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Experimental Modeling of the Compressive Behavior and Capillary Absorption of Mortars Based on Tuff of MEKLA

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Abstract: Mineral additions are currently part of the most recent developments in the field of Civil Engineering, as their use improves the mechanical properties and durability of cementitious materials. On the other hand, their uses aim to reduce the consumption of cement (reduction of CO2), contributing in a simple and economical way to solving problems related to the environment. This study aims to study the mechanical behavior of mortars based on tuff of MEKLA as a substitute for cement, using the following percentages: 5, 10, 15, 20, 25 and 30%. All the compositions were manufactured with a water to cement W/C= 0.5 ratio. The compressive strengths were determined at different ages: 7, 14, 28 and 90 days. We also carried out capillary absorption tests on the different samples studied. The results showed that all 28-day-old tuff samples had strengths greater than 30 MPa and those 90 days-old presented strengths greater than 40 MPa. Regarding the capillary absorption tests, mortars with 5% and 10% tuff aged 28 days showed lower capillary absorption coefficients than the control mortar.

Keywords: Mortar, Tuff of MEKLA, Compressive strength, Capillary absorption.

Introduction

In the field of construction, the search for new materials with low environmental impact is developed for energy saving and CO2 reduction. Indeed, some studies have shown that the manufacture of Portland cement generates a lot of CO2 and consumes a lot of energy (Kerbouche et al., 2009).

The use of hydraulic binders to replace cement is necessary to limit CO2 emissions and reduce energy consumption in order to ensure sustainable development in the cement industry. However, the partial substitution of a certain quantity of cement by one or more mineral additions when available can be very advantageous, not only from an economic point of view, but also from a strength and durability point of view (Mebrouki, 2003).

Mineral additions affect the kinetics of the hydration reaction, improve the physical characteristics of mortars and concretes in the fresh state and contribute positively to the mechanical resistance of mortars and concretes in the hardened state, due to their chemical composition, their reactivity and their particle size (Bessa et al., 2003; Turkmenoglu et al., 2002). The valorization of Tuff in Algeria in the field of civil engineering has been studied by several researchers (Colombier, 1988). This work consists in studying the mechanical behavior and durability of mortars based on Tuff of MEKLA as a substitute for cement. Four maturations were used for the compression tests and two for the capillary absorption tests.

Experimental Method

Materials

In this study, we used a CPJ CEM II/B 42.5 type cement from LAFARGE in Algiers, its specific surface area is 3555 cm^2/g. A sand with a grain size between 0 and 3mm. A quarry tuff from MEKLA, its absolute density is 2.53 g/cm3. The chemical composition of cement and tuff are shown in Table 1.

Table 1. Chemical composition of cement and tuff

Constituents (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5	TiO_2	PAF
Cement	20,71	5,45	3,63	60,4	2,15	2,37	0,65	0,23	0,10	0,23	4,28
Tuff	70,78	13,50	3,83	0,84	0,27	-	5,49	2,58	0,28	0,12	1,60

After the mess, the test pieces were made and kept in the water. We made two series of test tubes, a series is intended for compression tests at 7, 14, 28 and 90 days of maturation and the other series For the hair absorption test. Each series, was studied for seven values of adding tuf (0, 5, 10, 15, 20, 25, 30) % in substitution of the cement. The compression trials were carried out on cubes $(4 \times 4 \times 4)\ cm^3$ with the standard (NF P 18 - 406). Regarding, the hair absorption tests, they are carried out on cubic $(5 \times 5 \times 5)\ cm^3$. For this test, we measure the capillary absorption coefficient as a function of time on the following deadlines: 15 min, 30 min, 1h, 2 h, 4 h., 8 h and 24 hours. The test must be completed after 24 hours. The capillary absorption coefficient is defined by the following relation :

$$C_a = \frac{M_x - M_0}{A}\ (kg/m^2)$$

With :
M_x : The mass of the test tube has a given deadline (kg);
M_0 : The initial mass of the test tube (kg);
A : The sectors section (m^2).

Results

Compressive Strength

Table (2) presents the results of the compressive strength of the various mortars studied by calculating the average of three trials.

Table 2. Compressive strength of mortars studied at different ages.

	Compressive strength (MPa)			
	7 Days	14 Days	28 Days	90 Days
M0T	32,4	46,1	45,7	59,1
M5T	29,2	38,4	46,4	54,0
M10T	30,1	32,7	43,4	51,4
M15T	30,1	32,1	39,3	44,7
M20T	26,4	26,8	35,1	43,9
M25T	23,2	28,7	37,7	42,2
M30T	22,4	28,1	31,3	41,0

The compressive strength of the different mortars studied are presented in the form of a histogram and shown in figures (1), (2), (3), (4) and (5).

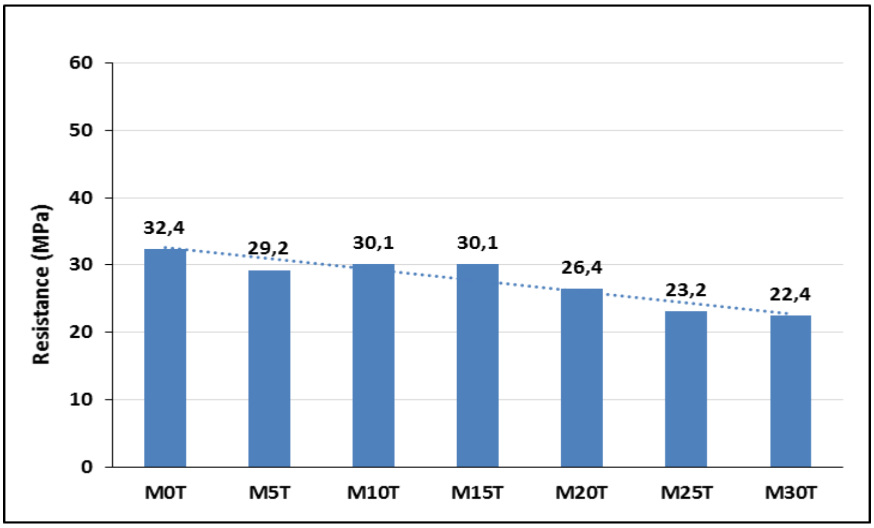

Figure 1. Compressive strength of mortars at 7 days of age.

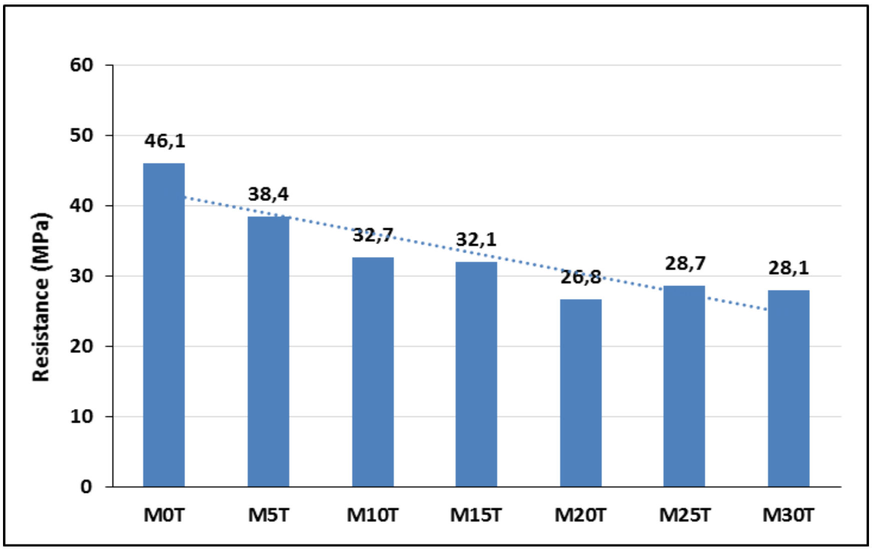

Figure 2. Compressive strength of mortars at 14 days of age.

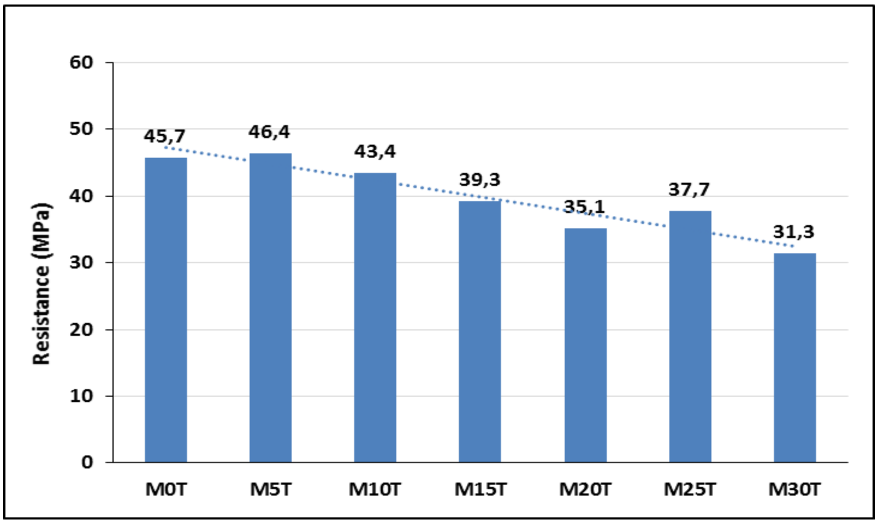

Figure 3. Compressive strength of mortars at 28 days of age.

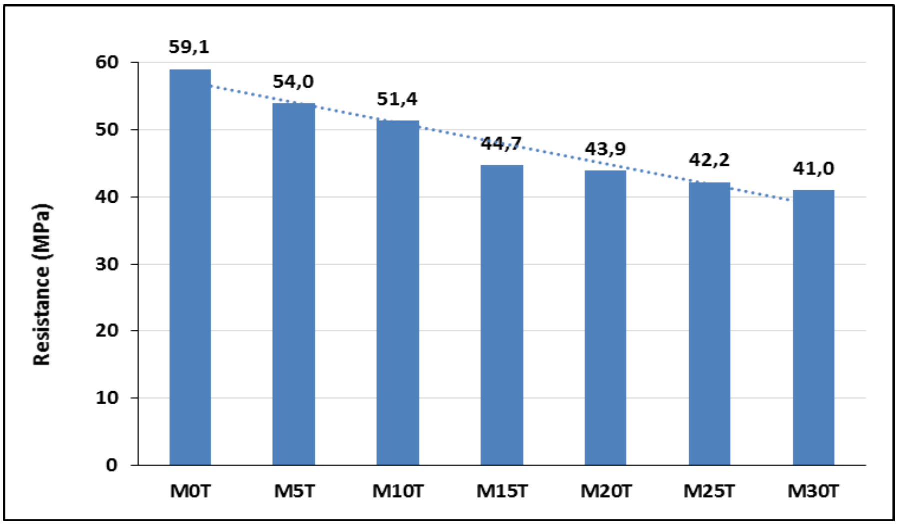

Figure 4. Compressive strength of mortars at 90 days of age.

For all ages studied, mortars with 30% of tuff presented a reduction in compressive strength of 31% compared to the control mortar. While mortars with 5% of tuff presented a decrease in resistance from 1% at 28 days and 8% at 90 days.

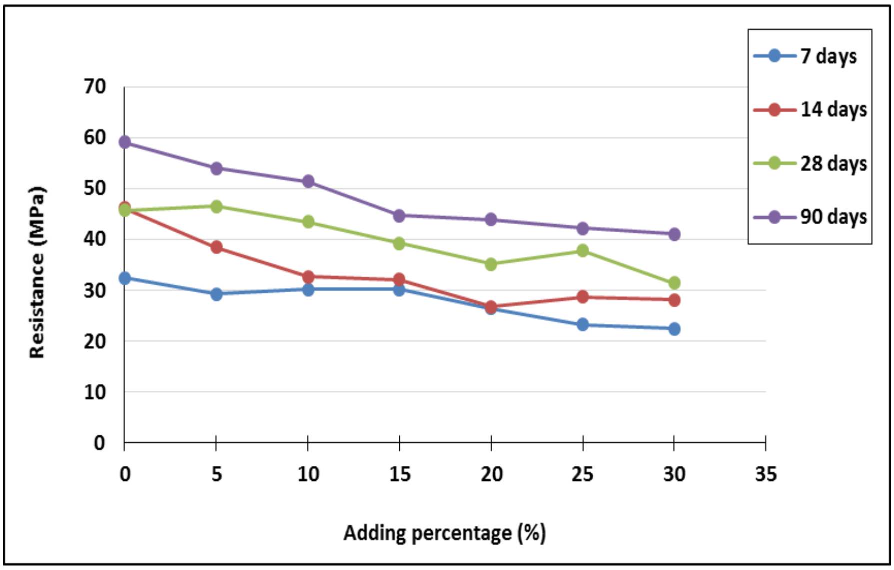

Figure 5. The compressive strength evolution as a function of the adding percentage.

At 28 days, the compressive strength of all mortars studied exceed 31.3 MPa. For 90 days, the compressive strength of all mortars exceed 41 MPa. For a substitution of 5 to 15% of tuff, the mortars presented a good compressive strength.

3.2 Capillary Absorption

The capillary absorption tests were carried out on the test tubes after 14 and 28 days of hardening. We have represented the evolution of the capillary absorption coefficient as a function of time in the figures (6) and (7).

We note that at 14 days of age, the mortars based on tuff, presented a capillary absorption coefficient greater than that of the control mortar (M0T). On the other hand at 28 days of age, the mortars with 5% (M5T) and 10% (M10T) based on tuff presented a capillary absorption coefficient lower than that of the control mortar which explains that the mortars had a less porous structure So a less important connectivity of pores. For the other tuff percentages, there is an increase in the capillary absorption coefficient, therefore a more porous structure.

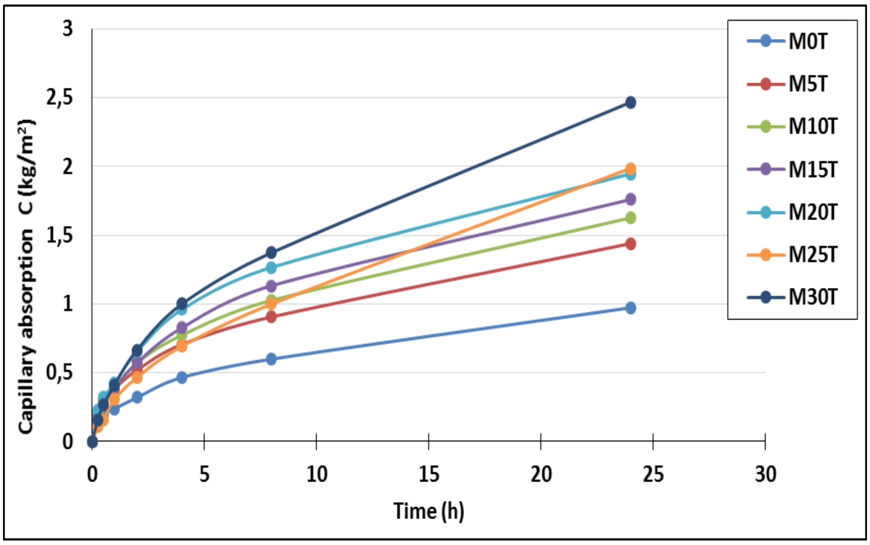

Figure 6. Evolution of the capillary absorption coefficient at 14 days of age.

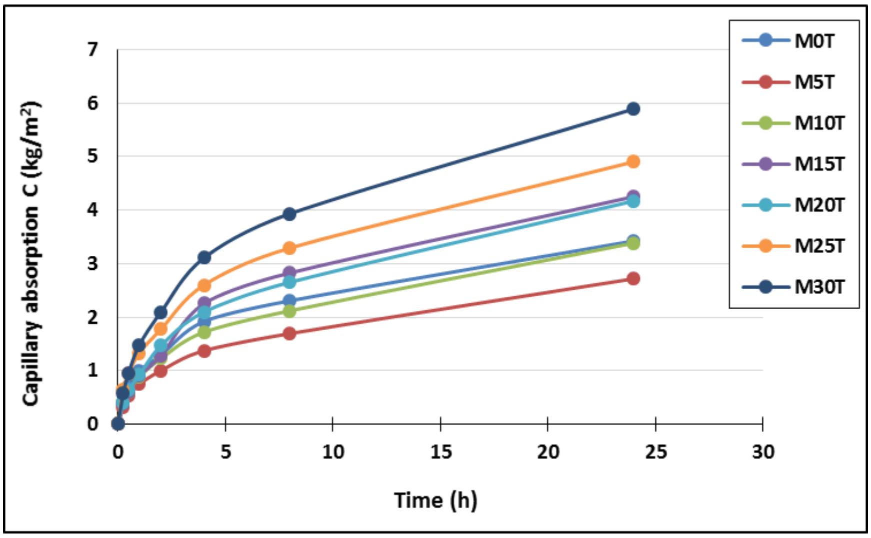

Figure 7. Evolution of the capillary absorption coefficient at 28 days of age.

Conclusion

The results obtained in this study allowed us to achieve the following conclusions:

- The mortars with 30% of tuff presented a decrease in compressive strength of 31% compared to the control mortar. While mortars with 5% tuff presented a decrease in resistance from 1% to 28 days and 8% to 90 days. At 28 days, the resistance of all the mortars studied exceeds 31.3 MPa. For 90 days, the resistances of all mortars exceed 41 MPa.

- At 28 days old, mortars with 5% (M5T) and 10% (M10T) of tuff presented a capillary absorption coefficient lower than that of the control mortar which explains that the mortars had a less porous structure therefore a connection less important pores. For the other tuff percentages, there is an increase in the capillary absorption coefficient, therefore a more porous structure.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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