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RESEARCH PAPERS

Date Palm Fibers to Improve Tensile Strength in Self-Compacting Concrete with Silica Fume

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ABSTRACT: Today, the use of new additives in self-compacting concrete leads to the improvement of its mechanical properties. Palm groves are one of the vegetation covers of Behbahan city in Iran, which cover a large area of land in this region. In this research, due to the abundance of palm groves in the south of Iran, the idea of using date palm fibers in the self-compacting concrete mixing plan has been proposed. The fibers were cut into 3 cm lengths and used in self-compacting concrete as a natural, cheap, and readily available admixture. In this research, palm fibers were used to make self-compacting concrete to improve the mechanical properties of this concrete with percentages of 0%, 0.5%, 1%, 1.5%, and 2% weight of cement. The results of the tests showed that the tensile strength of self-compacting concrete with and without date palm fibers with percentages of 0.5%, 1%, 1.5%, and 2% by weight of cement in 7 and 28 days of processing were 16.37%, 34.27%, 56.39%, 82.24% and 13.56%, 27.61%, 46.96%, and 67.6% tensile strength increased compared to the self-compacting concrete sample without date fibers. The compressive strength of self-compacting concrete with and without date palm fibers with 0.5%, 1%, 1.5%, and 2% by weight of cement in 7 and 28 days of processing are 5.19%, 10.87%, 17.81%, 22.60%, and 4.11%, 9.51%, 15.48%, 22.47% respectively of the compressive strength decreased compared to the self-compacting concrete sample without date fibers.

Keywords: Self-Compacting Concrete, Date Palm Fibers, Compressive Strength, Tensile Strength.

1. Introduction

Self-compacting concrete is an important material in the construction industry (Abani et al., 2018), which consists of fine and coarse aggregates (Alatshan et al., 2017), cement, additives, and water (Al-Hadithi et al., 2023). Self-compacting concrete is widely used in the construction industry due to its advantages, such as the availability of materials, smoothness, and efficiency (Askar et al., 2023; Ahmad et al., 2021a). The importance of self-compacting concrete is due to its high durability (Ayub

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et al., 2021), low cost in implementation compared to ordinary concrete (Asmaa and Khashaa, 2022), its efficiency and resistance (Abdullah and Sivakumar, 2023). One of the important characteristics of self-compacting concrete is its viscosity and stability compared to other types of concrete (Bozorgmehr Nia and Adlparvar, 2022).

This concrete is widely recommended in the construction of safe and durable structures that can withstand various loads (Bhat et al., 2023; Ahmad et al., 2021b). In addition, self-compacting concrete can be considered a cost-effective material to reduce costs in implementation, such as time and vibration due to compaction under its own weight (Dounia et al., 2023). This type of concrete flows easily in the mold, easily passes through the rebars (Djoudi et al., 2012), and under natural conditions (Ramli and Dawood, 2010), it condenses under the effect of its own weight. This concrete has a very high efficiency (Akhmetov et al., 2022). The use of fibers in concrete started four decades ago (Eskandari et al., 2021), and has continued to expand in order to improve the properties and mechanical behavior of concrete (Falahtabar Shiade and Tavakoli, 2018).

Fibers in concrete reduce the brittleness of concrete and ensure its plasticity (Fokam et al., 2020). Fibers may be vegetable (Ghobadi et al., 2019), synthetic, or metallic (IRIB News Agency, 2020). It improves the mechanical properties of concrete under compressive, tensile, bending, and shear loads (Jawad et al., 2021a), as well as resistance to erosion, creep, shrinkage, freezing, wear, and erosion, and creates a unified material (Ahmad et al., 2021). Using waste in concrete mix is one of the effective ways to reduce waste materials (Wang et al., 2022). In addition, the use of waste materials as a substitute for part of cement in concrete mix design is an effective solution to solve environmental problems (Modarres and Ghalehnovi, 2023). One of the natural fibers used in concrete is palm fiber (Mirabi Moghadam 2021). Considering that there are more than 45 thousand hectares of palm groves in Khuzestan province. Of this amount, there are more than 2 thousand hectares of palm groves in Behbahan city (Sor et al., 2022). So easy and cheap access to date palm fibers is possible in this region (Ramhormozy et al., 2023; Tawfeeq and Ganesh, 2022).

Various studies have been conducted in relation to the use of palm fibers to improve the properties of concrete, some of which have been reviewed below: Falahtabar Shiade and Tavakoli (2018) investigated the estimation of mechanical properties and durability of self-compacting concrete with fibers using ultrasonic pulse speed.

Boutarfa et al. (2018) studied cement mortar reinforced with plant fibers alpha, date, and dis on the mechanical properties of concrete in the field of construction. Abani et al. (2018) evaluted the flexural properties and tensile strength of concrete reinforced with palm fibers in the desert climate. Fokam et al. (2020) investigated cement mortar reinforced with natural fibers and palm kernel in a study of mechanical properties. Mirabi Moghadam (2021) evaluated the effect of the shape and amount of date palm sis fibers on the compressive and tensile strength of concrete. Modarres and Ghalehnovi (2023) investigated the effect of recycled steel fibers from waste tires on concrete properties.

One of the most important elements in the production of science is to consider the approach of sustainable development. Sustainable development with the concept of using existing potential and facilities and taking into account the needs of future generation, in line with the optimal use of available natural resources, is important (Alatshan et al., 2017; Abani et al., 2018). Many studies have been done on the possibility of using plant waste in concrete to strengthen tensile and compressive strength. Natural fibers are one of the existing solutions that can be used as a substitute for common fibers in cement and concrete mortar (Hossein Bar et al., 2017;

Ghobadi et al., 2019).

The innovative aspect of this project is the optimal use of waste resources and the minimization of waste and environmental pollution. Cement has tensile properties, but its tensile strength is very low compared to fibers. In order to reduce the amount of cement consumption in concrete and increase the tensile strength of concrete in the mixing design, palm fibers were used according to the weight of cement and silica fume, and Viscosity Modifying Admixtures (VMA) to increase the strength and strengthen the transfer zone of concrete in this mixing design. The difference between this research and other studies is the use of micro silica gel and VMA, which is an innovative aspect of this project. In this article, the mechanical behavior and compressive and tensile strength of self-compacting concrete with palm fibers in the Behbahan region are investigated considering the weather conditions.

2. Laboratory Program

2.1. Materials

2.1.1. Cement

In all 5 mixed designs, Portland cement Type 5 of Behbahan cement factory was used based on ASTM C150 (2012). The specifications are shown in Tables 1 and 2.

2.1.2. Date Palm Fibers

Date palm fibers are obtained by separating the two parts. First, the palm fiber should be separated from the main trunk of the palm (Figure 1). Then the fiber should be cut, and the broken fibers should be created with a suitable length of 3 cm as a natural, cheap, and accessible additive. It can be used in different weights in self-compacting concrete (Figure 2). According to Table 3, the specifications of date fibers have been determined for the mixed design (Figure 3). The values mentioned in Table 3 may be different depending on the type of palm fibers of each region and the test conditions used.

Table 1. Type 5 Portland cement specifications

Symbol	**IR**	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**
(%)	0.18	21.38	4.40	5.40	64.64	2.28	0.50
Symbol	O_2Na	K_2O	LOI	C_3S	C_2S	C_3A	C_4AF
(%)	0.26	0.77	0.19	61.12	15.23	2.52	16.42

Table 2. Mechanical characteristics of Type 5 Portland cement

Standard levels	**Blaine's elegance (cm^2/g) BF**	**Initial setup time (minutes) IST**	**Final setup time (minutes) FST**
Standard	3350	155	260
Standard levels	3-day compressive strength (kg/cm^2)	7-day compressive strength (kg/cm^2)	28-day compressive strength (kg/cm^2)
Standard	224	288	422

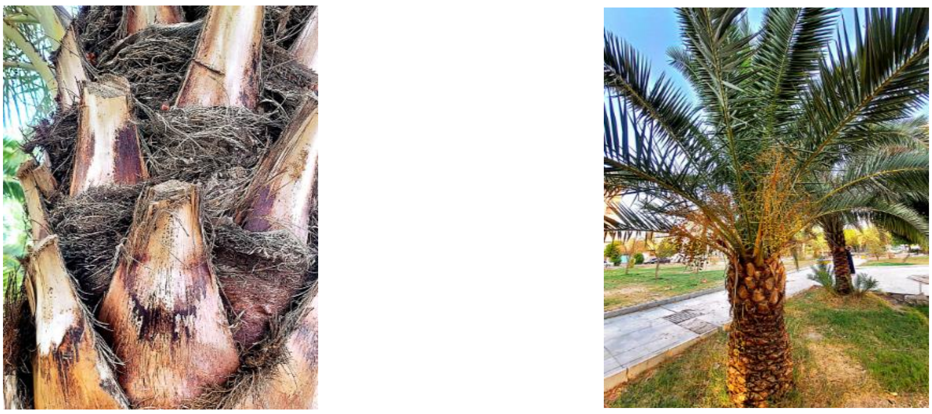


Fig. 1. Behbahan date palm

However, in general, palm fibers have good thermal insulation properties, and due to their low thermal conductivity, they can have different applications for temperature regulation and prevention of heat loss in concrete. The elemental composition of date palm fibers was investigated by Scanning Electron Microscope (SEM) analysis, which indicates the presence of silicon dioxide in their composition.

This element is effective in the mechanical properties of self-compacting concrete (Figure 4). According to the tensile test results of date palm fibers, male palm fibers have the highest tensile strength compared to female date palm fibers, and male date palm fibers were used for this project.

Fig. 2. Palm fiber components

Table 3. Characteristics of date palm fibers (Falahtabar Shiade and Tavakoli, 2018; Mirabi Moghadam, 2021; ASTM C496, 2002)

Characteristics	**Fiber diameter (mm)**	**Maximum tensile strength (MPa)**	**Modulus of elasticity (MPa)**	**Special Weight (gr/cm^3)**	**Extension (24 hours)**	**Cross-section increase (24 hours)**
Amount of	0.50	70.59	780.60	0.80	10.19%	1.94%
Characteristics	Water absorption (24 hr)	Thermal conductivity coefficient (W/m.K)	Thermal conductivity (W/m.K)	Specific heat capacity (Kj/k)	Thermal emission rate (mm^2/s)	Natural humidity percentage
Amount of	162%	0.045%	0.060	1.26	0.83	1.96

Fig. 3. Tensile test of date fibers with Bongshin device to determine tensile strength

2.1.3. Aggregates

In this mixed design, coarse aggregate with a maximum size of 19 mm and sand with a maximum size of 4.75 mm were used. The sand used in this design was mixed from Ramhormoz, Khuzestan. Gravel (peas, almonds) and sand were granulated using a suitable sieve. For pea sand passed through a 8/3 sieve, almond sand passed through a 1/2 sieve, and sand passed through a 8 sieve were used, which conforms to ASTM C33 (2003) (Table 4 and Figure 5).

2.1.4. Superplasticizer and Silica Fume

In order to achieve the mechanical properties of self-compacting concrete, super plast PC 5000, which is made based on polycarboxylate, was used as a type of water-reducing and reinforcing concrete. Also, to achieve rheological properties in the pasty state and to improve the quality of self-compacting concrete, silica fume was used, which is based on silica fume and is a strong reducer of concrete water. The use of silica fume increases the compressive strength, reduces the permeability of concrete, and eases concreting by increasing concrete slump and high efficiency. Also, silica fume can strengthen the transition zone and affect the final strength of concrete. It is in accordance with ASTM C494 (2002) (Table 5).

Element	Weight%	Atomic%
C K	49.81	57.67
O K	47.48	41.27
Si K	0.76	0.38
Ca K	1.95	0.68
Totals	100.00	

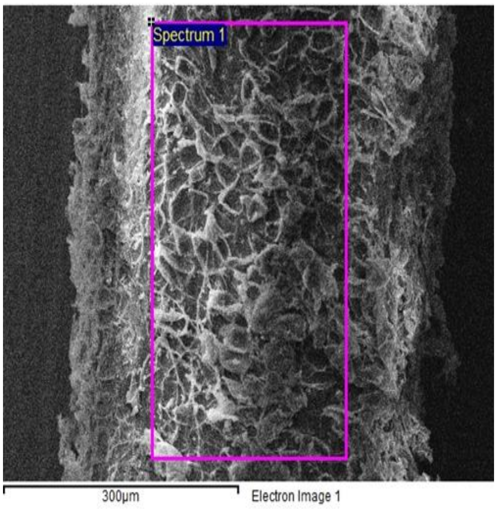


Fig. 4. Scanning Electron Microscope (SEM) analysis of date palm fibers

Table 4. Characteristics of aggregates

Characteristics	Sand water absorption percentage	Water absorption percentage of pea sand	Water absorption percentage of almond sand
(%)	2.2	0.80	0.90

Fig. 5. Washed sand and graded gravel (pea- and almond-sized aggregates)

2.1.5. Water

The water used in the self-compacting concrete mix design was potable. It was used to produce and process the samples, which conforms to the requirements of ASTM C94 (2009) (Table 6).

2.1.6. Limestone Powder

One of the necessary materials to ensure proper viscosity in self-compacting concrete is stone powder. Due to the presence of very fine particles, fillers such as stone powder fill the voids and voids between the cement and aggregate particles and therefore reduce the porosity and increase the bulkiness of concrete. This category of filler elements, due to having a very high specific surface area, increases the friction between grains and increases the viscosity of concrete. Therefore, the use of super-lubricants in order to increase the fluidity of concrete in the construction of such concrete is inevitable. The results of chemical analysis and physical characteristics of cement and limestone powder are shown in Table 7. In this design, Qom limestone powder was used.

2.1.7. VMA (Solidifier and Controller of Concrete Rheology)

VMA powder additive is developed to produce self-compacting concrete with increased viscosity and controlled rheological properties. VMA plays a significant role in controlling excess water in concrete. In this research, the master matrix VMA 358 additive was used based on heavy polymer molecular strands with extraordinary stability. The amount of this material in the concrete mix plan is calculated in relation to the percentage of cement. When all the ingredients were mixed in the mixer. At the last moment, when the concrete is formed, the mixer is turned off for a few seconds, and the concrete is allowed to rest. A certain amount of VMA is spread on the concrete so that the excess water in the concrete is controlled through VMA, and the concrete becomes fluid and more efficient, which is in accordance with the ASTM C494/C494 M (2002) (Figure 6).

Table 5. Technical specifications of superplasticizer and silica fume

Characteristics	**Physical condition**	**Specific gravity (kg/liter)**	**PH**	**Color**	**Special weight (kg/m^3)**
		Super plast PC5000 superplasticizer			
General	Liquid	1.1	6.2	Yellow	1.008
		Silica fume			
General	Thick liquid	1.35	9	Gray	320

Table 6. Characteristics of drinking water

Characteristics	**Temperature (℃)**	**PH**	**Chloride ion concentration**
amount of	20	6	50

Table 7. Qom limestone powder

Characteristics	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**MgO**	**Cao**	**SO_3**	**LOI**
(%)	2.8	0.35	0.50	1.8	51.22	1.24	43.2

Fig. 6. VMA (solidifier and controller of concrete rheology)

2.2. Mixed Design

5 mixing plans of self-compacting concrete with date palm fibers were investigated in this research. The percentage of date fibers is in different ratios (0%, 0.5%, 1%, 1.5%, 2% weight of cement). In all 5 mixed designs, the amount of materials is constant, and the percentage of date palm fibers is variable (Table 8).

2.3. Doing Experiment

To achieve the right mixing plan, first, different combinations of benefits such as; cement, sand, gravel (peas, almonds), water, superplasticizer, micro silica, rock powder, date palm fibers and VMA were mixed in a mixer in suitable and uniform environmental conditions, and as a result, self-compacting concrete with and without date palm fibers was produced. For the benefits mixture, the mixer was used for 8 min to prepare self-compacting concrete with and without fibers. The order of pouring benefits in the mixer is as follows: First, gravel (peas and almonds) and sand ASTM C33 (2003) were added in the mixer for 1 min, then stone powder and date palm fibers were added to the mixture for 3 min and mixed in the mixer. In the next step cement ASTM C150 (2012), water ASTM C94 (2009), superplasticizer, micro silica ASTM C494 (2002) and VMA ASTM C494/C494M (2002) were added in the mixer and were mixed for 4 min to produce a self-compacting concrete. After mixing the mentioned materials in the mixer, the slump flow test (ASTM C1611, 2009), v-funnel test (INSO 3203-9, 2013), l-box test (INSO 3203-10, 2013), and j-ring test (INSO 11271, 2014) are necessary for the properties of fresh-self-compacting concrete with and without palm fibers.

2.3.1. Slump Flow Test

The slump flow test is very common to determine the efficiency of self-compacting concrete due to its simplicity. The slump flow test was based on the ASTM C1611 (2009).

2.3.2. V-Funnel Test

The v-funnel test was performed to measure the ability of self-compacting concrete to change the flow direction and pass through the reinforced and bound sections, without separating the grains and blocking the flow. V-funnel tests were in accordance with the INSO 3203-9 (2013).

2.3.3. L-Box Test

The purpose of the L-Box test is to check the fluidity, the strength of the concrete passing between the rebar, the stability against the separation of the grains, and the filling ability. The L-Box test was in accordance with the INSO 3203-10 (2013).

2.3.4. J-Ring Test

The J-Ring test actually simulates the passage of concrete through rebar and is used to check the ability to pass. The J-Ring test was in accordance with the INSO 11271 (2014).

Table 8. Mixing design of self-compacting concrete with and without date palm fibers (Kg/m^3)

Superplasticizer	Palm fibers	VMA	Stone powder	Silica fume	Water	Sand	Almond sand	Pea sand	Cement
	Self-compacting concrete without date palm fibers (0%)								
10	-	0.160	160	5	135	1240	150	300	400
	Self-compacting concrete with palm fibers (0.5%)								
10	2	0.160	160	5	135	1240	150	300	400
	Self-compacting concrete with palm fibers (1%)								
10	4	0.160	160	5	135	1240	150	300	400
	Self-compacting concrete with palm fibers (1.5%)								
10	6	0.160	160	5	135	1240	150	300	400
	Self-compacting concrete with palm fibers (2%)								
10	8	0.160	160	5	135	1240	150	300	400

2.4. Molding of Concrete Samples

Fresh self-compacting concrete was poured into cubic molds with dimensions of 150 × 150 × 150 mm and cylindrical molds with dimensions of 150 × 300 mm and molded. They were kept at a temperature of 25 °C for 24 hr to harden, and after 24 hr, the samples were taken out of the molds and kept in a water tank for curing for 7 and 28 days. A total of 300 self-compacting concrete samples were made with and without date palm fibers. Of these, 150 specimens were made in a cube mold, and 150 specimens were made in a cylindrical mold. After the 5 mix designs reached the ages of 7 and 28 days, the compressive strength test of cubic specimens was performed according to the ISIRI 3206 (2003), and the tensile strength test of cylindrical specimens was performed according to the ASTM C496 (2002). A concrete breaker jack was used to break the concrete samples. Finally, after the failure test of the concrete samples, the results of the samples were compared and analyzed with self-compacting concrete without fibers.

3. Testing the Compressive Strength of Cubic Specimens

The results of compressive strength tests of concretes based on the ages of 7 and 28 days, with cubic dimensions of 150 × 150 × 150 mm on cubic test pieces according to the ISIRI 3206 (2003) showed that by adding date palm fibers to self-compacting concrete, the compressive strength decreases (Figure 7).

4. Testing the Tensile Strength of Cylindrical Samples

The tensile strength of concretes based on the ages of 7 and 28 days, with cylindrical dimensions of 150 × 300 mm was investigated. The results of tests on cylindrical specimens based on the ASTM C496 (2002) showed that the tensile strength increases with the addition of date palm fibers to self-compacting concrete (Figure 8).

5. Results and Interpretation

5.1. Slump Flow Test

The results of the slump flow test showed that with the increase in the percentage of date palm fibers in the self-compacting concrete, the slump diameter decreased, and the time also increased, which indicates a decrease in concrete flow. This issue was in accordance with the ASTM C1611 (2009).

Fig. 7. The failure of the cube specimen with the compressive strength device, and the specimen broken with palm fibers

5.2. V-Funnel Test

The results of the V-Funnel test showed that with the increase in the percentage of date palm fibers, the test time increased, which indicates that the concrete becomes harder and its flow decreases with the increase in the percentage of date palm fibers, which is in accordance with the INSO 3203-9 (2013).

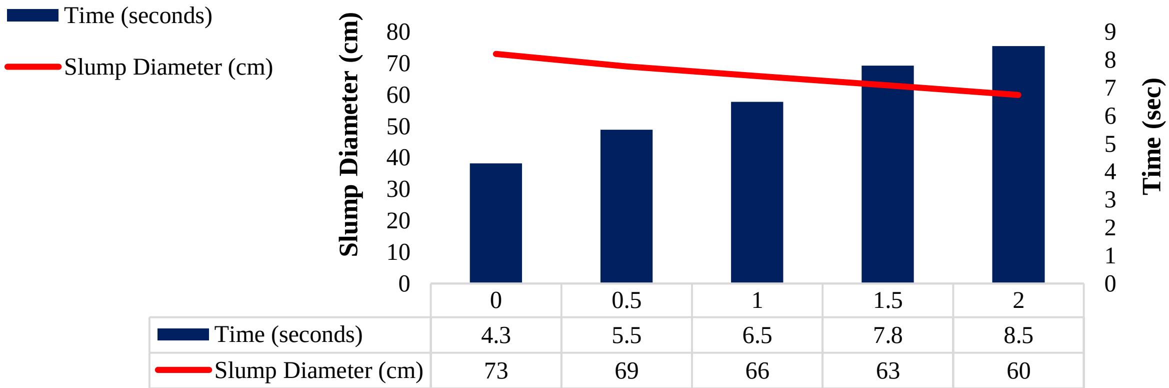
5.3. L-Box Test

The results of the L-Box test showed that with the increase in the percentage of date palm fibers, the test time increased and the height of the edge of the box to the vertical surface and the height of the edge of the box to the horizontal surface decreased, which is in accordance with the INSO 3203-10 (2013).

5.4. J-Ring Test

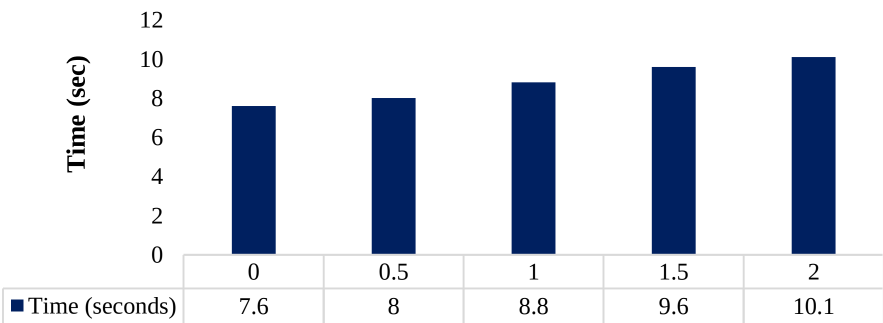
The results of the J-Ring test showed that with the increase in the percentage of date palm fibers, the test time increased and the diameter of the slump decreased, which is in accordance with the INSO 11271 (2014).

Fig. 8. Failure of the cylindrical test piece with the Brazilian device and the test piece broken with palm fibers



	0	0.5	1	1.5	2
Time (seconds)	4.3	5.5	6.5	7.8	8.5
Slump Diameter (cm)	73	69	66	63	60

Fig. 9. Slump flow test results



	0	0.5	1	1.5	2
Time (seconds)	7.6	8	8.8	9.6	10.1

Fig. 10. V-funnel test results

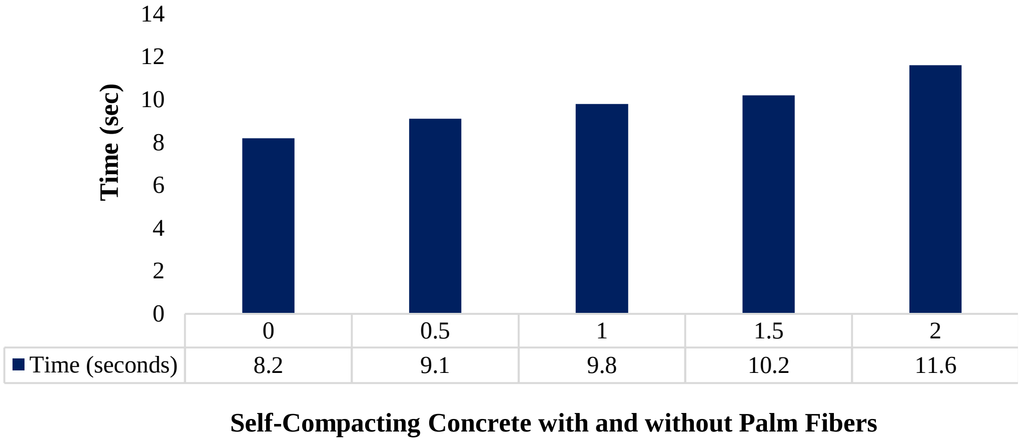


Fig. 11. Results of the 5-min v-funnel test

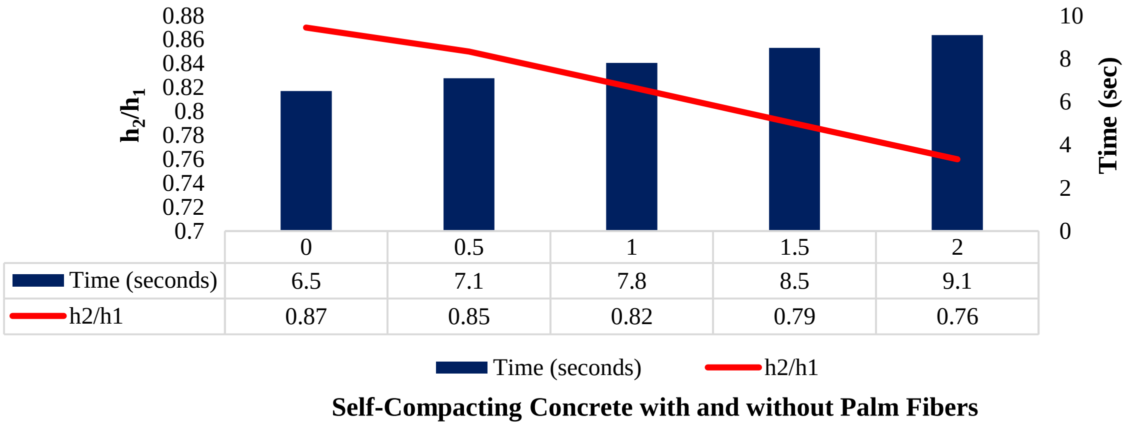


Fig. 12. L-Box test results

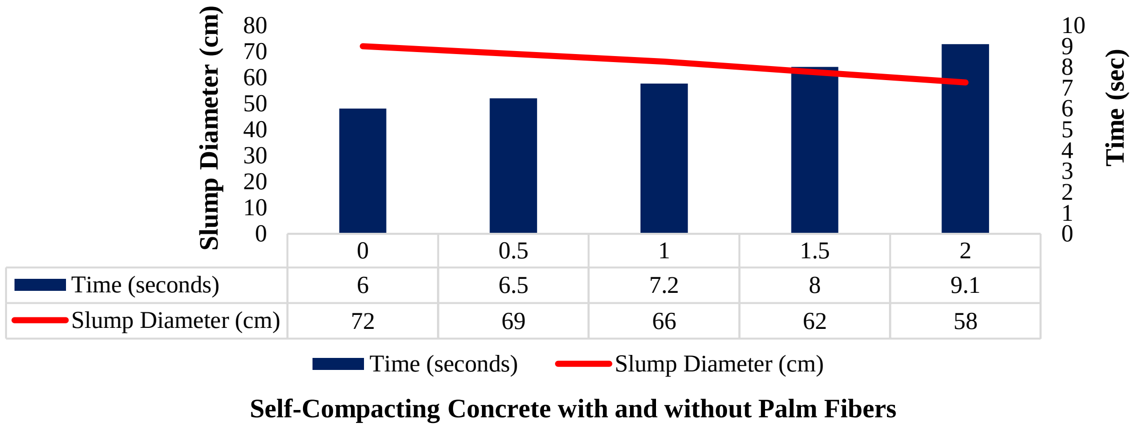


Fig. 13. J-Ring test results

5.5. Testing the Compressive Strength of Cubic Specimens

The reason for the decrease in compressive strength in self-compacting concrete for cubic samples is due to the negative effect of the empty space created in self-compacting concrete due to the amount, shape, and dispersion of fibers in concrete. Also, increasing the percentage of date palm fibers causes a decrease in porosity due to the addition of fibers and as a result, it causes a decrease in adhesion between cement and aggregates, a decrease in adhesion in the concrete transition area, and a lack of cohesion for sufficient concrete durability.

Table 9. Recorded results of compressive strength test data for cubic samples (MPa)

No	1	2	3	4	5
Type of concrete	**(SCC 0%)**	**(SCCPF 0.5%)**	**(SCCPF 1%)**	**(SCCPF 1.5%)**	**(SCCPF 2%)**
Compressive strength test results in 7-day curing for cubic samples (MPa)					
Data range	32.71 - 34.8	31.37 - 34.15	30.57 – 32.72	29.52 - 30.10	28.82 – 30
Average	33.67	32.65	31.63	30.44	29.41
Variance	0.5432	0.6590	0/4490	0.1647	0.1160
Standard deviation	0.737	0.8118	0.6701	0.458	0.3406
Coefficient of variation	0.0218	0.0248	0.0211	0.015	0.0115
Compressive strength test results in 28-day curing for cubic samples (MPa)					
Data range	40.04 – 41.58	38.28 – 39.81	37.37 – 38.80	35.87 – 37.31	34.72 – 35.98
Average	40.75	39.12	38.19	36.76	35.49
Variance	0.3034	0.2671	0.1929	0.2278	0.1852
Standard deviation	0.5522	0.5168	0.4392	0.4773	0.4303
Coefficient of variation	0.0135	0.0132	0.0114	0.0129	0.0121

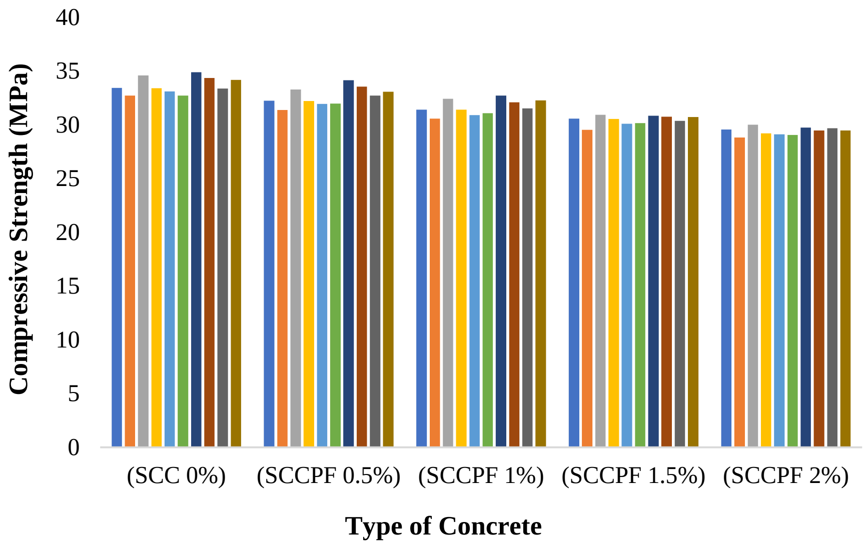


Fig. 14. 7-day compressive strength results of cubic samples

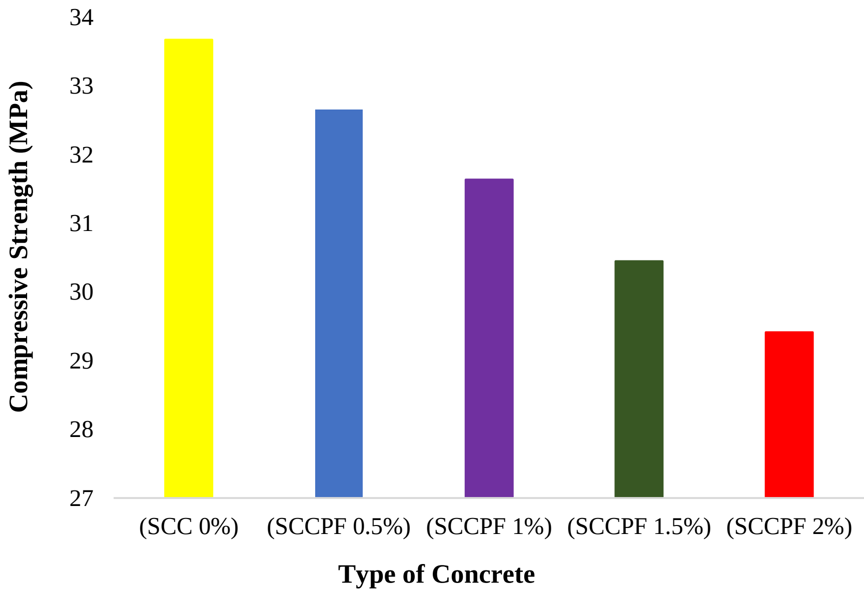


Fig. 15. Results of the 7-day average compressive strength of cubic samples

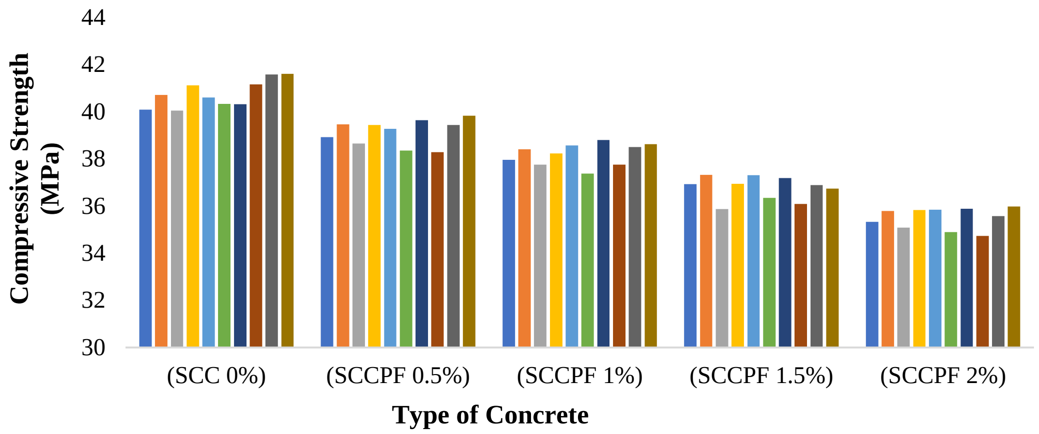


Fig. 16. 28-day compressive strength results of cubic samples

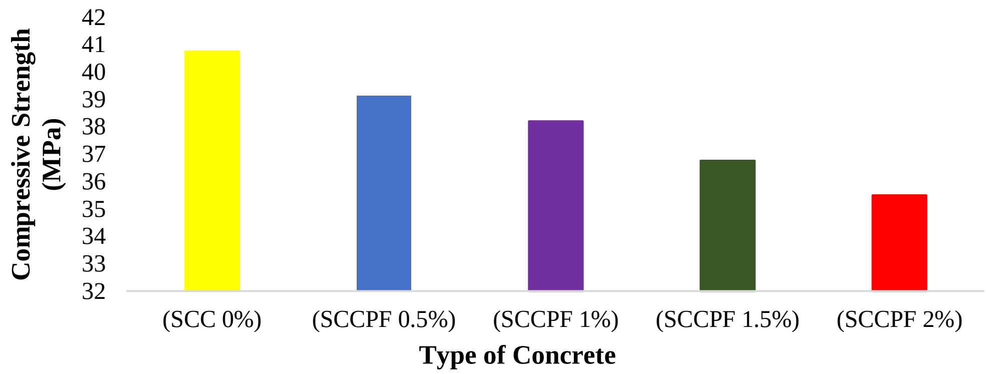


Fig. 17. Results of the 28-day average compressive strength of cubic samples

5.6. Testing the Tensile Strength of Cylindrical Samples

The reason for the increase in the tensile strength test of self-compacting concrete for cylindrical specimens is due to the positive effect of the unique characteristic of fibers with regard to the tensile strength and modulus of elasticity of date palm fibers in self-compacting concrete due to the quantity and size. According to the background of the research in Mirabi Moghadam (2021), with an increase of 2% of date palm fibers in concrete, the tensile strength increased. According to the results of this research, with an increase of 2% of date palm fibers in self-compacting concrete, the tensile strength increased. In the research of Falahtabar Shiade and Tavakoli (2018), the compressive strength decreased with an increase of 2% of date palm fibers in concrete. According to the results of this research, the compressive strength decreased with an increase of 2% of date palm fibers in self-compacting concrete.

Table 10. Recorded results of tensile strength test data for cylindrical samples (MPa)

No	1	2	3	4	5
Type of concrete	**(SCC 0%)**	**(SCCPF 0.5%)**	**(SCCPF 1%)**	**(SCCPF 1.5%)**	**(SCCPF 2%)**
Tensile strength test results in 7-day curing for cylindrical samples (MPa)					
Data range	12.10 – 12.9	14.30 -14.96	16.20 – 17.05	19.30 - 19.80	22.50 – 23.10
Average	12.525	14.61	16.748	19.6	22.831
Variance	0.0494	0.04194	0.05203	0.02346	0.02470
standard deviation	0.222	0.204	0.2281	0.1531	0.1571
Coefficient of variation	0.017	0.0140	0.0136	0.0078	0.0068
Tensile strength test results in 28-day curing for cylindrical samples (MPa)					
Data range	14.2 – 15.1	16.23 – 17.2	18.5 – 19.2	21.3 – 22.63	24.1 – 24.96
Average	14.671	16.587	18.769	21.677	24.731
Variance	0.0875	0.0650	0.0466	0.1232	0.0578
standard deviation	0.2958	0.255	0.216	0.3511	0.2404
Coefficient of variation	0.0201	0.0153	0.0115	0.0161	0.0097

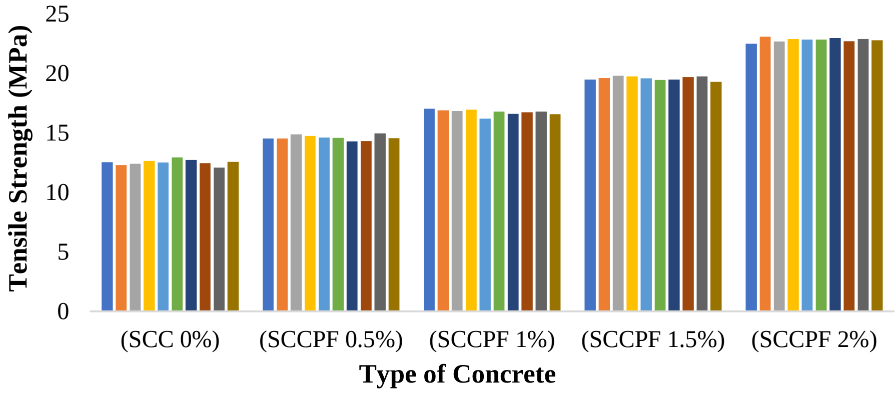


Fig. 18. 7-day splitting tensile strength of cylindrical specimens

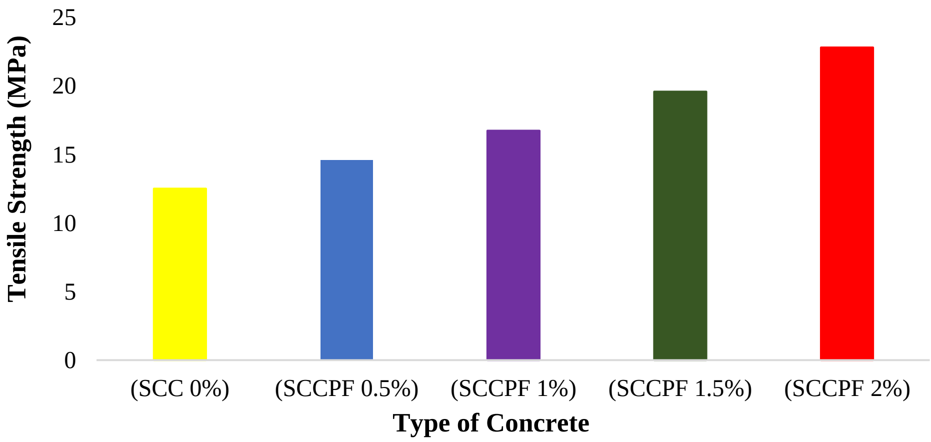


Fig. 19. Results of the 7-day splitting tensile strength of cylindrical specimens

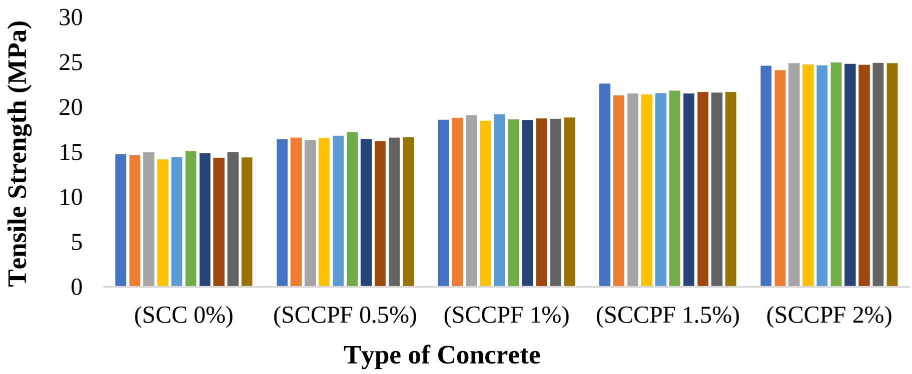


Fig. 20. 28-day splitting tensile strength of cylindrical specimens

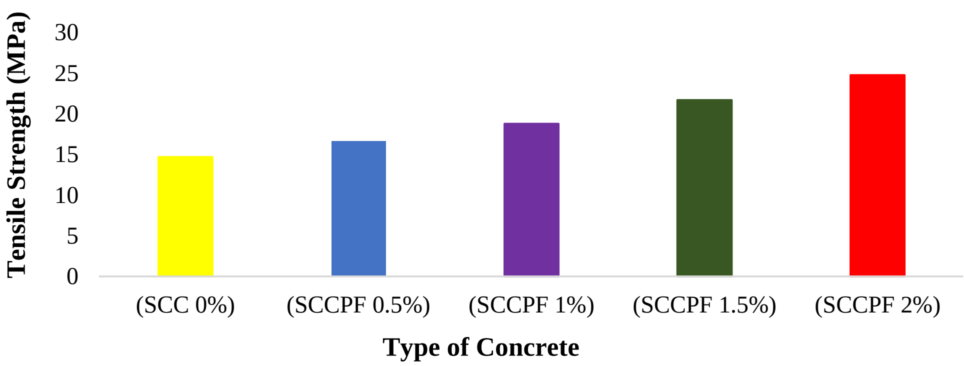


Fig. 21. Results of the 28-day splitting tensile strength of cylindrical specimens

By increasing the bearing capacity of concrete, palm fiber significantly improves tensile strength. This improvement is mainly due to the uniform distribution of stress in the concrete by the fibers. These fibers create bridges within the concrete that prevent the growth and expansion of cracks under loading. Date palm fibers in self-compacting concrete reduce fractures caused by tensile stresses. These fibers can absorb and distribute tensile stresses, which increases the resistance of concrete against bending and tensile loads.

Due to their natural structure and flexibility, date palm fibers help to improve the rheological properties of self-compacting concrete. Date palm fibers can play an important role in improving the resistance of concrete against thawing and thawing cycles. By reducing the permeability of concrete, these fibers prevent the entry of water and the formation of cracks caused by freezing and melting.

Palm fibers can increase the resistance of concrete against chemical attacks and corrosion. Due to its natural properties and special chemical composition, these fibers prevent the penetration of corrosive substances into the concrete. Date palm fibers in self-compacting concrete can significantly improve mechanical, rheological, and durability properties. By increasing tensile strength, improving rheological properties, reducing cracking, increasing resistance to environmental conditions, and having positive effects on microscopic and macroscopic levels, these fibers make self-compacting concrete an ideal option for complex and sensitive construction projects.

6. Conclusions

Self-compacting concrete is one of the most widely used building materials in the world, which is used in construction, but one of the problems of concrete should be kept in mind, its fragility and brittleness, which is considered as one of the mechanical behaviors of concrete. Measures have been taken to solve it. For this purpose, steel rebars are used to reinforce concrete to limit tension and brittleness. In fact, natural fibers are used to increase the mechanical strength and improve the stability of concrete. In this way, the capacity of palm fibers can be used to limit and control cracks, improve bending and tensile strength, and also improve resistance to stresses.

Due to the presence of many palm trees in the Behbahan region, easy and cheap access to these fibers, in this research, the effect of these fibers on the hardened properties of self-compacting concrete was investigated in a laboratory manner. The main purpose of this research is to investigate the effect of adding palm tree fibers on the tensile strength of self-compacting concrete. The results of the tests are as follows:

- The compressive strength of self-compacting concrete cube specimens with palm fibers with different percentages (0.5%, 1%, 1.5%, and 2% compared to the weight of cement) during 7-day processing, respectively, 5.19%, 10.87%, 17.81%, and 22.60% decreased compared to the sample without date fiber.
- The compressive strength of self-compacting concrete cube specimens with date fibers with different percentages (0.5%, 1%, 1.5%, and 2% compared to the weight of cement) during 28 days curing, respectively, 4.11%, 9.51%, 15.48%, and 22.47% decreased compared to the sample without date fiber.
- Tensile strength of cylindrical specimens of self-compacting concrete with palm fibers with different percentages (0.5%, 1%, 1.5%, and 2% compared to the weight of cement) during 7 days of curing, respectively, 16.37%, 34.27%, 56.39%, and 82.24% increase compared to the sample without date fiber.
- Tensile strength of cylindrical specimens of self-compacting concrete with date fibers with different percentages (0.5%, 1%, 1.5%, and 2% compared to the weight of cement) during 28 days curing,

respectively, 13.56%, 27.61%, 46.96%, and 67.62% increase compared to the sample without date fibers.

Date palm fibers are not useful at the moment, and when they are piled up, they cause environmental pollution, and due to their inflammability, they increase the possibility of fire in palm groves. The use of natural fibers from the point of view of using waste, reducing environmental pollution, reducing economic costs, their abundance and availability, as well as the ease of using this type of concrete due to the flexibility of the fibers, is significant in curved and resistant structures. It is a study and it is compatible with the environment and reduces the harmful effects on the environment.

7. References

Abani, S., Kriker, A. and Khenfer, M. (2018). "Flexural properties of reinforced date palm fibres concrete in sahara climate", *Technologies and Materials for Renewable Energy*, AIP conference proceedings, 1968, https://doi.org/10.1063/1.5039267.

Abdullah, A. and Sivakumar, K. (2023). "Effect of fibre diameter and tensile strength on the mechanical, fracture, and fibre distribution properties of eco-friendly high-strength self-compacting concrete", *Construction and Building Materials*, 403, 133161, https://doi.org/10.1016/j.conbuildmat.2023.133161.

Ahmad, J., Aslam, F., Zaid, O., Alyousef, R., Alabduljabbar, H. and Manan, A. (2021a). "Self-fibers compacting concrete properties reinforced with propylene fibers", *Science and Engineering of Composite Materials*, 28(1), 64-72, https://doi.org/64.72.10.1515/secm-2021-0006.

Ahmad, J., Zaid, O., Aslam, F., Martinez-Garcia, R., Alharthi, Y.M., El Ouni, M.H., Tufail, R.F. and Sharaky, I.A. (2021b). "Mechanical properties and durability assessment of nylon fiber reinforced self-compacting concrete", *Journal of Engineered Fibers and Fabrics*, 16, 15589250211062833, https://doi.org/10.1177/15589250211062833.

Akhmetov, D., Akhazhanov, S., Jetpisbayeva, A., Pukharenko, Y., Root, Y., Utepov, Y. Akhmetov, A. (2022). "Effect of low-modulus polypropylene fiber on physical and mechanical properties of self-compacting concrete", *Case Studies in Construction Materials*, 16, https://doi.org/10.1016/j.cscm.2021.e00814.

Alatshan, F., Altlomate, M., Mashiri, F. and Alamin, W. (2017). "Effect of date palm fibers on the mechanical properties of concrete", *International Journal oF Sustainable Building Technology and Urban Development*, 8(2), 68-80, https://doi.org/10.12972/susb.20170007.

Al-Hadithi, A.I., Majid, A. and Midher, A.H. (2023). "Structural behavior of reinforced lightweight self-compacting concrete beams using expanded polystyrene as coarse aggregate and containing polyethylene terephthalate fibers", *Structural Concrete Journal Citation Reports*, 24(5), 5808-5826, https://doi.org/10.1002/suco.202200381.

Askar, M.K., Al-Kamaki, Y.S.S. and Hassan, A. (2023). "Utilizing polyethylene terephthalate pet in concrete", *Journals Polymers*, 15(15), 3320, https://doi.org/10.3390/polym15153320.

Asmaa, H.S. and Khashaa, M. (2022). "Optimum characteristics of plastic fibres for sustainable self-compacting concrete SCC", *European Journal of Environmental and Civil Engineering*, 27(9), 2967-2984, https://doi.org/10.1080/19648189.2022.2119605.

ASTM C150/C150M. (2012). *Standard specification for Portland cement*, American Society of Testing and Materials Standards, West Conshohocken, PA.

ASTM C33. (2003). *Standard specification for concrete aggregates*, American Society of Testing and Materials Standards, West Conshohocken, PA.

ASTM C494. (2002). *Standard specification for chemical admixtures for concrete*, Annual Book of ASTM Standards, ASTM International, (Vol. 04.02), West Conshohocken, PA.

ASTM C494/C494M. (2002). *Standard specification for chemical admixtures for concrete*, Annual Book of ASTM Standards, ASTM International, (Vol. 04.02), West Conshohocken, PA.

ASTM C94. (2009). *Standard specification for ready-mixed concrete*, American Society of Testing and Materials Standards, ASTM International, West Conshohocken, PA.

ASTM C94/C94M – 09. (2009). *Standard specification for ready-mixed concrete*, Annual Book of ASTM Standards (Vol. 04.02), ASTM International, West Conshohocken, PA.

ASTM C1611. (2009). *Standard test method for slump flow of self-consolidating concrete*, ASTM International, West Conshohocken, PA.

ASTM C1611/C1611M – 09. (2009). *Standard test method for slump flow of self-consolidating concrete*, Annual Book of ASTM Standards (Vol. 04.02), ASTM International, West Conshohocken, PA.

ASTM C496. (2002). T*tensile concrete test* *equipment*, ASTM International, West Conshohocken, PA.

ASTM C496/C496M – 02. (2002). *Standard test method for splitting tensile strength of cylindrical concrete specimens*, Annual Book of ASTM Standards, (Vol. 04.02), ASTM International, West Conshohocken, PA.

Ayub, T., Khan, S. and Mahmood, W. (2021). "Mechanical properties of self-compacting rubberized concrete containing polyethylene terephthalate fibres", *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 46, 1073-1085, https://doi.org/10.1007/s40996-020-00568-6.

Bhat, A.H., Naqash, J.A., Habib, T. and Islam, S.U. (2023). "Compressive strength and microstructural properties of sustainable concrete containing nanosilica, alccofine and metakaolin", *Civil Engineering Infrastructures Journal*, 57(1), 1-15, https://doi.org/10.22059/ceij.2023.348240.1866.

Boutarfa, M., Belouettar, R. and Makradi, A. (2018). "Comparative study of cement mortar reinforced with vegetable fibers (alfa, date palm and diss): Mechanical properties and shrinkage", *Journal of Materials and Environmental Sciences*, 9(8), 2304-2314. https://www.jmaterenvironsci.com/Document/vol9/vol9_N8/253-JMES-4073-Boutarfa.pdf. jmaterenvironsci.com

Bozorgmehr Nia, S. and Adlparvar, M.A. (2022). "The effects of waste polyethylene terephthalate particles on the properties of fresh and hardened self-consolidating concrete", *International Journal of Civil Engineering and Construction*, 1(1), 6-12, https://doi.org/10.22271/27078329.2022.v1.i1a.3.

Djoudi, A., Khenfer, M.M., Bali, A., Kadri, E.H. and Debicki, G. (2012). "Performance of date palm fibres reinforced plaster concrete", *International Journal of Physical Sciences*, 7, 2845-2853, https://doi.org/10.5897/IJPS11.1553.

Dounia, D., Mourad, B. and Mohammed, B. (2023). "Effect of date palm and polypropylene fibers on the characteristics of self-compacting concrete", *Structural Integrity and Durability of Structures*, 17(64), 31-50, https://doi.org/10.3221/IGF-ESIS.64.03.

Eskandari, A., Omidinasab, F., Sahraei, A.M. and Dalvand, A. (2021). "Investigating the effect of different types of fibers in improving the flexural performance of recycled concrete beams in the elastic and plastic zones", *Journal of Structural and Construction Engineering*, 8(12), 344-362, https://doi.org/10.22065/JSCE.2021.280477.2411.

Falahtabar Shiade, M. and Tavakoli, H.R. (2018). "Estimation of mechanical and durability properties of self-compacting concrete with fibers using ultrasonic pulse velocity", *Journal of Rehabilitation in Civil Engineering*, 6(2), 43-53, https://doi.org/10.22075/JRCE.2018.798.1099.

Fokam, C.B., Kenmeugne, E., Meva'a, L. and Mansouri, K. (2020). "Cement mortar reinforced with palm nuts naturals fibers: Study of the mechanical properties", *Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials*, 30(1), 9-13, https://doi.org/10.18280/rcma.300102.

Ghobadi, M., motaghed, S., Mirzaei Aliabadi, M. and Gharaibi, Y. (2019). "Investigating the fresh and hardened properties of fiber self-compacting concrete", *Scientific Research Journal of Structural and Construction Engineering*, 6(4), 43-61, https://doi.org/10.22065/JSCE.2018.102143.1366.

Hossein Bar, A., Mirabi Moghadam, M.H. and Shahryari, A. (2015). "Investigation of the effect of date palm sisal fibers on the tensile strength of concrete", *Proceedings of the National Conference on Civil and Architectural Engineering and Physical Development*, Saravan, Iran.

INSO 3203-9. (2013). *Testing fresh concrete - part 9: self-compacting concrete V-funnel test*, Iranian National Standardization Organization, Karaj, Iran, (in Persian).

INSO 3203-10. (2013). *Testing fresh concrete - part 9: self- compacting concrete -L box test*, Iranian National Standardization Organization, Karaj, Iran, (in Persian).

INSO 11271. (2014). *Concrete - measurement of passing ability of self-consolidating concrete by J-ring- test method*, Iranian National Standardization Organization, Karaj, Iran, (in Persian).

IRIB News Agency. (2020). "More than 9 thousand tons of dates were harvested from Behbahan groves", News code: 2851756, https://www.iribnews.ir/, (in Persian).

ISIRI 3206. (2003). *Standard test determining the compressive strength of concrete samples*, Institute of Standards and Industrial Research of Iran, Tehran, Iran, (in Persian).

Mirabi Moghadam, M.H. (2021). " Investigation of Cis Palamfiber on the mechanical properties of concrete", *Structural and Construction Engineering Scientific-Research Journal*, 8(3), 169-176, https://doi.org/10.22065/jsce.2019.168289.1766.

Modarres, Y., Ghalehnovi, M. (2023). "The effect of recycled steel fibers from waste tires on concrete properties", *Civil Engineering Infrastructures Journal*, 56(1), 1-18, https://doi.org/10.22059/CEIJ.2022.339592.1820.

Ramhormozy, A., Kazeminezhad, E. and Safakhah, S. (2023). "Effect of polyethylene terephthalate and polypropylene fibers on the shear behavior of rc deep beams", *Revista de la Construcción*, 22(1), 223-241, https://doi.org/10.7764/RDLC.22.1.223.

Ramli, M. and Dawood, E.T. (2010). "Effects of palm fiber on the mechanical properties of lightweight concrete crushed brick", *American Journal of Engineering and Applied Sciences*, 3(2), 489-493, https://doi.org/10.3844/ajeassp.2010.489.493.

Sor, N.H., Ali, T.K.M., Vali, K.S., Ahmed, H.U., Faraj, R.H., Bheel, N. and Mosavi, A. (2022). "The behavior of sustainable self-compacting concrete reinforced with low-density waste Polyethylene fiber", *Materials Research Express*, 9(3), 035501, https://doi.org/10.1088/2053-1591/ac58e8.

Tawfeeq, A.W. and Ganesh, S. (2022). "Study on fresh properties, mechanical properties and microstructure behavior of fiber reinforced self-compacting concrete", *Materials Today: Proceedings*, 62(12), 6663-6670, https://doi.org/10.1016/j.matpr.2022.04.666.

Wang, J., Dai, Q. and Si, R. (2022). "Experimental and numerical investigation of fracture behaviors of steel fiber-reinforced rubber self-compacting concrete", *Journal of Materials in Civil Engineering*, 34(1), 04021379, https://doi.org/10.1061/(ASCE)MT.1943-5533.0004010.