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Effect of Curing Temperature on Mortar Based on Sustainable Concrete Material's and Poly-Carboxylate Superplasticizer

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Abstract: Nowadays, technologies in construction field have offered several kinds of chemical admixtures, which offer different behaviors at the fresh state of the batch and by consequence, it is resulted with different mechanical behaviors at the solid state of the mix. This study focused on the behavior of a new kind of admixture at fresh and solid states. Currently, the concrete material has become a very expensive material because the high price mostly of aggregates, representing the three quarters of the concrete components. By consequence, it costs money and on the other hand, it produces a lot of wastes. The main aspect which guides this study is to make a kind of concrete based mainly on local material and sustainable concrete material (SCM or waste material), which is one very abundant material in quality and quantity, under the current tendency the results obtained in this study summarize up the importance of the temperature during the development of the mechanical characteristics of mortar, mainly on compressive strength at age of 28 days. This is in the case of the addition of limestone crushed additive by percentage of substitution.

Key words: Mortar, crushed limestone additive, substitution, admixture, temperature.

1. Introduction

The results of compression tests according to the temperature show clearly the increase of the compressive strength (around 20%), compared with the value obtain for specimen saturated with water. The increase on resistance of cement matrix can be attributed to two phenomena: The first one is the effect of capillary suction, it causes a compression of the solid skeleton, which leads to a "pre-stress" of the material becomes more resistant, this phenomenon is also found in rocks, in this case even without water gradient there is increases in the compressive strength. The second phenomenon is related to water gradients created in the specimen during the desiccation process: the edges of the specimen shrink in the direction of the heart of this one, causing a micro-cracking and also a confinement of the heart of the specimen [1-3].

However, the experimental results on the effect of the temperature are very variables, the initial fast rate of hydration at curing temperature causes non-uniform distribution of the hydration products inside the paste. In this case, the products do not have sufficient time to precipitate uniformly in interstitial space (like the case at low temperature) [4].

The desired objective of this study is the use of local materials mainly crushed limestone SCM's (sustainable concrete material's), it is important to notice that some researchers do not like to use the name waste they use recycled products or eco-materiel but now the common name is SCM's. Our SCM's, is the result of crushed manufactory, contain 40% of fine limestone, the other part is composed by different size of aggregates. Based on this context, this research is based on the use of the local material existing in very large quantity and available locally, the main aspect are economic and environmental parts, using local materials will be very important in the field of

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construction to decrease the price of concrete.

The main aspects which guide this study is the current tendency to make a concrete based only on one very abundant material in quality and quantity which is the sand. The results obtained in this study summarize up the importance of the chemical admixture mainly PC (poly-carboxylate) superplasticizer and there influence on the behavior of batch, than finally the mechanical behavior of concrete, also this study summarize up the importance of curing temperature during the development of the mechanical characteristics of concrete mainly compressive strength at age of 28 days, the capillarity suction and the diffusion coefficient variation.

2. Experimental Investigation

2.1 Cement

Cement used in this study is the CEM II/A 42.5, its chemical composition and the proportions of principal components are summarizes in Tables 1 and 2. It is made up primarily of clinker 81%, of high quality of limestone 8%, pozzolana 6% and gypsum (regulating of batch) 5% (Tables 1 and 2).

2.2 Admixture

The chemical admixture used in this study is PC superplasticizer based on modified poly-carboxylate (Table 3).

Table 1 Chemical analyze of cement.

Chemical composition	Proportions
C3S	60
C2S	14
C3A	6
C4AF	10

Table 2 Clinker composition.

Clinker composition	Proportions
Fire loss	5.9
Insoluble	1.1
SO3	2.1
MgO	1.7
Chloride	0.01
Alkalis'	0.40

Table 3 Admixture characteristics.

Properties	Values
Density	1.17 ± 0.015
pH	7.5 ± 1.5
Content of ions chlorides	< 0.1%
Content of Na_2O-eq	≤ 4%
Dry extract	35 ± 1.5%

2.3 Sand

Bechar City (south west of Algeria) benefit of a large number of building materials, and the main choice is the nearly site, the used sand is the principal existing sand in this region which has good characteristics. The SCM's used result from the crushed limestone in the manufactories of crushed aggregate, these SCM's contains about 40% of fine limestone used in the research as addition, in this study, it is used as corrector sand and achieve the principal aim of this study (Table 4 and Fig. 1).

2.4 Mixes

In this study, the aims desired by this study are the parameter's which may change the behavior of the mixture and studying the influence of percentage of SCM's substitution and superplasticizer on the

Table 4 Physical characteristics.

	Bulk density	Specific gravity	Fineness modulus	SE*	MBt**	Nature
Sand	2.63	1.72	2.55	63.1	1.33	Limestone
SCM's	2.67	1.42	1.52	33.3	0.50	

*Sand equivalent test; **the methylene bleu test.

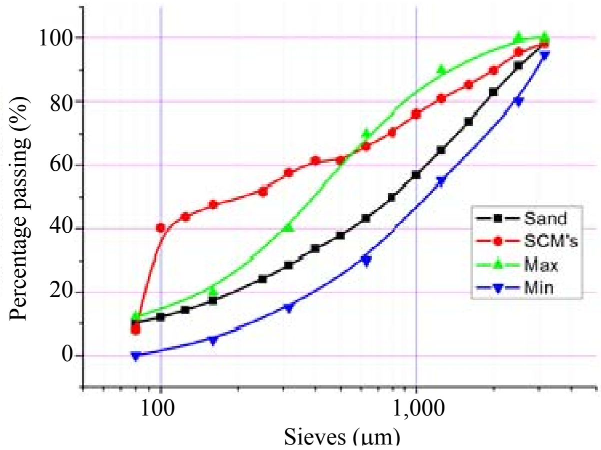

Fig. 1 Granular distribution of sand and SCM's.

behavior of concrete at normal and curing temperature.

Based on substitution of crushed sand from SCM's, we can change some important characteristic as the finesses modules, the specific surface. To maintain the same characteristics of the different mixture, we base on the maintained of the normal workability. In mixture used in this study the quantity of sand (1,350 kg/m^3) represent three times of the weight of the cement (450 kg/m^3) (Table 5).

2.5 Conservation Mode

We chose two cases of conservation, the first one is conservation in saturated milieu at 25 °C and sealed milieu at curing temperature about 55 °C (Fig. 2). We note that the choose of this different case of conservation is based on the aim to studies the influence of the type conservation on the mechanical behavior of concrete.

After 24 hours of the introduction into the mold, specimens will be preserved in different thermal degrees. We note that to eliminate the influence of the formulation, work up and the temperate setting influence, specimens conserved in different temperatures are from the same batch [1].

To avoid any change in the characteristics of mortar by thermal action, specimens are protected by sticker aluminum foil usually used in this type of test [2]. In this regard, it is underlined that the packaging of specimens ensures the internal humid stability of the moisture, even if this stability is guaranteed only within the packing.

3. Results and Discussion

In several experiments, the temperature released during the hydration of cement paste, enters into an exchange relationship with the ambient conditions, the hydration becomes fast in a curing temperature, slow in a low temperature [3, 5].

Table 5 Characteristics of different mixtures.

	W/C	Slump
Sand	0.5	32
10% substitution	0.5	30
20% substitution	0.54	37
30% substitution	0.54	33

Fig. 2 Conservation of specimens at curing temperature (55 °C).

3.1 The Variation of the Workability as Function on the Substitution

In this part of the research, we focus on the influence of the substitution on the workability of the mortar batch, and the parameters which can follow the changing of the formulation (substitution) (EN 413-2 Masonry cement—Part 2: Test methods: the workability is measured by the plunger penetration as prescript in the standard).

In Fig. 3, we notice that arriving to 20% of substitution, we are obliges to raise up the W/C ratio to maintain the normal workability such as found by several research [4]. In this case, it is remarkable that the workability of the mortar decrease by the decreasing of the finesses module's because of the rising up of specific surface. Moreover, for high finesses modulus suggest much coarse sand grains which decrease the specific surface, but for low finesses modulus suggest much fine sand element or grains which rise up the specific surface, which significantly rise up the water demand.

3.2 The Influence of Conservation Mode on the Compressive Strength

The thermal activation used in the field of civil engineering to activate the hydration of the concrete and achieve appreciable resistance of concrete at early age. It is considered that the curing temperature promotes hydration, while the temperature is a result of the hydration phenomenon [5]. In this study, after 28 days of conservation in sealed milieu at curing temperature around 55 ^{o}C, the specimen are tested on the compressive strength at age of 28 days (EN 196-1 test method of cement: determination of compressive strength test).

The use of admixtures or superplasticizers (high range water reducer) has become a quite common practice. The main purpose of using superplasticizers is to produce flowing concrete with very high slump. In our case of study and like it is shown in Fig. 4, it is very clear that the limestone substitution can change the behavior of mortar even in saturated milieu and at curing temperature [4, 6].

In Fig. 5, it is clear to notice that the variation function of compressive strength as function of percentage of substitution take the form of curve, even in sealed milieu at curing temperature or in saturated milieu.

By definition, the superplasticizers are chemical linear products, reducer of water demand by dispersion. The development of several kind of

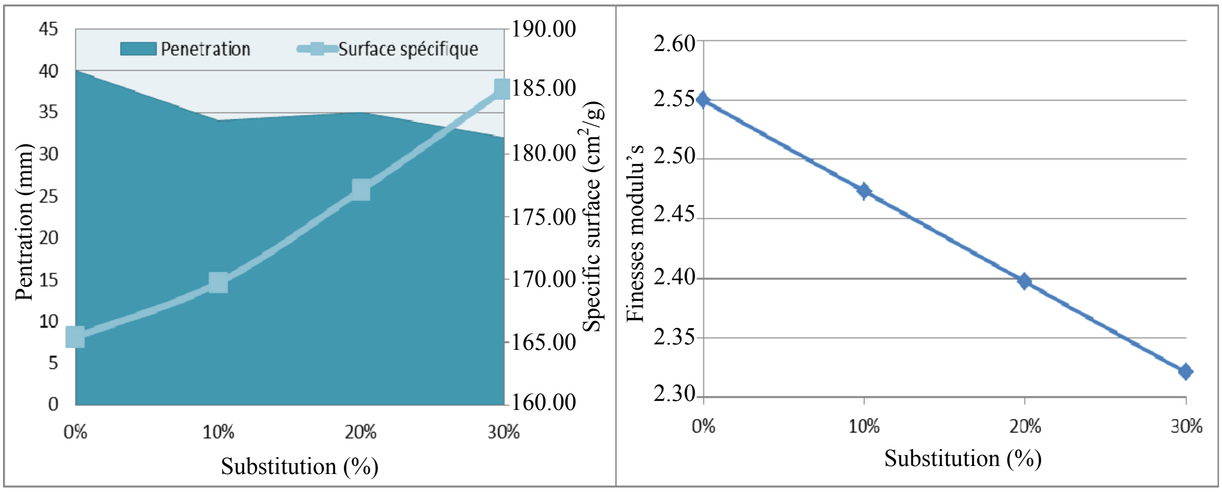

Fig. 3 The variation of workability function as substitution mixed with substitution.

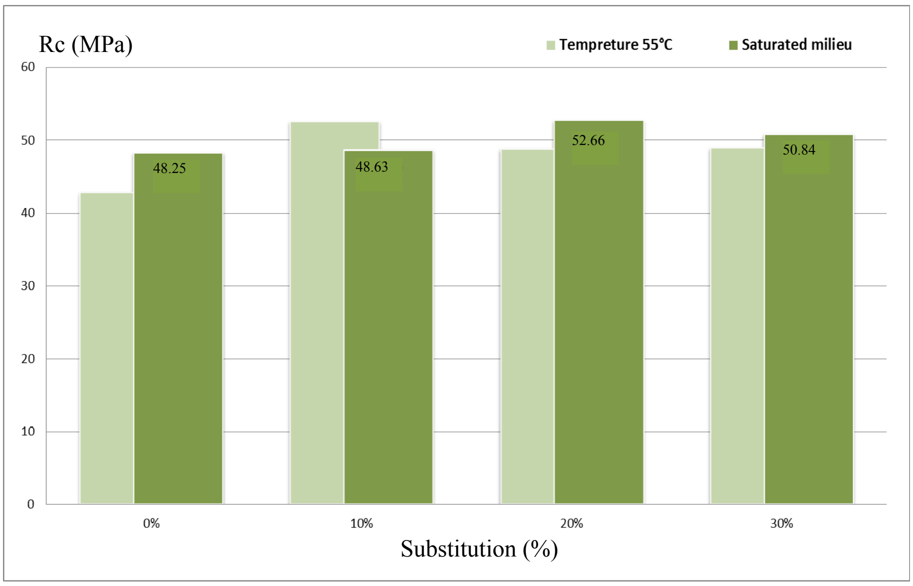

Fig. 4 Representation of the compressive strength for different mixture of mortar.

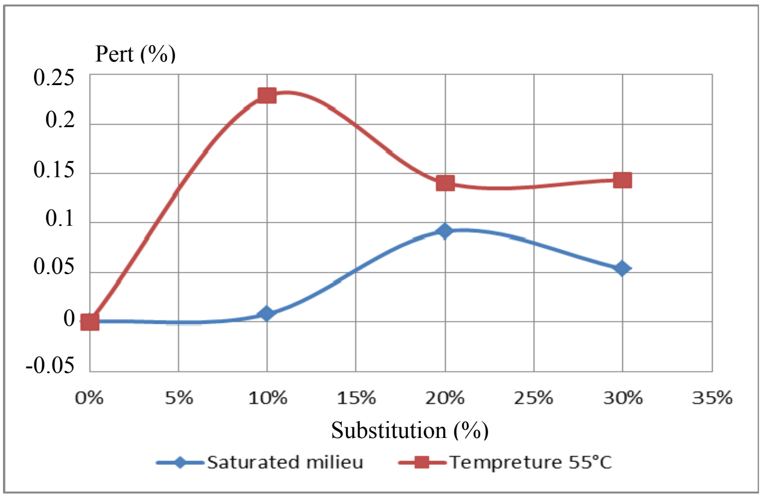

Fig. 5 Representation of the gain or lose strength for the different mixture of mortar based on substitution percentage.

chemical product allows the production of different kind of superplasticizer with different mechanism of dispersion [6, 7]. It is remarkable, to notice that in 10% of substitution at curing temperature, the compressive strength rises up about 9 MPa, which can be explained by the rise up of the fresh density, in this case 10% of substitution seems be an optimum of suspension. The gain can be explained by the contraction (shrink) of the specimen when the optimum of suspension is attained and the loss is explained by the expansion of the specimen in that milieu.

The optimum of suspension as notice previously, and as it is shown in Fig. 6, the porosity of the substitution composition take the curve of a convex at 10% of substitution, and as it is shown the substitution function take at the same point (10% percentage of substitution). Moreover, an optimum of substitution by using chemical admixture based on poly-carboxylate favorite the phenomenon of matrix contraction at curing temperature resulting from capillarity forces of meniscus, at saturated milieu these forces change the sense and promote an expansion. By the way, there are no methods to calculate the summation of these forces in mortar or in any kind cementious material.

3.3 The Influence of Type of Superplasticizer on the Capillarity Suction

Concrete as a porous material may interact with its

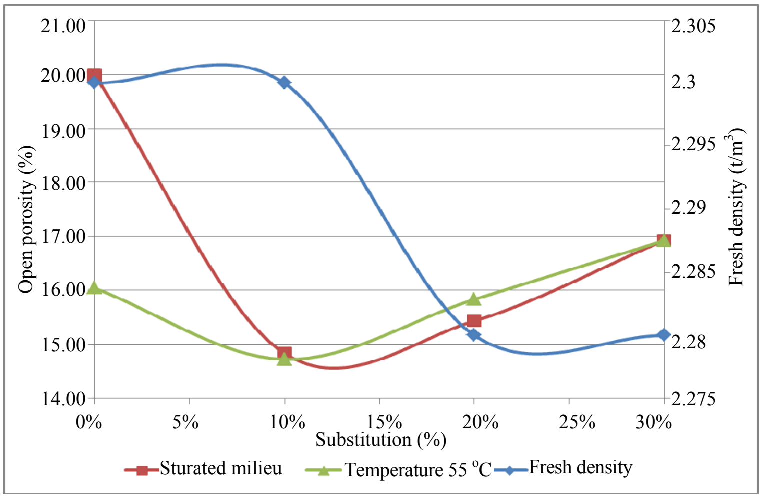

Fig. 6 Representation of the open porosity and fresh density for the different mortar composition.

environment: i.e., compounds of concrete may be leached out, thus weakening the structure of the concrete, or material from the environment may penetrate into the concrete, thereby causing chemical or physical interactions with concrete compounds. The capillarity suction is a test of the penetration of water due to capillary and under a negligible applied pressure into a non-saturated sample, this test method can be an indicator on the durability of concrete suction (EN 1015-18 methods of test for mortar for masonry—Part 18: Determination of water absorption coefficient due to capillary action of hardened mortar). The substitution by SCM's can make a different between the conservation at saturated and curing milieu [3, 5].

As represented in the previous Fig. 7, it is very clear the significant variation of the capillarity suction and when changing the conservation milieu the variation is not very large about 0.76% of the rise up of capillarity suction. It may be important to notice, the changing of the conservation milieu does not affect the capillarity suction when superplasticizer is used.

3.4 The Influence of Type of Superplasticizer on the Coefficient Diffusion

The transports mechanisms are presented that are normally associated with the ingress of deleterious material into concrete. The transport mechanisms also serve as the theoretical models to evaluate the transport characteristics of concrete in different test methods one of this test is the diffusion coefficient in non-steady state [8].

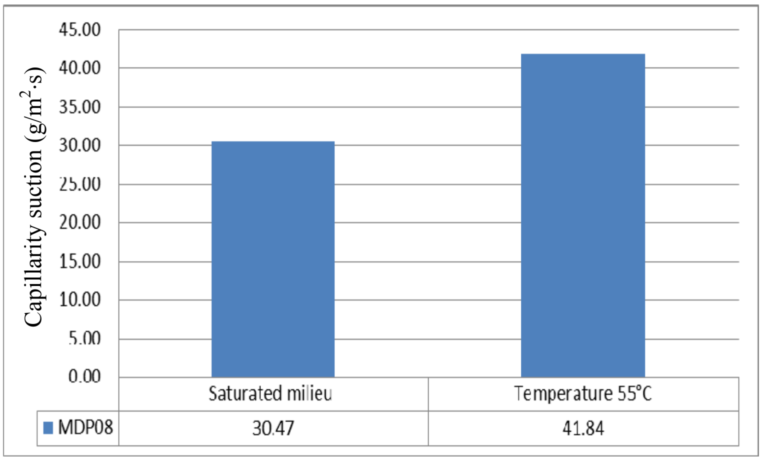

Fig. 7 Representation of capillarity suction of mortar.

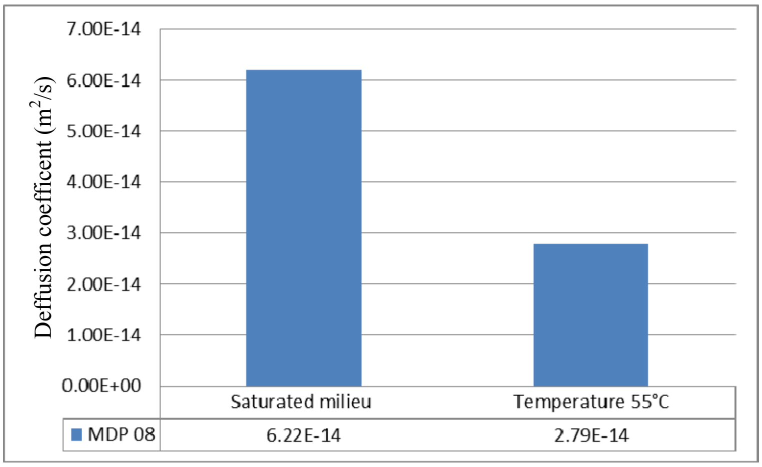

Fig. 8 Representation of coefficient diffusion of mortar.

By definition the diffusion coefficient is an indicator of the concrete permeability and it is very clear in Fig. 8 the large difference between the conservation in saturated milieu and curing temperature milieu. The superplasticizer based on poly-carboxylate by its mechanism of flowing the fresh concrete, it make possible to rearrange the aggregate between themselves, by consequence it is rise up the compactness of concrete and finally decrease the coefficient of diffusion and the concrete want be more durable.

The use of superplasticizer permit it is possible to eliminate an important percentage of vacuums, which can create a significant capillarity forces when the concrete is conserved at curing temperature the decrease is about 55% compared by saturated milieu.

4. Conclusions

In this study, we notice that the offered superplasticizer can improve the characteristic of concrete even if this concrete is based on SCM's. The use of an optimum percentage of SCM's and superplasticizer can improve the behavior of concrete without losing workability, finally make a concrete more durable and sustainable.

A variety of different physical and/or chemical mechanisms may govern the transport of the media into the concrete, depending on the substance flowing and its local concentration, the environmental conditions, the pore structure of concrete, the pore radius, the degree of saturation of the pore system and the temperature. Considering the wide range of pore sizes and a varying moisture concentration in the concrete as a function of the climatic exposure conditions, the transport of media into concrete in most cases is not due to one single mechanism. But several mechanisms may act simultaneously.

In this study, it may be possible to promote the compressive strength of mortar or cementious material at the curing temperature by assuring the sealed condition and let the capillarity forces take the role in the matrix structure.

Moreover, the main aim of this research is the use of SCM's by substitution to rise up the density of mortar composition therefore resulting the rising up of the compactness and the compressive strength, even if sealed in exhaustive environment at curing temperature about 55 ^{o}C. This fact cannot be possible without the use of SCM's characterized by their good aggregate/matrix cement adherence.

Furthermore, the compressive strength rise up at 10% of substitution about 20% at curing temperature, then the use of SCM's rise up a parameter related directly with the durability which is the diffusion coefficient about 55% at curing temperature. Maybe explain by the summation of capillarity forces promoted by the rising up of density and the decreasing of the pores structure (decreasing of open porosity).

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