Properties of Sand Concrete from Oil Wells Reinforced by Polypropylene Fibers

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Abstract
The disposal of waste produced during drilling activities in the hydrocarbon industry poses a significant environmental risk, necessitating its effective management. To address this issue, a viable solution is to utilize this waste in the production of sand concrete as a substitute for conventional sand concrete.This research endeavor focuses on conducting experimental investigations to explore the feasibility of incorporating oil well sand into sand concrete and reinforcing it with polypropylene fibers. By partially replacing oil well sands with dune sands (at percentages of 8%, 15%, and 25%) and alluvial sands (at percentages of 12%, 20%, and 30%), the oil content in the sand from oil wells was reduced from 20% to 5%. Additionally, various fiber dosages (1 and 1.5 kg/m^3) were used to reinforce the sand concrete.The introduction of dune sand and alluvial sand successfully decreased the proportion of oil sand obtained from oil wells. This incorporation resulted in enhancements to both the fresh and hardened properties of the sand concrete. The most favorable strengths, in terms of compressive and tensile properties, were achieved when utilizing a blend of 30% alluvial sand and 70% oil well sand.Furthermore, the addition of fibers at a dosage of 1.5 kg/m^3 exhibited a more pronounced impact on the strength (compressive and tensile) and shrinkage of the mixtures comprising 30% alluvial sand and 70% oil well sand.
Keywords: Sand concrete; Oil wells sands; Dune sands; Alluvial sands; Polypropylene fibers; Mechanical properties.

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1. Introduction

The Hassi Messouad area in Algeria is recognized as a crucial hub for the oil industry. Throughout the processes of drilling, production, and refining, a substantial quantity of solid and liquid waste is produced. These waste materials, known as cuttings, are disposed of in a designated crevice called a quagmire. However, the discharge of these environmentally hazardous wastes poses a significant risk of contaminating the surrounding environment. Such contamination could have detrimental impacts on both human health and the overall ecosystem.

The presence of oil spills has a detrimental impact on the properties of the adjacent sand, leading to modifications in its physical and chemical attributes [1]. Environmental concerns related to petroleum-based substances frequently involve the introduction of hydrocarbon pollutants [2]. Utilizing the contaminated soil for construction purposes emerges as a feasible approach for remediation [3].

Several researchers have investigated the feasibility of utilizing oil-contaminated sand as an alternative method for remediation in engineering applications. Their findings suggest that sand contaminated with oil can be effectively employed in the construction of road base materials or as topping layers for parking areas [4,5]. Although the use of such contaminated sand in civil engineering construction is considered a cost-effective and environmentally friendly solution, there is a limited understanding of the mechanical properties of oil-polluted sand, as only a few studies in the existing literature have addressed this aspect [6].

Studies conducted by Saberian and Khabiri [7], Akinwumi et al. [8], and Hassan et al. [9] have investigated the beneficial outcomes of incorporating cement and other materials into oil-contaminated sand to stabilize it. As a result, these findings have transformed the perspective of oil-contaminated sand from mere waste to a resource with economic potential.

In this study, we aim to address this research gap by focusing on the incorporation of dune and alluvial sands, as well as the reinforcement of concrete with polypropylene fibers to enhance its strength. Previous investigations by Bédérina et al. [10] have demonstrated that dune sand can optimize the compaction of river sand, thereby improving the workability and mechanical properties of sand concrete. Several studies have also examined the influence of sand type on the properties of concrete [11,12].

The utilization of polypropylene fibers has been recognized as a cost-effective method to enhance various characteristics of concrete. Previous research has highlighted the benefits of using these fibers, including improved bonding strength [13], long-term tensile strength [14], impact resistance [15], resistance to abrasion-erosion [16], reduction in plastic shrinkage [17], and mitigation of crack propagation [18] .[19]It has been reported that polypropylene fibers effectively mitigate plastic and early drying shrinkage by enhancing the tensile properties of concrete and resisting crack development induced by drying shrinkage.

The main objectives of this paper are to reduces the environmental impact of the reject sands contaminated by the hydrocarbure fluid in the area of drilling oil wells , this study is based on the determine the effect of substitution oil wells sand by dune sand and alluvial sand and the addition of polypropylene fibers on the mechanical properties of oil wells sand concrete.

2. Materials

2.1 Cement

The cement used in this study was Portland cement CRS CEMI 42.5, specifically chosen for its sulfate resistance. It was procured from the Biskra Factory in Algeria. The cement exhibited an absolute density of 3.25 g/cm^3 and a specific surface area of 3215 cm²/g. A detailed analysis of its chemical composition and clinker mineralogical composition can be found in Table 1.

Table 1. Chemical and mineralogical compositions of cement (%).

Chemical composition (wt %)							
Al_2O_3	SiO_2	Fe_2O_3	SO_3	CaO	K_2O	Na_2O	LOI
4.68	21.14	5.45	2.44	65.23	0.35	0.17	0.78

Mineralogical composition (%)			
C_3S	C_2S	C_3A	C_4AF
69.42	8.36	3.02	17.26

2.2 Sands

Three sands were used (Table 2) in this study.

Oil wells sand

Oil wells sand from Hassi Messaoud oil wells drilling site was used; its fineness modulus and absolute density were 2.35 and 2.45g/cm^{3}respectively.

Alluvial sand

Alluvial sand, sourced from Baâge (El Meghaier, Algeria), was utilized in this research. The maximum particle size of the sand was 4 mm. It possessed a fineness modulus of 1.87 and an absolute density of 2.7 g/cm^{3}respectively.

Dune sand

Dune sand from El Oued, Algeria, characterized by a maximum particle size of 1 mm, was employed in this study. The sand had a fineness modulus of 1.2 and an absolute density of 2.64 g/cm^{3}respectively.

Table 2 Physical properties of used sands.

Sand	Apparent density (Kg/m^3)	Specificdensity (Kg/m^3)	Sand equivalent (SE) (%)	Finenessmodulus (FM) (%)
Oil well sand (OWS)	1370	2450	74	2.35
Dune sand (DS)	1560	2640	85	1.2
Alluvial sand (AS)	1640	2700	80	1.87

2.3 Adjuvant

The mortar mixtures incorporated an Algerian superplasticizer known as Medaplast SP 40. This superplasticizer is based on Ether Polycarboxylate and was selected for its performance-enhancing properties. The manufacturer's recommended dosage ranged from 0.5% to 2.5% by weight of cement, depending on the desired performance.

2.4 Polypropylene fibers

To reinforce the sand concrete derived from oil wells, polypropylene (PP) fibers of the monofilament type were employed. These fibers were obtained from the TEKNACHEM Company in Setif, Algeria. Table 3 provides a comprehensive overview of the characteristics of these fibers.

Table 3. Physical and mechanical properties of polypropylene fibers

Length (mm)	Diameter (microns)	Tensile strength (MPa)	Elasticmodulus (MPa)
12	28	320-400	3500-3900

The raw materials used in this work and previously described, have been photographed and presented in Fig. 1.

Oil Wells Sand (OWS) **Dune Sand (DS)** **Alluvial Sand (AS)** **polypropylene Fibers**

Fig. 1. Raw materials

3. Experimental study

In order to create plain sand concrete, the cement-to-sand ratio adhered to the EN 196 standards, where one part cement was combined with three parts sand in all mixtures, both with and without fibers. The amount of water required was determined using a flow table.

For the formulation of polypropylene fiber-reinforced sand concrete, two fiber quantities were incorporated: 1 kg/m^3 and 1.5 kg/m^3. The introduction of fibers resulted in a significant decrease in workability [18]. As a result, the addition of a superplasticizer became necessary.

Three distinct mixtures of plain sand concrete were prepared and labeled as follows: 100% OWS (consisting of 100% oil wells sand concrete), 25% DS and 75% OWS (comprising 25% dune sand and 75% oil wells sand), and 30% AS and 70% OWS (containing 30% alluvial sand and 70% oil wells sand).The proportions of the mixtures are given in Table 4.

Table 4. Mixtures proportions (1 m^3).

Mixtures	Sand (Kg)	Cement (Kg)	Water (L)	Fibers (Kg)	Superplasticizer (Kg)	W/C
100% Oil well sand	1394.85	464.95	278.97	/	9.30	0.6
	1418.07	472.69	283.61	/	4.72	0.6

25% Dune sand	1410.72	470.24	282.14	1	4.70	0.6
+ 75% Oil well sand	1403.70	467.90	280.74	1.5	4.68	0.6
30% Alluvial sand	1447.83	482.61	289.57	/	4.82	0.6
+	1441.74	480.58	288.34	1	4.80	0.6
70% Oil well sand	1431.78	477.26	286.35	1.5	4.77	0.6

The mixing procedure involved initially blending the various sands together, followed by the addition of cement to the mixture. The polypropylene fibers were then carefully dispersed by hand to ensure a uniform distribution within the concrete. Water was gradually introduced into the mixture. The resulting mixtures were cast in two layers into molds and compacted using a vibration table. After approximately 24 hours, all specimens were demolded and placed under laboratory conditions with a temperature range of 25-35°C and a humidity level of 40% ± 10%.

To evaluate the mechanical properties, several prismatic test samples measuring 40 mm x 40 mm x 160 mm were prepared in accordance with European Standard EN 196-1.The samples were immersed in water for a duration of 28 days. Tensile strength tests were conducted using three-point bending on three prismatic samples of the same dimensions. Subsequently, half of the samples resulting from the tensile strength test were subjected to compression testing on a 40 cm x 40 cm section, following EN 196-1 guidelines. The compressive and tensile strengths were assessed at different ages.

The shrinkage test, carried out according to standard NF P 15-433, involved monitoring the change in length of a specimen over time, starting from the moment it was removed from the mold until its length stabilized. The shrinkage test was evaluated at different ages to determine the extent of shrinkage.

4. Results and discussion

Effect of substitution on mechanical strength: Compressive strength

Compressive strengths were evaluated for different types of concrete composed of various sands: 100% oil wells sand (OWS), 25% dune sand (DS) + 75% OWS, and 30% alluvial sand (AS) + 70% OWS. The progression of compressive strength over time for the concrete specimens immersed in plain water is depicted in Figure 2.

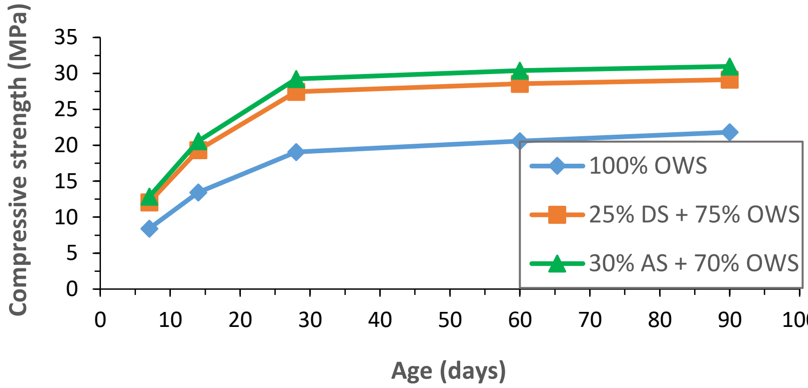

Fig. 2. Compressive strength as a function of age

The impact of substitution on the mechanical compressive strength of concrete is illustrated in Figure 2. The findings demonstrate an enhancement in the compressive strength of concrete when using proportions of 25% dune sand (DS) + 75% oil wells sand (OWS) and 30% alluvial sand (AS) + 70% OWS, in comparison to plain concrete composed solely of 100% OWS. The increase in compressive strength amounted to 33.51% and 41.87%, respectively, attributable to the reduced usage of oil well sand. Moreover, the compressive strength of concrete incorporating a mixture of OWS and AS exhibited a 6.35% improvement when contrasted with concrete incorporating OWS and DS. This divergence in strength is attributed to the granular gradient and smoothness factor inherent in each type of sand utilized in the concrete. A lower smoothness coefficient signifies smoother sand, leading to less resistant concrete, as elucidated in previous studies [20, 21].

Effect of substitution on mechanical strength: tensile strength

Tensile strengths were evaluated for different types of concrete incorporating various sands: 100% oil wells sand (OWS), 25% dune sand (DS) + 75% OWS, and 30% alluvial sand (AS) + 70% OWS. The changes in tensile strength over time for the concrete specimens stored in plain water are depicted in Figure 3.

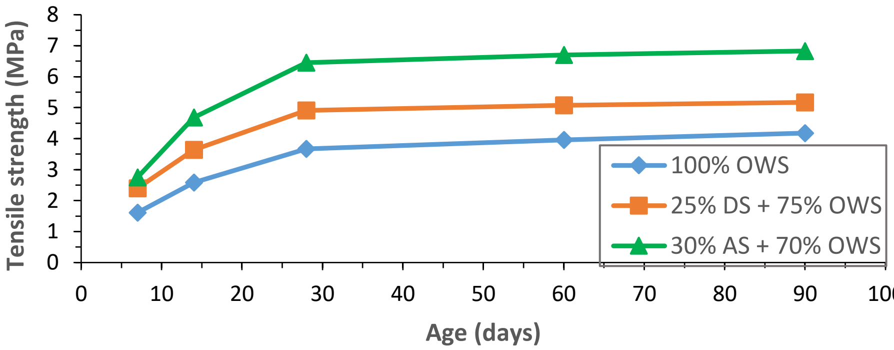

Fig. 3.Tensile strength as a function of age

Similar to the case of compression, it is evident that the concrete incorporating alluvial sand (30% AS + 70% OWS) exhibited superior bending resistance. The tensile strength achieved by the concrete with alluvial sand was higher than that of the concrete with dune sand (25% DS + 75% OWS). There was an increase of approximately 53.39% in tensile strength compared to the lowest resistance observed in the concrete composed solely of 100% oil wells sand. This disparity in strength can be attributed to the fact that dune sand possesses a significantly higher specific surface area than alluvial sand, resulting in an increased volume of voids. Moreover, the larger particle size of hill sand contributes to the enhanced resistance of concrete made with alluvial sand when compared to concrete made with dune sand [22].

Effect of substitution on mechanical strength: Water absorption

The impact of substitution on capillary water absorption in concrete incorporating different sands, namely 100% oil wells sand (OWS), 25% dune sand (DS) + 75% OWS, and 30% alluvial sand (AS) + 70% OWS, is illustrated in Figure 4.

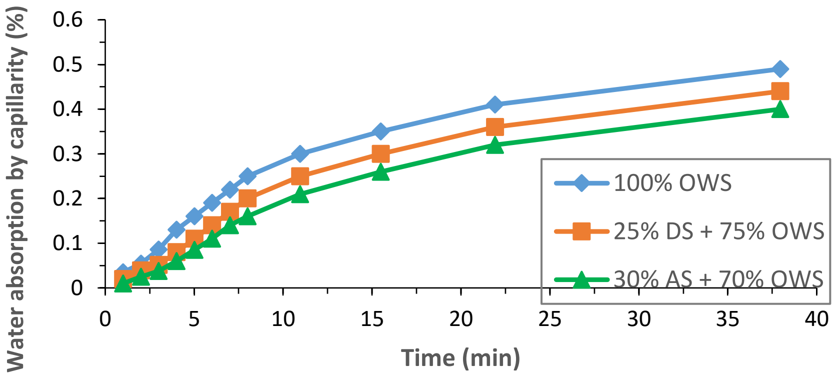

Fig. 4. Effect of substitution on water absorption by capillarity

A reduction in capillary water absorption was observed for the concrete mixtures containing 25% dune sand (DS) + 75% oil wells sand (OWS) and 30% alluvial sand (AS) + 70% OWS, in comparison to plain concrete made solely with 100% OWS. After an 8-hour exposure period, the decrease in water absorption by capillarity was measured at 18.36% for 30% AS + 70% OWS and 10.21% for 25% DS + 75% OWS. The decrease in water absorption can be attributed to the presence of a higher percentage of voids and pores in the dune sand concrete, which is a result of the fineness and softness of the dune sand grains. These characteristics create multiple pathways within the concrete, facilitating water penetration. Conversely, alluvial sand contains fewer voids compared to dune sand, and its larger grain size further contributes to a lower rate of water absorption. This finding aligns with the observations made by Luo et al. [23], who noted that dune sand exhibits a significantly higher surface area and a greater amount of adsorbed layer water compared to river sand.

Effect of substitution on mechanical strength: Shrinkage

The variation in shrinkage measurements at different ages is depicted in Fig. 5 for the concrete mixtures incorporating different sands: 100% oil wells sand (OWS), 25% dune sand (DS) + 75% OWS, and 30% alluvial sand (AS) + 70% OWS.

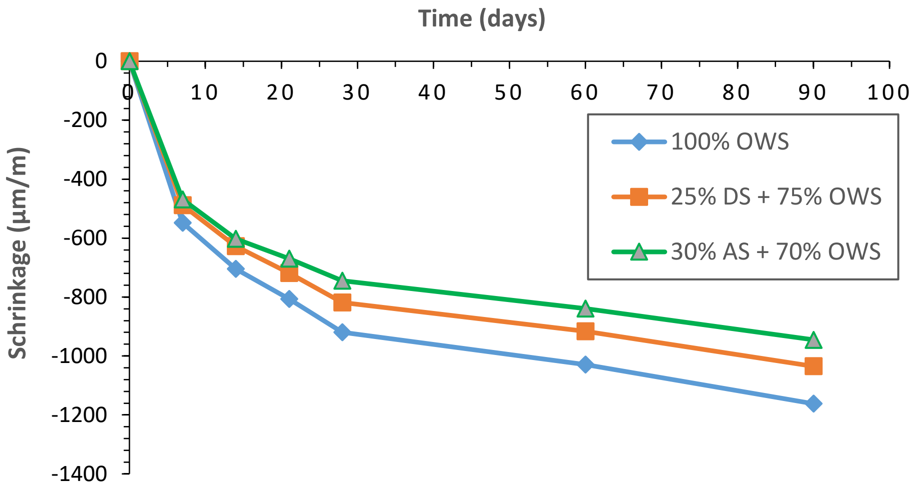

Fig. 5. Shrinkage as a function of age

The shrinkage of the concrete mixtures containing 25% dune sand (DS) + 75% oil wells sand (OWS) and 30% alluvial sand (AS) + 70% OWS was found to be lower compared to plain concrete made solely with 100% OWS. After 90 days, the reduction in shrinkage was 9.95% and 18.67%, respectively, with the 30% AS + 70% OWS mixture resulting in a 9.04% decrease compared to the 25% DS + 75% OWS mixture.This decrease in shrinkage can be attributed to the variation in granular gradient and smoothness characteristics of the sands used in these concrete mixtures. Previous research has shown that concrete mixtures made with a combination of river sand and 15% dune sand exhibited the highest shrinkage, while mixtures made solely with river sand had less shrinkage[24]. These findings align with our study, where an increase in the proportion of dune sand resulted in an increase in shrinkage.

Effect of polypropylene fibers on mechanical strength

Compressive strength

The compressive strength of polypropylene fiber-reinforced sand concretes, specifically the mixtures of 25% dune sand (DS) + 75% oil wells sand (OWS) and 30% alluvial sand (AS) + 70% OWS, with fiber dosages of 1 and 1.5 kg/m^3, is presented in Figure 6.

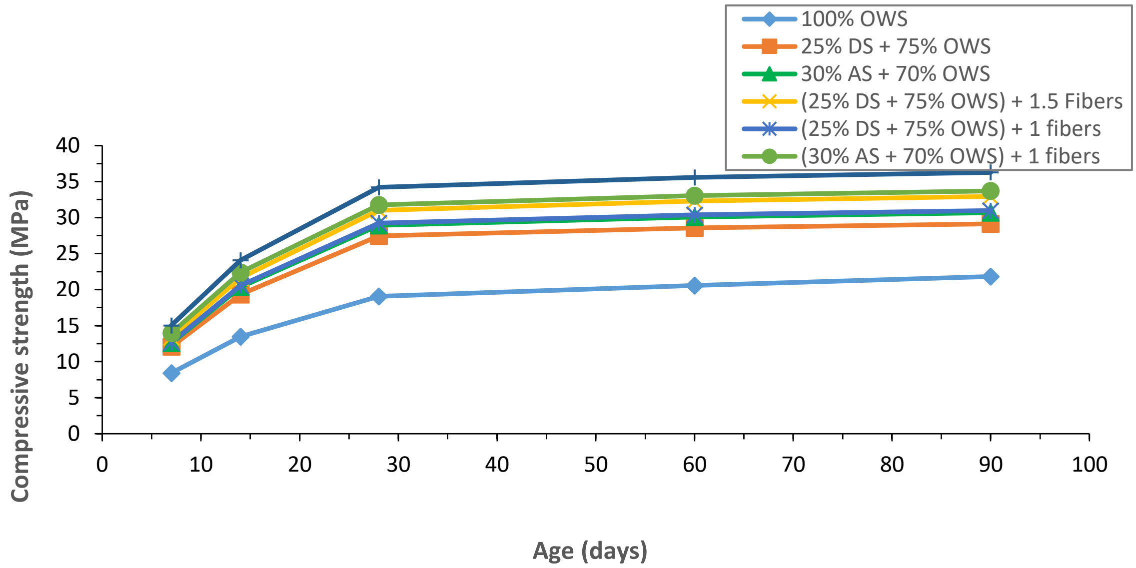

Fig. 6. Effect of polypropylene fibers on compressive strength

Figure 6 illustrates the enhancement in compressive strength of sand concrete when alluvial sand is incorporated into the mixture with oil wells sand (30% AS + 70% OWS) compared to dune sand (25% DS + 75% OWS). The improvement in compressive strength ranges from 9.48% to 13.69% for different fiber contents (1 and 1.5 kg/m^3) after a 90 day period. The presence of polypropylene fibers within the matrix, with a preferred orientation, contributes to the increased compressive strength. This phenomenon can be attributed to the fibers' ability to reduce crack formation and development, as demonstrated by Topçu and Canbaz [25].

Tensile strength

The tensile strength of polypropylene fiber-reinforced sand concretes, specifically the mixtures 25% DS + 75% OWS and 30% AS + 70% OWS, with fiber dosages of 1 and 1.5 kg/m^3, is depicted in Figure 7.

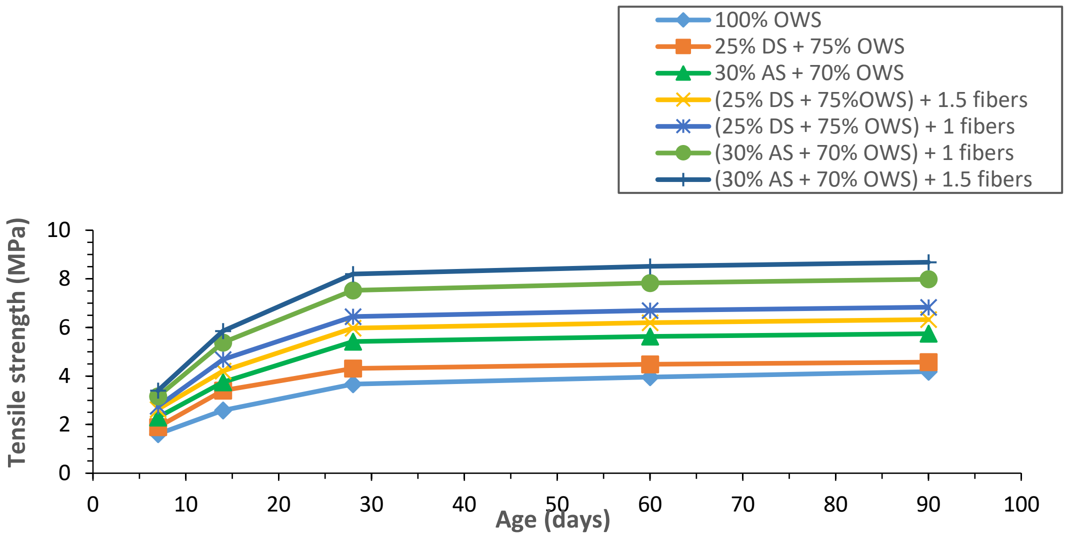

Fig. 7. Effect of polypropylene fibers on tensile strength

Figure 7 illustrates a notable enhancement in the tensile strength of sand concrete derived from oil wells when combined with alluvial sand (30% AS + 70% OWS) compared to sand concrete made with dune sand (25% DS + 75% OWS). The increase ranges from 11.06% to 14.77% across different fiber contents (1 and 1.5 kg/m^3) after a period of 90 days. Moreover, the tensile strength of the mixture (30% AS + 70% OWS) with a fiber content of 1.5 kg/m^3 surpasses that of the mixture (30% AS + 70% OWS) with a fiber content of 1 kg/m^3. The effect of fiber content was particularly significant in influencing the tensile strength. This improvement can be attributed to the fibers' inclination to align in the lengthwise direction of the specimens. Consequently, during their crushing, the load acts perpendicularly to the fibers, reducing crack formation and increasing tensile strength. S. Kakooei et al. [26] reported that the bolstering of mechanical strength in polypropylene fiber-reinforced concretes stems from the provision of fibers, which are wider than the cracks, thereby creating connecting bridges that enhance the concrete's resistance.

Shrinkage

Figure 8 depicts the measurements of shrinkage in sand concretes that have been reinforced with polypropylene fibers, specifically the mixtures 25% DS + 75% OWS and 30% AS + 70% OWS, with fiber dosages of 1 and 1.5 kg/m^3.

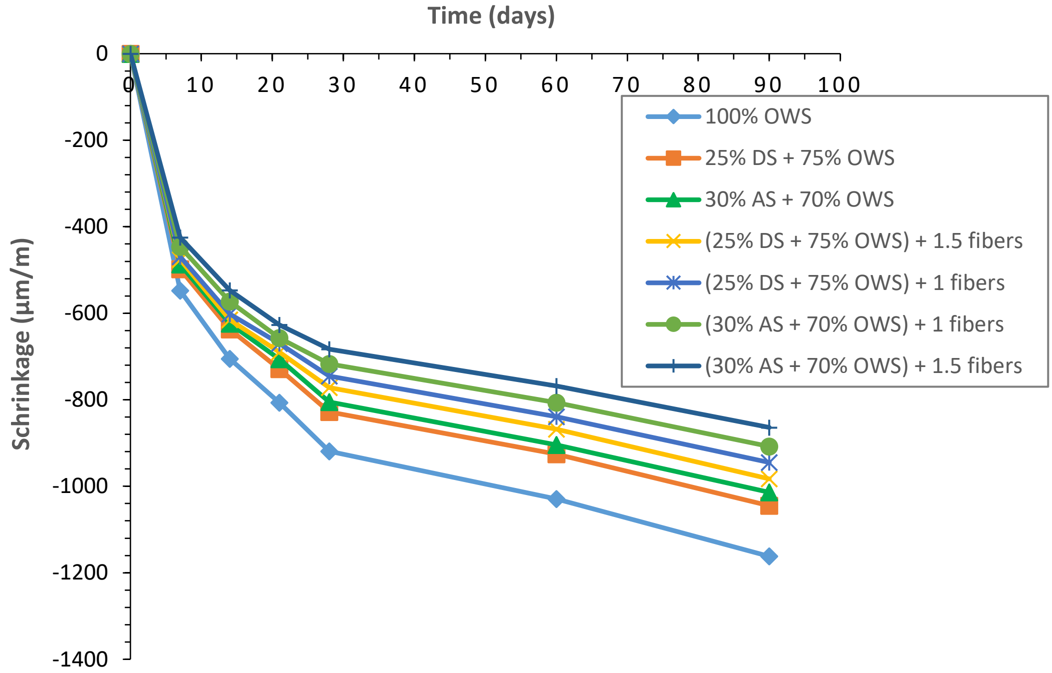

Fig. 8. Effect of polypropylene fiber on shrinkage

Figure 8 illustrates a reduction in drying shrinkage for the concrete mixtures (25% DS + 75% OWS) and (30% AS + 70% OWS) with varying fiber content (1 and 1.5 kg/m^3) compared to plain concrete made solely with 100% oil well sand, as observed at the 90-day mark. The addition of fibers contributes to a decrease in drying shrinkage within the reinforced sand concrete. For mixtures containing 1 kg/m^3 of fibers, the reduction in drying shrinkage at 90 days amounts to approximately 8.69% for (25% DS + 75% OWS) and 11.5% for (30% AS + 70% OWS). With mixtures containing 1.5 kg/m^3 of fibers, the reduction in drying shrinkage at 90 days is about 12.45% for (25% DS + 75% OWS) and 16.79% for (30% AS + 70% OWS). Notably, the incorporation of fibers at a content of 1.5 kg/m^3 exhibits a more pronounced influence than the concrete formulations with a content of 1 kg/m3. The decrease in drying shrinkage becomes more significant with an increase in fiber content. This decline in shrinkage can be attributed to the formation of fiber networks, which induce a seaming effect, resulting in a lower shrinkage rate for the fiber-reinforced concrete. Numerous studies [27-30] have reported similar findings, with the addition of fibers leading to a reduction in shrinkage. Feldman et al. [31] have highlighted that the inclusion of polypropylene fibers significantly mitigates shrinkage, aligning with previous research in this field.

5. Conclusions

In this study, the properties of sand concrete from oil wells reinforced with polypropylene fibers were investigated. Based on the experimental results obtained, the following conclusions can be drawn:

- The increase in compressive strength observed in concrete made with dune sand (25% DS + 75% OWS) and alluvial sand (30% AS + 70% OWS) compared to plain concrete made with 100% oil wells sand can be attributed to several factors. These include the reduction of oil content in the oil wells sand, as well as the difference in granular gradient and smoothness factor of each type of sand used in these concretes.
- The tensile strength of the sand concrete made with alluvial sand (30% AS + 70% OWS) is superior to that of the concrete made with dune sand (25% DS + 75% OWS). This difference in resistance can be attributed to the significantly higher specific surface area of dune sand, which leads to an increase in the volume of voids.
- The water absorption by capillarity is reduced in the concrete mixtures of 25% DS + 75% OWS and 30% AS + 70% OWS compared to plain concrete made with 100% oil wells sand. This reduction is due to the high percentage of voids and pores present in dune sand concrete, resulting from the fine and soft nature of the sand grains. In contrast, alluvial sand contains fewer voids and larger grains than dune sand.
- Shrinkage is decreased in the concrete mixtures 25% DS + 75% OWS and 30% AS + 70% OWS compared to plain concrete made with 100% oil wells sand. This decrease in shrinkage can be attributed to the difference in granular gradient and smoothness factor of each type of sand used in these concretes.
- The compressive strength of sand concrete from oil wells, when mixed with alluvial sand (30% AS + 70% OWS), improves compared to sand concrete made with dune sand (25% DS + 75% OWS) at different fiber contents (1 and 1.5 kg/m^3) after 90 days. Increasing the content of polypropylene fibers has been shown to enhance the compressive strength.
- The tensile strength of sand concrete from oil wells, when mixed with alluvial sand (30% AS + 70% OWS), improves compared to sand concrete made with dune sand (25% DS + 75% OWS)

at different fiber contents (1 and 1.5 kg/m^3) after 90 days. This increase can be attributed to the tendency of fibers to orient in the length direction of the specimens.

- The shrinkage is reduced in the concrete mixtures (25% DS + 75% OWS) and (30% AS + 70% OWS) with different fiber contents (1 and 1.5 kg/m^3) compared to plain concrete made with 100% oil wells sand after 90 days. The influence of incorporating fibers at a content of 1.5 kg/m^3 is more significant than that of concretes formulated with a content of 1 kg/m^3. The decrease in shrinkage can be explained by the formation of fiber networks, which create a seaming effect, resulting in a lower shrinkage rate for the fiber-reinforced concrete.

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