MECHANICAL AND PHYSICAL PROPERTIES OF HIGH-STRENGTH MORTAR: EXPERIMENTAL AND ANALYTICAL STUDY

PROPRIÉTÉS MÉCANIQUES ET PHYSIQUES D'UN MORTIER À HAUTE RÉSISTANCE : ÉTUDE EXPÉRIMENTALE ET ANALYTIQUE

Réception : 18/03/2023 Acceptation : 27/11/2023 Publication : 15/01/2024

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Résumé - Cet article étudie l'influence d'un superplastifiant et de l'âge d'hydratation sur les propriétés mécaniques et physiques d'un mortier à haute résistance (MHR). L'étude expérimentale consiste à faire varier progressivement le rapport eau / ciment pour évaluer les résistances à la compression et à la flexiondu MHR à différents âges d'hydratation. Le MHR a été préparé avec l'utilisation d'un superplastifiant et de sable de dune pour assurer la stabilité et la fluidité du mortier. Les résultats de l'analyse montrent qu'en augmentant le rapport eau / ciment, la résistance à la compression, la résistance à la flexion et la masse volumique du MHR diminuent. En outre, sur la base de ces résultats expérimentaux, des équations empiriques ont été développées pour prédire les propriétés mécaniques du MHR en fonction du rapport eau / ciment. Les relations entre les différents paramètres sont discutées et des lois de corrélation ont été dérivées. Enfin, la résistance à la compression du MHR à 28 jours a été vérifiée analytiquement et l'étude a mis en évidence la limitation de la loi d'Abrams, la formule de Bolomey ou l'équation Singh pour prédire de manière fiable la résistance du MHR.

Mots - clés : Mortier à haute résistance, rapport eau/ciment, propriétés mécaniques, étude analytique.

Abstract - This paper studies the influence of the superplasticizer and the hydration age on the mechanical and physical properties of a high strength mortar (HSM). The experimentalstudyconsists of varying progressively the water-to-cement ratio to assess the actual compressive and flexural strengths of HSM at different ages of hydration. The HSM has been prepared with the use of superplasticizer and dune sand to provide stability and fluidityof the mortar. The result of the analysis shows that by increasing of the water-to-cement ratio, the compressive strength, flexural strength and dry density of hardened mortar decreases. Furthermore, based upon these experimental results, empirical equations have been developed to predict the mechanical properties of the mortar as a function of the water-to-cement ratio. The relationships between the different parameters are discussed, and correlation laws have been derived. Finally, the compressive strength of HSM at 28-days was verified analytically, and the study highlights the limitation of the Abrams's law, Bolomey's formula or Singh equation to reliably predict the resistance of HSM.

Keywords : High strength mortar, Water-to-cement ratio, Mechanical properties,Analytical study.

1- Introduction

The compressive strength of cement-based materials such as concrete is influenced by several factors like water-to-cement ratio (W/C) [1], cement type [2, 3], admixtures and curing conditions [4, 5]. The W/C ratio is considered as an important formulation parameter which mainly affects the final properties of concrete. It is generally admitted that using an appropriate amount of water is mandatory to ensure large hydration of cement [6]. However, using disproportional water dosage is considered as a detrimental element to the porosity, strength and durability of concrete and mortar.

Several investigators studied the relationship between the W/C ratio and the compressive strength of concrete and mortar [8-16]. The assessment of the compressive strength of cement mortars as a function of the W/C ratio was linearly described by Bolomey's formula [17]. Even more, Abram's generalized law [18] precisely indicates that the compressive strength of concrete is inversely proportional to W/C ratio. Recently, Yeh [13] confirmed the applicability and the validation of the Abrams' law as the concrete age ranges from 3 days to one year. Consequently, numerous empirical models were developed to predict the compressive strength and/or split tensile strength of mortar as a function of the W/C ratio [10, 12]. However, a consistent prediction of the mortar compressive strength is bounded by the cement mortar workability (W/C between 0.4 and 1.2). Accordingly, the mechanical properties of the cementitious materials could be directly linked to their constitutive elements.

For hardened concrete, the increase in uniaxial load bearing capacity is accompanied by the improvement of other properties such as flexural strength, dry density and absorption [19-20]. To this end, a superplasticizer is a major ingredient of interest within the improvement of concrete strength. The introduction of a superplasticizer increases both initial and final strengths of concrete.The assessment of the compressive strength was performed by verifying the applicability of mathematical models at early and full curing age.even though the water demand is reduced by up to 30%. Furthermore, a superplasticizer involves significant cement hydration and workability for cementitious materials [21].

In the purpose to improve the concrete workability, additional solutions could be adopted, like the use of dune sand as ascertained by Al-Harthy et al. [22]. The authors of this study investigated the contribution of partial introduction of dune sand as a fine aggregate to the evolution of concrete strength and workability. The optimum replacement ratio is found to be 50 % for a strength decrease of around 25 %. Thus, the introduction of both dune sand and superplasticizer in concrete could have antagonistic effect. Consequently, the compressive strengths of mortar and concrete could be likely unpredictable or/and largely affected by strength variation. Additionally, if the compressive strength predictive models of concrete as afunction of the W/C ratio are prolific, the influence of the hydration age of HSM has received less academic study. More interestingly, the effect of low W/C ratio's and hydration age on the properties of HSM when using both dune sand and superplasticizer may receive much more interest.

This study presents an experimental investigation about the derivation of predictive compressive strength models of HSM as a function of W/C ratio and hydration age. Different preparations are tested as the W/C is ranging from 0.35 to 0.5. The introduction of both Algerian dune sand and a superplasticizer is associated with the constancy of the workability.

2- Materials and methods

2.1- Materials

An ordinary Portland cement (OPC) as a CEM I 52.5 N type was used in this study. The mineralogical compositions of the cement compounds are summarized in Table 1. In this work, the mineral composition of cement was calculated according to the equations provided by Bogue (Bogue, 1955).

Table 1: Mineralogical compositions of OPC

Table 1: Composition minéralogique de CPA

OPC	C3S	C2S	C3A	C4AF
	45.9	28.43	5.32	11.4

Natural coarse sand (CS) and an over fine sand called dune sand (DS) are used in this work. The fineness modulus, specific gravity and bulk density of the coarse sand and dune sand are summarized in Table 2. The different curves of the different grain size curves of the sand are plotted in Figure 1.

Table 2: Characteristics of the coarse and fine sands

Table 2: Caractéristiques des sables grossier et fin

Characteristics	coarsesand	Dune sand
Finenessmodulus	3.3	1.2
Specificdensity	2.57	2.65
Apparentdensity (g/cm^3)	1.55	1.60

A new generation of superplasticizer (SIKA VISCOCRETE TEMPO 12) based on an acrylic copolymer has been used in this study. This superplasticizer is considered as a super-synthetic, high range water-reducing additive, non-chlorinated, and in compliance with the EN 934-2 standard [23]. The superplasticizer density and the dry extract are 1.06 g/cm^3 and 30.2%, respectively.

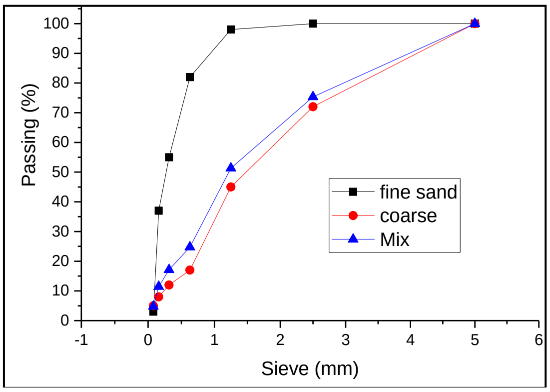

Figure 1: Granulometric curves of sands

Figure 1: Courbes granulométriques des sables

2.2- Samples preparation

Different formulations labelled E1, E2, E3 and E4 are prepared in this experiment. Each formulation corresponds to a specific value of the W/C ratio and a constant cement-to-sand ratio (C/S). The optimization of granulate phase consists to take CS (FM1 = 3.1) and mix it with DS (FM2 = 1.1) to target a specific sand gradation (FM = 2.6) by using Abrams' rule. The equation 1 and equation 2 were used to calculate coarse sand (G1) and dune sand (G2) proportions respectively. The mixing proportions of the formulations are listed in Table 3.

Table 3: proportions of mixtures

Table 3: proportions de mélanges

Mix	Cement	coarsesand	Dune sand	Water	SP
E1	450	335.5	1014.5	157.5	9
E2	450	335.5	1014.5	180.0	6.5
E3	450	335.5	1014.5	202.5	4.7
E4	450	335.5	1014.5	225.0	2.2

$$G1 = \frac{FM-FM2}{FM1-MF2} * 100 = 75\% \quad G1 = \frac{FM-FM2}{FM1-MF2} * 100 = 75\% \qquad (1)$$

$$G2 = \frac{FM1-FM}{MF1-FM2} * 100 = 25\% \quad G2 = \frac{FM1-FM}{MF1-FM2} * 100 = 25\% \qquad (2)$$

Figure 2 : High-strengthmortarspecimens

Figure 2 : Eprouvettes de mortier à haute résistance

In order to reduce the influence of additional parameters to derive compressive strength predictive models as a function of W/C ratio, the workability of the cement mortar has been limited to $20^{\pm 1}$ cm. The assessment of the mortar spreading has been performed with a flow test. The experiment consists of filling a metal mini-cone in two layers with mechanical vibration for a period of 5 seconds for each layer. The mini-cone is lifted vertically and the spreading is measured. The mini-cone should be placed on a smooth and horizontal surface, once the cone is lifted, the spread diameter of the mortar is measured in two perpendicular directions to obtain the average value.

The preparation of HSM samples was made by using a prismatic mould of 40 × 40 × 160 mm (figure 2). A table vibrator was applied to compact the filled prismatic mould. The specimens were kept in a moist cabinet for 24 hours at room temperature (T = 23 °C). The specimens were demoulded after 24 h and directly immersed in water at 20° C. The periods of conservation are 3, 7, 28 and 90 days.

2.3- Tests procedures

The flexure and compressive strength tests were carried out by an electromechanical universal testing machine with a capacity of 300 kN.The machine is equipped with Test-Suit software for programming loads and indicating the frequency of acquisition.

2.3.1- Bending strength

The bendingstrengthtest was performed according to the EN 12390-5 standard [24]. This test is conducted by referring to the three-point bending test procedure. A displacement rate of 50 N/s is applied (see figure 3-a). The flexural strength of a beam prism is calculated by the following equation:

$$f_{ct,fl} = \frac{3Fl}{2bd^2} \; f_{ct,fl} = \frac{3Fl}{2bd^2} \qquad (3)$$

Where :$_{ct,fl}$is bending strength [MPa]; F is the maximum load at the fracture point [N]; l is the length of the support [mm]; b is the width of the beam [mm]; d is the thickness of the beam [mm].

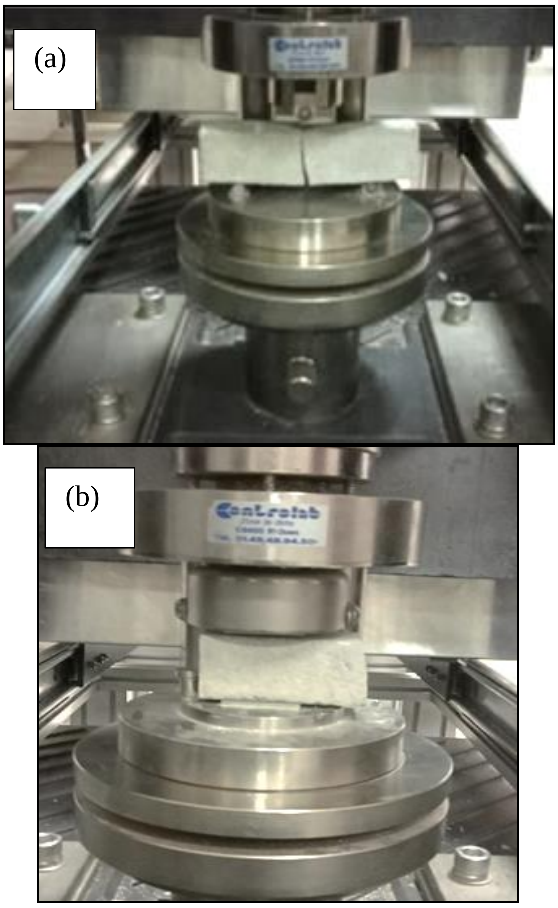

Figure 3: Mechanical strength tests: (a) bending strength and (b) compressive strength

Figure 3: Essais mécaniques : (a) résistance à la flexion et (b) résistance à la compression

2.3.2- Compressive strength

The compressive strength test of HSM samples was carried out by the procedure presented in the EN 12390-3 standard [25]. The test consists of placing a half-specimen between two loading plates and applies a uniaxial loading with a constant rate of 2400 N/s (Figure 3-b). In this study, the mean compressive strength was assessed by crushing three (03) specimens. The compressive strength of theHSM half-prism was calculated by the following formula:

$$f_c = F/A_c \qquad (4)$$

Where :$_c$ is the compressive strength [MPa]; F is the maximum load at failure [N]; A_c is the specimen cross sectional area [mm2].

2.3.3- Dry density

Dry density (ρ_d) was measured for the 28 days aged specimens. A vacuum saturation method was performed according to the test procedure described in NF P18-459 (2010) standard [26]. ρ_d is obtained :

$$\rho_d = M_{dry}/(M_{air}-M_{water})\rho_{water} \quad (5)$$

where :M_{dry} and M_{air} are the sample mass after and before drying at 50 °C, respectively. M_{water} is the mass of immersed sample in water; and ρwater is the water density at 20 °C. The test procedure has been completed by drying the samples in an oven at 50 °C for several days to get a constant mass. This step provides less change in the hydrated cement microstructure.

2.3.4- Water absorption

Water absorption test by immersion of HSM specimens was carried out according to ASTM C 642 [27]. It consists to determine the saturated mass of the samples after immersion in water at 21 °C for 48 hours. The constancy of mass is derived after two successive measurements of the mass of the surface-dried samples. The later measurement should be performed after 24 hours from the former test. The absorption results of the hardened HSM are calculated as the average of three tested specimens. The absorption capacity index (Ab) is given by :

$$A_b = \frac{M_{air}-M_{dry}}{M_{dry}} x100 \quad A_b = \frac{M_{air}-M_{dry}}{M_{dry}} x100 \quad (6)$$

3- Results and discussion

3.1 Effect of W/C ratio on high strength mortar properties

3.1.1- Compressive strength

The compressive strengths (f_c) of high strength mortar HSM were estimated at 3, 7, 28 and 90 curing days. The dependency of the compressive strength with the variation of the W/C for mortar mixes is presented in Figure 4. It could be observed that independently of the W/C ratio, the compressive strength for all specimens increases as the curing period becomes important. The evolution of the compressive strength is expected with the ongoing cement hydration and matrix forming [28]. The strength gain rate is faster at the beginning and decreases progressively with curing age [29]. For instance, at a W/C ratio equal to 0.50, the gain in fc from 3 to 28 days was 32.05% where it's limited to 7.80% from 28 to 90 days. Considering the lowest report (W/C = 0.35), the gain in f_c from 3 to 28 days was 40.40 % and the fc from 28 to 90 days was 8.95%.

The compressive strength decreases as strongly as the W/C is higher, and this trend was observed in all hydration ages. For example, an increase in W/C ratio from 0.35 causes a decrease in the 28-day compressive strength of HSM by 8.78%, 23.16% and 40.44% to respectively 0.40, 0.45 and 0.5 W/C ratios. These results are in concordance with those obtained by [30-31].

Referring to the compressive strength of mortar, the W/C ratio is more important than the other factors [32-33]. The increase in W/C means that there is more water between the solid particles which results in more voids and finally leads to a structure with more porosity [10]. Thus, a higher W/C ratio disperses the cement particles of concrete and leads to less bridging of cement hydration product (CSH) [34].

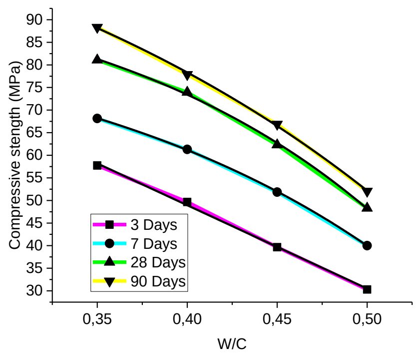

Figure 4 : Effect of W/C report on compressive strength at different hydration age

Figure 4 : Effet du rapport E/C sur la résistance à la compression à différents âges d'hydratation

The relationship between the compressive strength of HSM and theW/C ratio at anearly age (3 days) was represented by a linear function and is given by equation 7. The nonlinear curves of the evolution trends of the compressive strength at 7, 28 and 90 days were fitted with an exponential decay function (ExpDec1) and are expressed by equation 8.

$$f_{c,3days} = 122 - 124 * \frac{W}{C} \quad (7)$$

$$f_c = y0 + A * e^{-\frac{w}{c*t}} \quad (8)$$

where: y is the compressive strength, y0 is the offset, A is theamplitude, t is thetime constant, x is the W/C ratio, and 1/t is thedecay rate. The ExpDec1 equation parameters values (equation 8) for compressive strength at 7, 28 and 90 days are given in table 4.

By referring to the curing age of cementitious materials, the early age ofstrength (3 days) is very important in building. The early age strength can be used to identify some safety parameters such as the safe stripping time, the application of prestressed concrete, and the monitoring of the strength evolution, particularly under harsh weather conditions, etc. This valuable indication is generally used to estimate the quality of material used in structural elements and its durability [35]. The compressive strength of cement-based materials at a curing age of 28days is one of the first and foremost properties for structural design in civil engineering [36]. Enamur et al. [7] confirmed that the 28-day compressive strength of cement (CEM II) with different W/C (0.275 to 0.80) varies non-linearly with a decreasing trend in the compressive strength as the W/C ratio increases.

Table 4 : Equation parameters values of compressive strength

Tableau 4 : Valeurs des paramètres de l'équation de la résistance à la compression

age	y0	A	T	Regression (R^2)
7 days	91.16	- 3.53	- 0.18	0.999
28 days	103.90	- 2.52	- 0.16	0.997
90 days	135.90	- 12.87	- 0.26	0.998

3.1.2- Flexural strength

Figure 5-a shows the relationship between the flexural strength of the HSM and theW/C ratio at different hydration times. It could be deduced from that figure that the increase in water content induced a decrease in the HSM flexural strength. For instance, an increase in the W/C ratio from 0.35 (E1) to 0.5 (E4) causes a flexural strength decrease of 23.05% at 28 days of curing age.

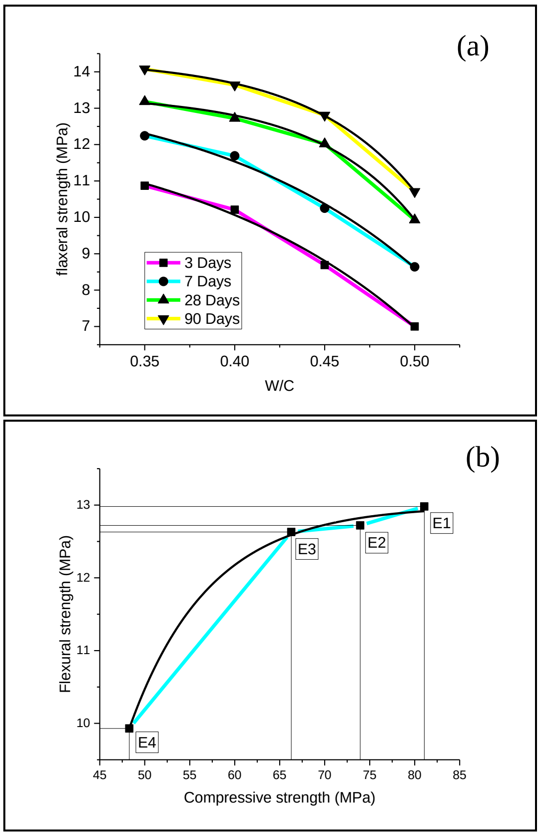

Figure 5: Flexural strength: (a) Effect of W/C report at different ages of hydration and (b) relationship between flexural strength and compressive strengths at 28 days

Figure 5: Résistance à la flexion : (a) effet du rapport E/C à différents âges d'hydratation et (b) relation entre les résistances à la flexion et la résistance à la compression à 28 jours

Regression analysis has been applied to the flexural strength (f_{cf}) curves of HSM at all ages of hydration [12]. It is important to mention that the relationship between flexural strength and W/C could also be represented by a nonlinear curve fitted with an exponential decay function (as shown for the HSM compressive strengths in Eq. 8). The parameters of the functions for flexural strengths at curing ages of 3, 7, 28 and 90 days are reported in Table 5.

Table 5: Equations parameters values of flexural strength at different hydration age

Tableau 5: Valeurs des paramètres del'équation de la résistance à la flexion à différents âges d'hydratation

age	y0	A	T	Regression (R^2)
3 days	12.84	- 0.13	- 0.13	0.986
7 days	13.82	- 0.08	- 0.12	0.983
28 days	13.36	- 4.03	- 0.05	0.994
90 days	14.34	- 7.61	- 0.06	0.998

At the curing age of 28 days, the flexural strength can be expressed as a function of compressive strength as follows (Eq. 9):

$$f_{cf,28d} = 12{,}99 - 710 * e^{\frac{-f_{c,28d}}{8{,}86}} \qquad (9)$$

It can be deduced that there is a positive correlation between the compressive strength and the flexural strength. For instance, the f_{cf} of HSM increases from 9.93 to 12.98 MPa when the f_c increased from 48.28 to 81.07 MPa.

3.1.3- Dry density

The evolution of dry density as a function of the W/C ratio is reported in figure 6-a. A marked influence of the W/C ratio on the variation of the dry density of the HSM is noticed. Taking E1 as a reference, dry density was 1.47% lower in E2, 2.63% lower in E3 and 7.46% lower in E4.

An empirical expression (see Eq. 10) has been derived to predict the dry density of the HSM for various W/C ratios at 28 days of hydration age. The nonlinear curves were fitted with an exponential decay function with a coefficient of regression R^2 higher than 0.968.

$$\rho_{d,28d} = 2323 - 0{,}024 * e^{\frac{-W/C}{-0{,}056}} \qquad (10)$$

Figure 6-b presents a linear relationship between the dry density and compressive strength of mortar mixes [37]. It can be seen that there is a positive correlation between the dry density and the compressive strength. The HSM density can be predicted for a particular compressive strength as follows:

$$\rho_{d,28d} = 1893{,}89 + 5{,}28 * f_{c,28d} \qquad (11)$$

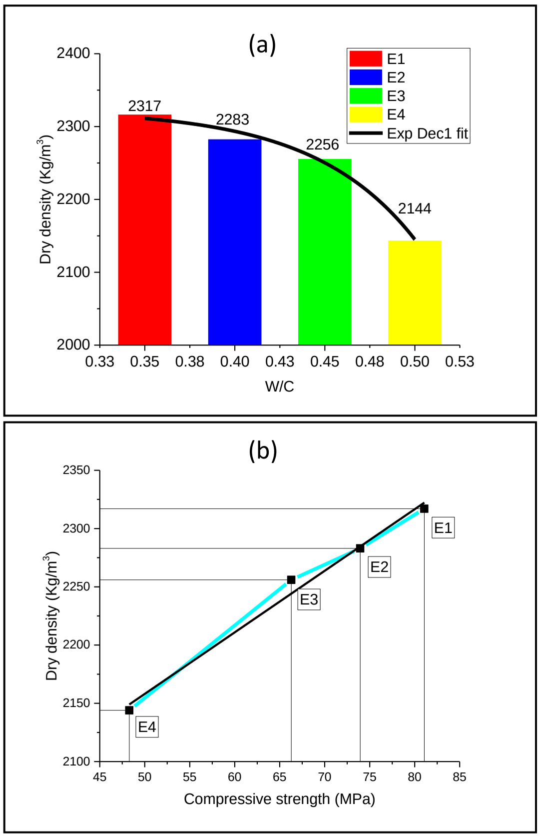

Figure 6 : Dry density: (a) effect W/C ratio and (b) Relationship between dry density and compressive strength

Figure 6 : Masse volumique : (a) effet du rapport E/C et (b) relation entre la masse volumique et la résistance à la compression

An increase in dry density is accompanied by an increase in compressive strength. In fact, the ρ_d of HSM increased from 2144 to 2317 kg/m^3 when the f_c went from 48.28 to 81.07 MPa. This result may be related to the pore distribution and the dry density. In fact, small and large pores impose defects, causing low compressive strengths [38].

3.1.4- Water absorption

The evolution of water absorption (Ab) as a function of W/C is reported in figure 7-a. It can be deduced from that figure 7-a that the variation in the W/C ratio has a significant effect on the water absorption capacity of HSM.

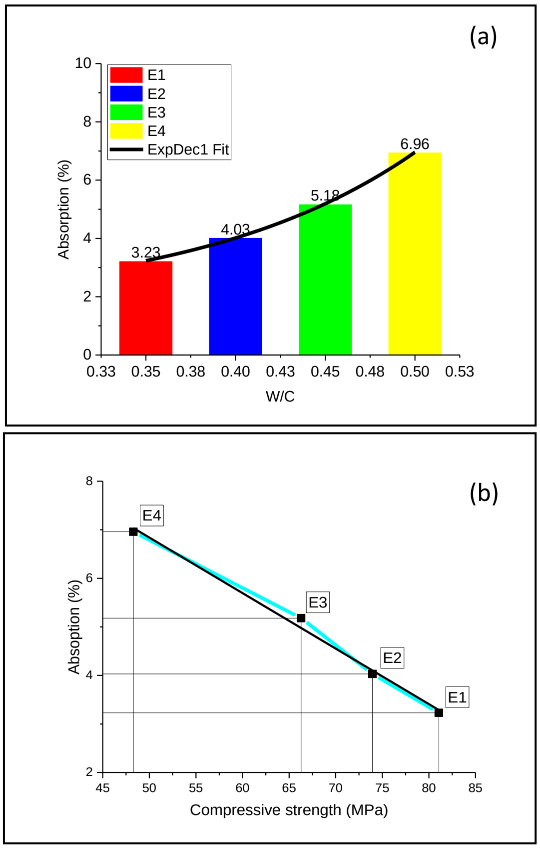

Figure 7: Absorption capacity: (a) effect of W/C ratio and (b) relationship between absorption capacity and com-pressive strength

Figure 7: Capacité d'absorption : (a) effet du rapport E/C et (b) relation entre la capacité d'absorption et la résistance à la compression

The relationship between absorption and W/C at 28-hydration age was represented by nonlinear curvesfitted with an exponential growth function (Eq. 12), the regression coefficient (R^2) is 0.999.

$$Ab_{28d} = 1.689 + 0,088 * e^{\frac{-\frac{W}{C}}{-0,122}} \qquad (12)$$

Figure 7-b shows the relationship between the compressive strength and water absorption of HSM at 28 days. It can be seen that there is an inversely proportional correlation: the water absorption decreases with the increase in compressive strength. Similar conclusions were drawn by Zhang and Zong [39] et Warzer et al. [40]. The relationship between f_c and water absorption of HSM is given as follows:

$$Abs_{28d} = 12.55 - 0.11 * f_c \qquad (13)$$

3.2- Effect of W/C ratio on compressive strength-analytical study

In this section, a likely extension of the applicability of concrete mathematical modelstothe assessment ofthe compressive strength of HSM is discussed. From the experiment, the fc values of the HSM at 28 hydration days were found to range from 41 MPa to 68 MPa (Sample in cylindrical form), and the dry density ranges from 2100 to 2400 kg/m^3. In a comparison with an ordinary concrete, as the dry density ranges from 2000 kg/m^3 to 2600 kg/m^3, the compressive strength limits are 30 and 50 MPa [41]. The most adopted mathematical expression that describes the relationship between the compressive strength of concrete and its W/C ratio is Abrams' formula, given as follows [8]:

$$f_c = \frac{K_1}{K_2^{W/C}} \qquad (14)$$

Where fc is the compressive strength (MPa), W/C represents the water-to-cement ratio of the mix originally taken by volume, and K1 and K2 are parameters linked to cement type, cement content, curing condition, etc. [36]. In order to use that expression (eq.14) for the assessment of the compressive strength of theHSM, it is important to mention some specific parameters of the HSM. Furthermore, the validity of Abrams' formula is pinpointed as the W/C ratios are between 0.3 and 1.20 [42]. More precisely, the use of the generalized Abrams' law for mortars should respect a minimum W/C ratio of 0.40 [10].

Through those specific indications, both coefficients K1 and K2 are identified. The compressive strength of HSM as a function of theW/C ratio is given as follows:

$$f_{c,28d} = \frac{96.55}{8.2^{W/C}} \qquad (15)$$

Concerning the Bolomey's law (Eq.9) [43], it has been used to link the W/C ratio to thecompressive strengths of concrete [44]. The relationship between compressive strength and W/C ratio, according to Bolomey's formula, is described by:

$$f_c = A * \left(\frac{1}{\frac{W}{C}}\right) + B \qquad (16)$$

Where Aand B are parameters linked to concrete components and curing conditions. According to Singh et al. [12], for the 28-days compressive strength and W/C ratio relationship of cement mortar for a1:3 C/S ratio, the A and B parameters were estimated at 6.39 and 11.16.

However, the Singh formula forgeneralized correlation has been derived to predict the 28-day compressive strength of cement mortar prepared with a W/C ratio ranging from 0.3 to 1.2 and without using superplasticizer [12]. The relationship between the 28-day compressive strength and W/C ratio of cement mortar for a1:3 cement sand ratio is given by Equation 17 using regression analysis.

$$f_{c,28d} = 17.46 * (W/C)^{-0.46} \qquad (17)$$

Table 6 shows the percentage gap of analytical compressive strength at 28-days hydration considering the experimental value equivalent to 100%. The factor 0.84 has been used to get the relevant cylinder strength for the cube strength from theexperiment (Singh et al [12]). Thus, the estimated experimental compressive strengths of cylindrical specimens were 68, 62, 52 and 41 MPa for E1, E2, E3 and E4 respectively.

Table 6 : Compressive strengths of cement mortar specimens from our experimental results and existed models

Tableau 6 : Résistances à la compression : résultats expérimentaux et résultats obtenus à partir des modèles existants

$f_{c,28d}$ [%]	Reference	Water-to-cement ratio			
		0.40	0.45	0.50	0.35
$f_{c,28d}$(Eq.8)	Authors	100	100	100	100
$f_{c,28d}$ (Eq.15)	[8, 9]	-32	-33	-28	-17
$f_{c,28d}$(Eq.16)	[43, 44, 12]	-57	-56	-52	-41
$f_{c,28d}$(Eq.17)	[12]	-52	-61	-64	-65

The compressive strength of HSM at 28-days using the Abrams's law (Eq.15), Bolomey's formula (Eq.16) and Singh equation (Eq.17) was carried out analytically, and the results are shown in table 6. The differences between the experimental results and theempirical equations given in Eq.15, Eq.16 and Eq.17 were very important. From table 8, for a W/C ratio of 0.35, 0.40, 0.45, and 0.50, the relative deviations between the experimental results and theanalytical results using Abrams' law were -17%, -28%, -33% and -32%. The maximum relative deviation between the analytical results and measured results was obtained using Singh's model (Singh et al. [12]). In addition, lower was the W/C ratio higher was the compressive strength deviation.

To confirm the potentiality of using both an optimal amount of superplasticizer and dune sand, figure 8-a shows the regression curve obtained from a point cloud. These points represent the compressive strength of concrete/mortar as a function of the W/C ratio from several scientific works dealing with the topic treated in this paper (figure 8-a). It can be clearly seen that for mortar with a low W/C ratio (0.30 to 0.50), the addition of optimal amount of superplasticizer it is very important to have a good workability.

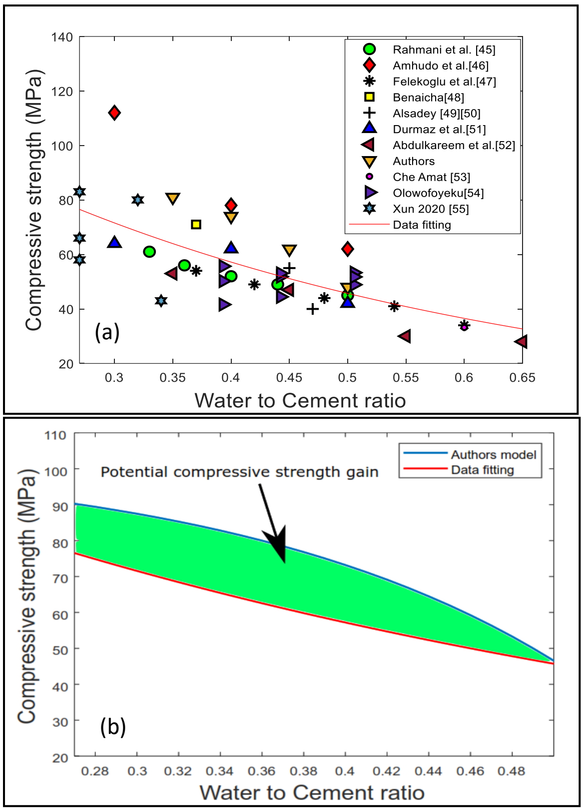

Figure 8: Compressive strength gains by using superplasticizer and dune sand (a) compressive strength trend of concrete/mortar vs. W/C ratio (b) Potential compressive strength gain.

Figure 8: Gains de résistance à la compression grâce à l'utilisation du superplastifiant et du sable des dunes : -(a) Tendance de la résistance à la compression du béton/mortier par rapport au rapport E/C ;- (b) Gain potentiel de résistance à la compression.

In the other hand, the mechanical strength values obtained in the present experimental work are much higher than those achieved in previous research. In this perspective, figure 9-b shows the evolution trend of the compressive strength of concrete/mortar as a function of thelow W/C ratio derived from published papers and the model derived within this work.

It could be noticed that an appropriate selection of mortar compounds reveals that a potential compressive strength gain could be achieved. Furthermore, the potential gain is strongly pinpointed as the W/C ratio is around 0.35. This result unveils a concise indication that the antagonistic effect originated from using an optimal amount of superplasticizer and Algerian dune sand has been successfully controlled.

4 - Conclusion

This paper reports on a recent experimental investigation into the potential use of dune sand and superplasticizer (SP) in the preparation of HSM. The experiment consists of the comparison between different mortar formulations, by varying the W/C ratio and hydration age to assess their mechanical and physical properties. The results clearly represent the dependence of compressive strength on W/C ratio. In fact, it has been illustrated that there is adecrease in the compressive strength with the increase of the W/C ratio at all hydration times. The same trend was deduced about the flexural strength concerning the effect of theW/C ratio. There were correlations between f_c and f_{cf}, with density and with absorption. The relationship between f_c and $f_{cf}$was presented with a nonlinear curve, where the linear curve was used to present the relationship between f_c and the dry density and water absorption. The W/C ratio to compressive strength regression analysis, using exponential decay functions, illustrates a better simulation for the prediction of the 28-day compressive strength of HSM in thepresence of SP. The limitations of the use of Abram's, Singh's and Bolomey's laws to predict the compressive strength of mortar at 28 days of hydration age have been addressed. The paper also points out the potential compressive strength gain that can be reached by selecting appropriate proportions of SP and dune sand.

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