by 34.5 %, 3.5 %, respectively. Hybrid concrete (20 % D.S + 1 % H.S.F) achieved a tensile strength 5.2 MPa, namely greater than the mixtures (20 % D.S without fibers), (20 % D.S + 1 % S.F.S) and (20 % D.S + 1 % S.F.L) by 52.9 %, 30 %, 4 %, respectively. as the role of the hybrid fibers helped to improve the splitting tensile strength so that the short (straight) fibers by 0.35 % have 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. We also note that the effect of dunes sand inside concrete has achieved acceptable results for the tensile strength of hybrid concrete and concrete containing single fibers due to the interaction of its fine grains between the components of gravel and sand, up to the replacement ratio 60 %, as shown in Fig. 25 for a, b, c.

When dune sand is replaced by 100 % as an alternative to sand, the tensile strength of the hybrid mixture (100 % D.S + 1 % H.S.F) of 3.24 MPa, namely 40.2 % greater than 100 % D.S without fibers, 6.9 % greater than (100 % D.S + 1 % S.F.S) but 12.4 % less than the mixture (100 % D.S + 1 % S.F.L).

Thus all hybrid fiber reinforced mixtures showed a positive effect on tensile splitting strength, the maximum improvement was obtained mixture (0.35 % short fiber + 0.65 % long fiber) without dunes sand and the least effect was for the hybrid fiber reinforced concrete mixture (100 % D.S + 1 % H.S.F), as shown in Fig. 26.

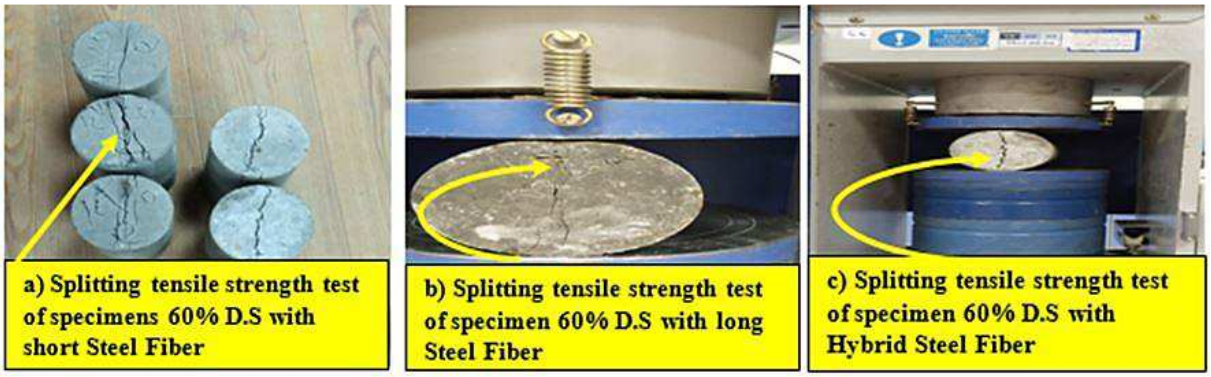


Fig. 25: Failure pattern of samples 60 % D.S when testing split tensile strength: a) with short steel fiber, b) with long fiber, c) with hybrid steel fiber.

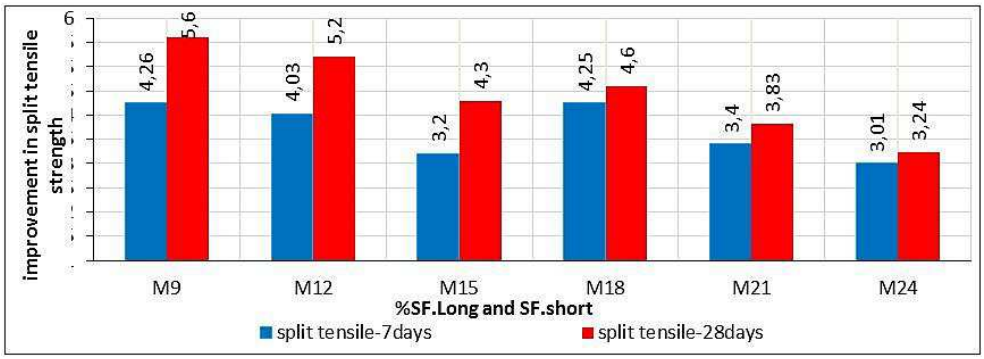


Fig. 26: Improvement in split tensile strength of S.F (hook end) 0.65 % + S.F (straight) 0.35 % hybrid fibers reinforced concrete SHFRC mixes.

3.5 Flexural strength results

The results of samples at 7 days age indicated that the mixture (40 % D.S without fibers) achieved the highest flexural strength of 6.24 MPa (4.3 % higher than the reference specimen). While for fully sand replacement by dunes sand (100 % D.S) the flexural strength decreased by 13.7 % less than the reference specimen.as shown in Fig. 27.

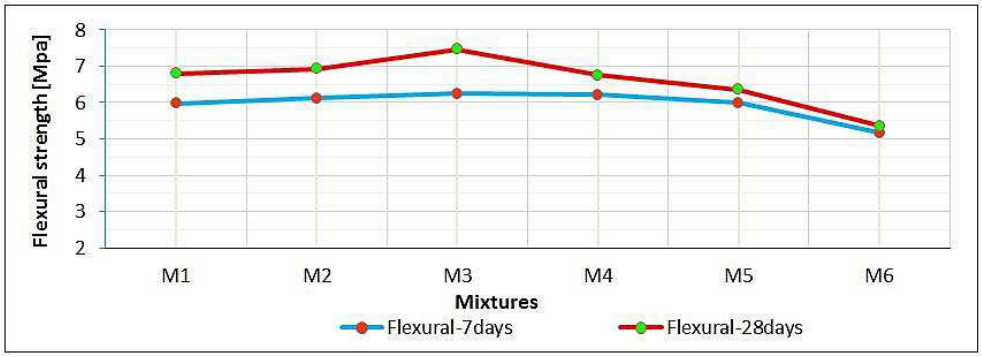


Fig. 27: Relationship between flexural strength and replacement ratios of dune sand without steel fibers.

The results of flexural strength of fiber reinforced concrete at 7 days age show an increase in flexural strength in varying proportions according to the type of fibers, Where the highest flexural strength 8.58 MPa for the mixture (20 % D.S + 1 % S.F.L), namely 40.4 % greater than the mixture (20 % D.S without fibers). Followed by the fibrous concrete mixture (40 % D.S + 1 % S.F.L) that achieved a flexural strength of 7.86 MPa, namely 25.9 % greater than the mixture (40 % D.S without fibers). When replacing dunes sand 100 % as an alternative to sand in concrete containing hybrid steel fibers, we notice a decrease in the flexural strength at the age of 7 days by about (22.8 %, 21.7 %, 27.1 %, 24.7 %, 17.5 %) less than the hybrid mixtures that contain dune sand for the percentages (0 %, 20 %, 40 %, 60 %, 80 %) respectively, but still higher than the mixture (100 % D.S without fibers) by 10.2 %, as shown in Fig. 28 and Table 10.

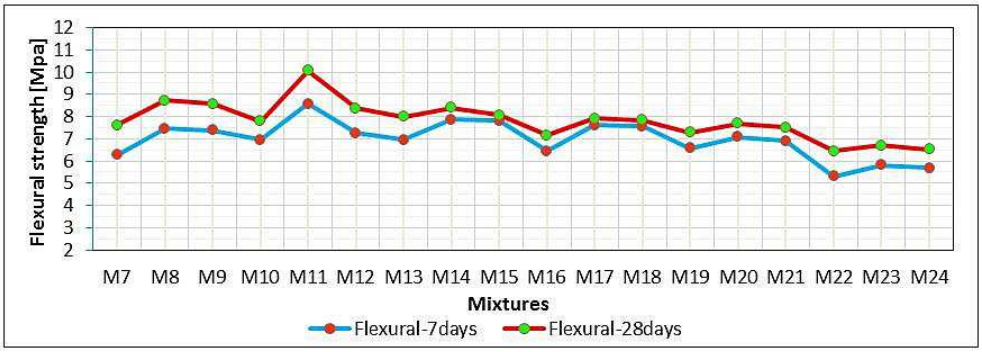


Fig. 28: Relationship between flexural strength and replacement ratios of dune sand with steel fibers.

The results of the flexural strength at the age of 28 days indicate that the specimen (40 % D.S without fibers) achieved the highest flexural strength of 7.47 MPa (9.85 % greater than the reference specimen). the flexural strength decreases with an increase in the dunes sand content, where at replacement ratio 100 % D.S, the flexural strength decreased by 21.3 % compared to the reference mixture, the reason for the decrease in the strength is due to the increase in the fineness of the fine aggregate particles in the concrete, which affected the bearing of the prism under the influence of flexural. The results of the flexural strength at the age of 28 days for mixtures that contain steel fibers showed that the concrete mixture (20 % D.S + 1 % S.F.L) has achieved the highest flexural strength of 10.07 MPa, namely greater than the mixtures (20 % D.S without fibers), (20 % D.S + 1 % S.F.S) and (20 % D.S + 1 % H.S.F) by 45.3 %, 29.2 %, and 20.3 %, respectively. Hybrid concrete (0 % D.S + 1 % H.S.F) achieved a flexural strength of 8.56 MPa, namely greater than the reference specimen (0 % D.S without fibers) and (0 % D.S + 1 % S.F.S) by 25.8 %, 12.6 %, respectively.

When the dunes sand content is increased in the hybrid concrete, the flexural strength decrease with the increase of this content in equal proportions ranging from 3.3 % - 4 %, this conclusion is consistent with other studies [6, 9, 10] . However, the role of fibers in hybrid concrete greatly helped in delaying the early failure of the prism.

We note that the samples containing steel fibers, despite the increase in the content of sand dunes in concrete, but the examined samples containing steel fibers did not split into two parts during the examination and as shown in Fig. 29 for (a , b, c) except for the crack that starts from the bottom and then to the middle of the sample due to the cohesion of the fibers between the two ends of the crack, where we note that its role fiber acts as a bridge for cracks in the concrete and transfers the crack stress from one side to the other side, which helps reduce stress concentration on both ends of the crack and thus prevents cracks from growing.

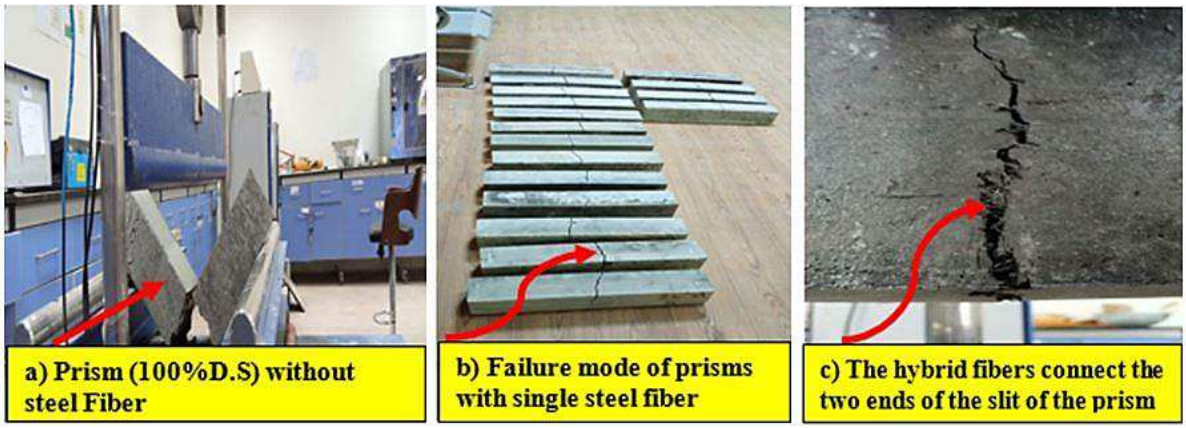


Fig. 29: Failure mode of prisms: a) without fiber, b) with single steel fibers, c) with hybrid steel fibers with different proportions of dunes sand.

Flexural strength decreases at the age of 28 days for the hybrid fiber reinforced concrete mixes as well as the mixes containing single fibers at higher dunes sand ratios of 80 % and 100 %. When dunes sand is replaced by 100 % as an alternative to sand, the flexural strength of the hybrid concrete mixture (100 % D.S + 1 % H.S.F) of 6.53 MPa, namely 22 % greater than the mixture (100 % D.S without fibers), 1.39 % greater than specimen (100 % D.S + 1 % S.F.S) but 2.6 % less than the mixture (100 % D.S + 1 % S.F.L).

We note the effect of the fibers on the hybrid prisms samples in terms of flexural strength. All the hybrid mixtures showed a positive effect. also, the ratio (0.65 % long fiber + 0.35 % short fiber) without dunes sand has achieved the maximum positive effect, which helped to increase the flexural strength due to the proportion of long fibers in the mixture more than the short ones. Followed by Hybrid Concrete (20 % D.S + 1 % H.S.F). The lowest effect as in the case of compression and split tensile strength is the hybrid concrete (100 % D.S + 1 % H.S.F).as shown in Fig. 30.

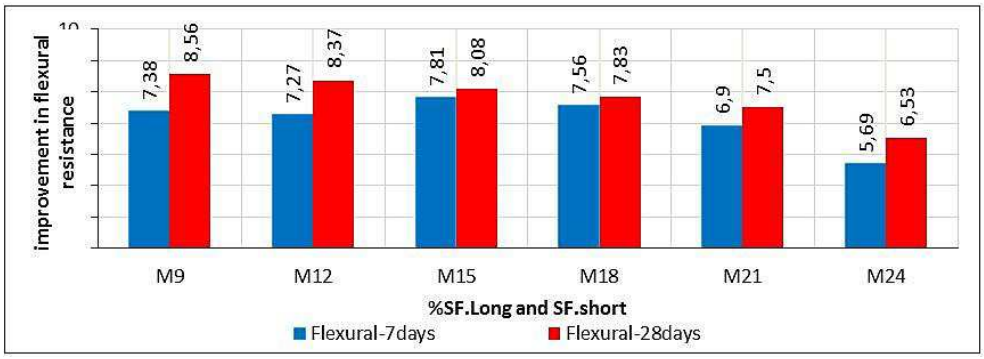


Fig. 30: Improvement in flexural strength of S.F (hook end) 0.65 % + S.F (straight) 0.35 % hybrid fibers reinforced concrete SHFRC mixes.

3.6 Absorption results

The absorption test accomplished on the cubes samples containing dunes sand as an alternative to sand (without steel fibers) at age 28 days that were examined according to ASTM –C642 [20]. The results indicated that the specimen (40 % D.S without fiber) achieved the lowest water absorption rate 1.44 % (namely 33.6 % less than the reference mixture), and it is considered a good concrete (low water absorption) according to CEB 1989;192 [26]. When the dunes sand content increases at rates 60 %, 80 % and 100 % without fibers, the water absorption rate increases. at the specimens (80 % D.S) and (100 % D.S), the absorption rate increases by 41.9 % and 49.3 % respectively, greater than the reference mixture, and the quality of the concrete is medium as per CEB 1989;192 [26]. This is consistent with the conclusions of previous studies [3]. This increase in the rate of absorption when the content of dunes sand in the mixture increases. It may be due to the fineness of the dunes sand grains, which absorb a greater amount of mixing water and increase the surface area of fine aggregate, which generates voids or pores, which in turn increases the rate of absorption, as shown in Fig. 31 and Table 11.

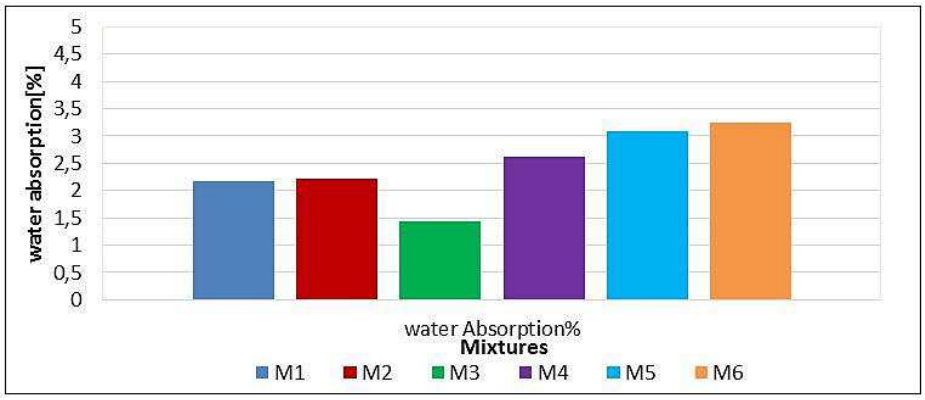


Fig. 31: Relationship between water absorption % and replacement ratios of dunes sand without steel fibers.

The results of fiber reinforced concrete indicate that the sample of hybrid concrete (0 % D.S + 1 % H.S.F) without dunes sand achieved the lowest absorption rate compared to the rest of the results of other hybrid concrete containing dunes sand. It is also lower than the mixture (0 % D.S + 1 % S.F.L) by 47 % and the quality of concrete is good as per CEB1989; 192. When increasing the content of dunes sand, we notice that concrete mixtures that contain replacement rates of dune sand (40 %, 60 %, 80 %, 100 %) with hybrid steel fibers, have achieved a higher absorption rate than concrete that contains the same replacement ratio of dune sand, but with long steel fiber. and in close proportions with the short fibers, as shown in Fig. 32. When natural sand is replaced by 100 % dunes sand, we note that the hybrid fiber reinforced concrete (100 % D.S + 1 % H.S.F) achieved an increase in the absorption rate by 20.3 % and 1.29 % greater than the mixtures (100 % D.S without fibers) and (100 % D.S + 1 % S.F.L) respectively, but 1.76 % less than the mixture (100 % D.S + 1 % S.F.S), and the concrete quality is good according to CEB 1989, namely the rate of absorption increases with the increase in the content of dune sand in the mixture and with varying percentages of increase when

adding steel fibers due to the effect of dune sand on the specific surface area. However, the fibers reduce the rate of absorption, as in the mixtures (40 % D.S + long or short or hybrid fiber) and (0 % D.S + long or short or hybrid fiber) in which the rate of water absorption decreased. Excessive absorption weakens the concrete and leads to cavities, which reduce the strength and quality of the concrete. In general, all mixtures in this study are good quality concrete, and no absorption rate higher than 4 % was observed from the results.

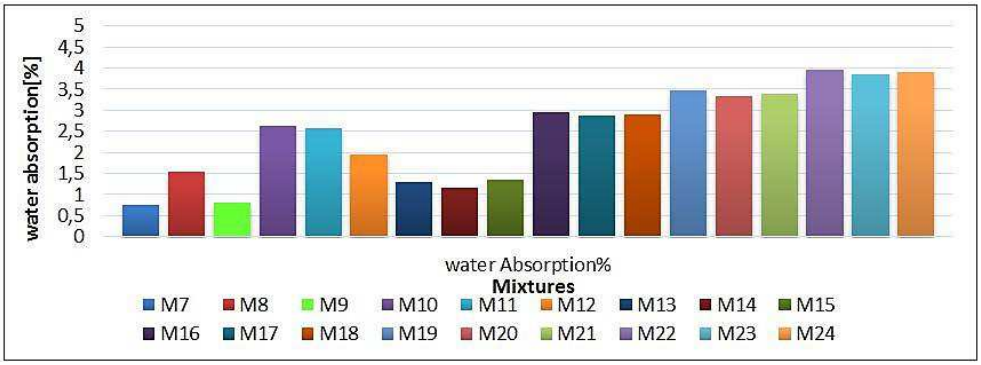


Fig. 32: Relationship between absorption and replacement ratios of dune sand with steel fibers.

We observe the effect of fibers on the cubic samples in terms of water absorption of the hybrid fiber reinforced mixtures SHFRC. All the hybrid mixtures showed a positive effect within acceptable absorption limits. The maximum effect was obtained when mixed (0.35 % short fiber + 0.65 % long fiber) without dunes 0 % D.S, which is the lowest water absorption. The minimum effect was obtained when mixing concrete (100 % D.S + 1 % H.S.F) and as in Fig. 33.

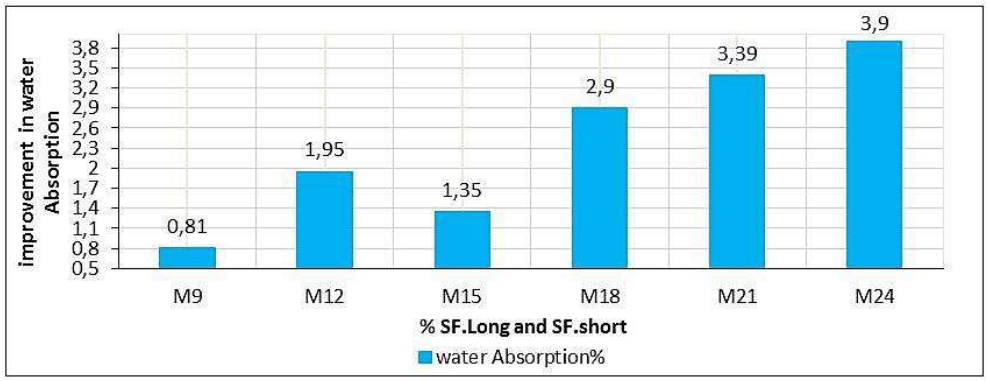


Fig. 33: Improvement in water absorption of S.F (hook end) 0.65 % + S.F (straight) 0.35 % hybrid fibers reinforced concrete SHFRC mixes.

3.7 Ultra-sonic pulse velocity results

The pulse velcity test accomplished on the cubes samples containing dunes sand as an alternative to sand (without steel fibers) at age 28 days as shown in Fig. 34, the results indicated that the pulse velocity of all concrete mixtures is between (4400 - 6100) m/s and this indicates that Concrete quality is good and homogeneous according to BS1881, 1983, Part 116 [24]. we note that the reference specimen (0 % D.S without fibers) has achieved a pulse velocity rate of 4894 m/s and the concrete quality is considered good according to the limits of IS code BS 1881,1983 [24]. For concrete mixture (20 % *D.S* without fibers), the pulsing velocity increases by 1.98 % greater than the reference specimen (0 % D.S), and the pulse velocity decrease with increase the dunes sand content for the ratios (40 %, 60 %, 80 %, 100 %), as shown in Fig. 35 and this is consistent with the absorption and density test as they decrease with the increase in the dune sand content due to the fineness of the dune sand and the increase in the specific surface area of the dune sand, which absorbs a greater amount of water, causing the appearance of gaps or pores inside the concrete, which appears by reading the pulse velocity of the cubes. The hybrid fiber reinforced concrete mixture (0 % D.S + 1 % H.S.F), which consists of fibers (0.65 % long + 0.35 % short) achieved the highest value of the pulse velocity of 6212 m/s, namely greater than the mixtures (0 % D.S without fibers), (0 % D.S + 1 % S.F.S)

and (0 % D.S + 1 % S.F.L) by 26.9 %, 23.8 % and 0.33 %, respectively as shown in Fig. 36 and Table 12. Followed by the mixture (20 % D.S + 1 % H.S.F) less than the hybrid mixture (0 % D.S + 1 % H.S.F) by about 3.9 % and the quality of concrete is considered very good according to BS1881, 1983 classification. The pulse velocity rate of hybrid fiber reinforced concrete mixes that contains dunes sand as an alternative to sand for proportions (40 %, 60 %, 80 %, 100 %) is decreased by about (20.5 %, 23.8 %, 23.5 %, 25.4 %) compared with the hybrid concrete mixture (0 % D.S + 1 % H.S.F). When the natural sand is replaced by dunes sand by 100 %, the hybrid concrete (100 % D.S + 1 % H.S.F) achieves an increase in the pulse velocity of 4630 m/s, namely 3.3 % greater than the mixture (100 % D.S without fibers), 2.5 % greater than (100 % D.S + 1 % S.F.L) but 1.55 % less than (100 % D.S + 1 % S.F.S). Meaning that when the dunes sand content is increased for the mixtures, the pulse velocity decreases, but the addition of hybrid fibers improves the results of the examination due to the role of fibers in the cohesion and homogeneity of the concrete components. Despite the decrease in the pulsation velocity in the mixtures when the content sand dunes increased. However, it did not drop less than 4 km/s, which is very good and acceptable results according to BS 1881, 1983. This indicates that the effect of sand dunes on concrete mixtures in general, and hybrids with fibers in particular, was a small effect and did not reduce the quality of concrete to a large extent due to the addition of fibers Steel that increases the cohesion of concrete.



Fig. 34: Ultrasonic pulse velocity.

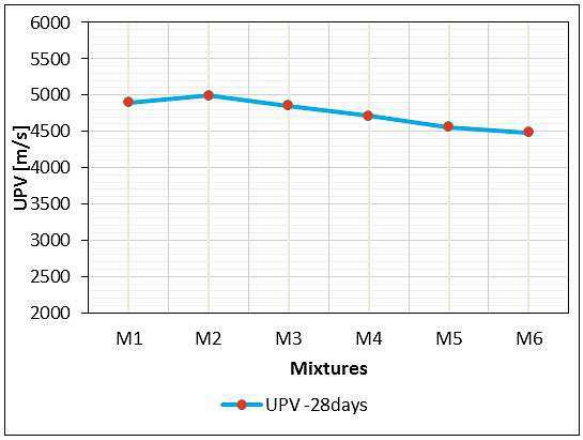


Fig. 35: Relationship between Ultrasonic pulse velocity UPV and replacement ratios of dune sand without steel fibers.

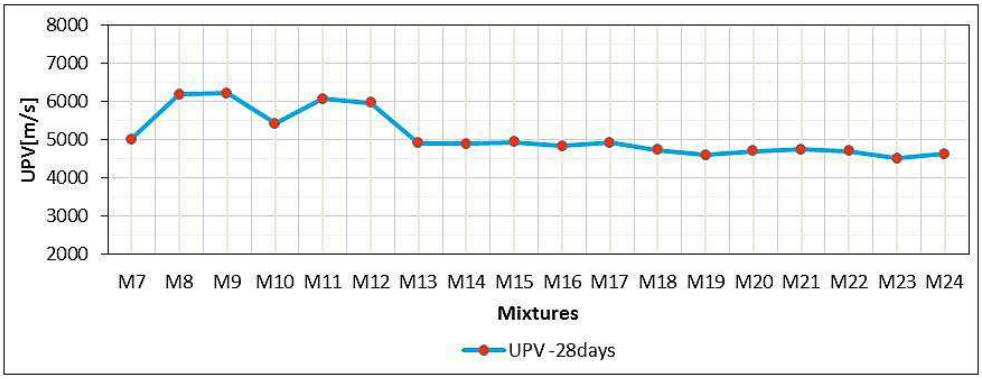


Fig. 36: Relationship between Ultrasonic pulse velocity UPV and replacement ratios of dune sand with steel fibers.

4 Conclusions

In this research, 24 concrete mixtures containing different proportions of dunes sand were prepared as an alternative to sand with the addition of single and hybrid steel fibers to the mixtures in order to verify the effect of dune sand on the mechanical properties of hybrid fiber reinforced concrete. Based on the results of these examinations, the following conclusions are drawn:

a) The use of dunes sand as an alternative to sand in proportions 20 - 100 % in hybrid concrete that contains steel fibers, reduces workability, addition to the presence of steel fibers reduces workability despite the use of plasticizers in mixtures.

b) The dry density of concrete increases with the increase in the content of dunes sand as sand replacement for mixtures without steel fibers up to the ratio 40 % D.S, then the density begins to decrease. The dry density of hybrid fiber reinforced concrete increases with the use of dunes sand up to 40 % D.S.

c) The compressive strength increases with the increase of the sand dunes content by 40 % D.S without fibers, then the compressive strength decreases with the increase of the sand dunes. For fiber reinforced concrete, the hybrid mixture 40 % D.S + 1 % H.S.F) achieved a higher increase in compressive strength, namely 26 % greater than the control mixture. The compressive strength decreases when the dunes sand content for proportions is increased (60 %, 80 %, and 100 %) in hybrid concrete.

d) The splitting tensile strength increases with the increase of the dunes sand content for the ratio 40 % D.S without fibers, then the tensile strength decreases with the increase of dunes sand. For fiber reinforced concrete, the hybrid mixture (0 % D.S + 1 % H.S.F) achieved the highest tensile strength, namely 71 % greater than the reference mixture. The splitting tensile strength decreases when the dunes sand content for proportions is increased 80 % and 100 % in hybrid fiber reinforced concrete.

e) The flexural strength increases with the increase of the dunes sand content for the ratio 40 % D.S without fibers, and then the flexural strength decreases with the increase of dunes sand. For fiber reinforced concrete, the hybrid mixture (0 % D.S + 1 % H.S.F) achieved the highest flexural strength, namely 25.8 % greater than the control mixture. The flexural strength decreases when the dunes sand content for proportions is increased 80 % and 100 % in hybrid fiber reinforced concrete.

f) The absorption rate of concrete for water decreases with the increase in the sand dune content for ratio 40 % D.S without fibers, The absorption rate of concrete for water increases with the increase in the dunes sand content for the ratio 100 % D.S. For fiber reinforced concrete, the hybrid mixture (0 % D.S + 1 % H.S.F) achieved the lowest absorption rate, namely 62.6 % less than the reference mixture. The absorption rate increases when the dunes sand content for proportions is increased 80 % and 100 % in hybrid concrete.

g) The ultrasonic pulse velocity increases with the use of dune sand by 20 % D.S without fibers, then the pulse velocity decreases with the increase of dunes sand. For fiber reinforced concrete, the hybrid mixture (0 % D.S + 1 % H.S.F) achieved the highest pulse velocity, namely 26.9 % greater than the control mixture. Then the ultrasonic pulse velocity decreases with the increase of dunes sand to 100 % D.S in hybrid fiber reinforced concrete.

h) Increasing the fineness of dunes sand positively affects the mechanical properties of hybrid fiber reinforced concrete when using dunes sand in partial proportions with natural sand, while the effect decreases when dunes sand is used in a total proportion.

i) The addition of the hybrid steel fibers helped greatly in improving the mechanical properties of the concrete and better performance than the properties of concrete without the fibers.

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