International Journal on "Technical and Physical Problems of Engineering" (IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

June 2022 | Issue 51 | Volume 14 | Number 2 | Pages 330-338

EFFECT OF TEMPERATURE ON MECHANICAL PROPERTIES OF MORTARS WITH INCORPORATION OF DIFFERENT CHEMICAL ADMIXTURES

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Abstract- The goal of this study is to see how temperature affects the mechanical properties of admixture mortars. For this purpose, the chemical admixture which have been used in our work are two superplasticizers (SP1, SP2), air entrainers (MC), setting retarders (RT), water repellents (HY), and Hardening accelerators (AC). The influence of temperature on residual compressive strengths was investigated using prismatic specimens (4×4×16 cm^3), residual tensile strengths, and mass losses between 20 °C (ambient temperature) and 105 °C, comparatively; these admixtures are added into mortars in three different dosages of each chemical admixture (Min, Med, and Max) by cement mass. The results of the experiments reveal that the evolution of residual compressive strength and mass loss for all mortars between 20 °C and 105 °C is identical. The Temperature is inversely proportional to strength and mass. The incorporation of the air entrainer admixture resulted in better workability and an important loss of strength and mass compared to other admixtures mortars. The evolution of compressive strengths confirms that observed during the tensile tests. At a temperature of 105 °C, the mortars added by the superplasticizers show the lowest losses (strength and mass loss). The two (SP1, SP2) superplasticizers improved the workability.

Keywords: Mortar, Chemical Admixtures, Temperature, Workability, Strength, Mass Loss.

1. INTRODUCTION

Mortar is a building material that is used to join the elements together, to ensure the stability of the structure, and to fill the gaps between the building blocks. In general, the mortar is a mixture of a binder (lime or cement), sand, water and possibly admixtures. Multiple mortar compositions can be obtained based on the different parameters: binder (type and dosage), water dosage, admixtures and additions. Admixtures are currently one of the newest developments in mortar because their uses improve the properties of cementitious materials. Admixtures are chemical products that are added to concrete, mortars, or grouts in small amounts (less than 5% of the mass of cement) during mixing or before installation to improve the qualities of fresh or hardened concrete [1, 2].

Three primary families of admixtures might be specified depending on the desired result. Plasticizers and superplasticizers are two types of additives that change the workability of concrete. Second, there are setting retarders, hardening accelerators, and setting accelerators, which adjust the setting and hardening. Finally, there are air-entraining agents and water repellents [2], which affect specific qualities.

The temperature is a crucial factor-in gaining or losing strength in concrete-putting at the time of hardening it must be taken into account the time and methodology to ensure that the concrete gets its optimal resistance [3]. Conversely, the action of fire as an important point for the technical design is not taken into account today, in order to understand what are the behavior of structures and the level of safety that can be provided to users under the actions of fire or high temperatures [4]. So, the most essential parameter in the study of concrete structure behavior is temperature; predicting this behavior requires knowledge of the evolution of the thermal field and variations in mechanical characteristics under this thermal field. Concrete is considered as a three-phase mixture, water being a fundamental parameter in the changes in the characteristics of concrete (mortars). Thus, the variation of mechanical and thermo-physical properties as a function of the temperature generally takes place in three stages:

- Ambient temperature (wet porous medium).
- The 60-130 °C range (vaporization of water and significant mass transfer).
- The zone of evolution towards the quasi-dry state (beyond 130 °C).

The main physicochemical reactions in concrete at high temperature are:

- Free water and some of the absorbed water escape from the concrete at around 30-120 °C [5]. Drying at 105 °C, usually used to remove free water from the material, causes dehydration of the CSH gel contained in the cement paste and therefore the onset of its deterioration at relatively low temperatures [6]. This dehydration occurs at several levels since it consumes energy [7]. At 120 °C, the unbound water is fully removed.
- A twofold endothermic reaction related to the decompositions of gypsum might occur between 130 and 170 °C [5].
- Heat fractures the cement gel and removes water molecules from hydrated silicates at temperatures ranging from 180 °C to 300 °C. Water that has been chemically bound begins to escape from the concrete [5].
- Small endothermic peaks can be found between 250 and 370 °C, showing the effects of breakdown and oxidation of metallic elements (ferric) [5].

Fire is one of the most damaging hazards to buildings and underground infrastructures. Apart from the degradation of the mechanical properties of concrete, high temperatures can cause spalling explosives from it, resulting in the sudden removal of the coating [8, 9]. Heating induces various modifications of its properties and, especially, changes in microstructure due to the evaporation of water and the progressive dehydration of the CSH gel, accompanied by loss of mechanical resistance and mass [10].

The higher the temperature, the greater the reduction in both compressive strength [11] and modulus of elasticity. For the same strain rate, cooling by water appears to be more detrimental to compressive strength than cooling by air or room temperature [12]. Studies conducted by several scholars [2, 13] show that the existence of admixtures in the mortar under high temperatures caused variable changes in the compressive strength, the tensile strength in bending, the loss of mass, and the porosity compared to the control mortar.

The loss of compressive strength of concrete specimens up to 200 °C is almost negligible but will be 40% and 64% when the temperature increases by 400 °C and 600 °C, respectively [14]. Other works [15, 16] have also shown the low resistance to high temperatures of concrete composed of silica-limestone aggregates from the Seine. Concrete's compressive strength reduces moderately between 20 °C and 150 °C due to hydrothermal changes in free water loss [17]. It has been reported that the concrete is capable of recovering some of its strength [18]. This phenomenon of self-repair of concretes can be explained by the rehydration of non-hydrated cement grains present in concretes characterized by a very low W/C ratio [19]. The results of research on residual tensile strength all concur that strength decreases as temperature rises [20]. This decline is nearly linear and more significant than the fall in compressive strength [5, 16, 21, 22]. A drop in tensile strength is generally observed with increasing temperature [2]. Up to 300 °C the values are quite scattered with relative resistances ranging from 35% to 100%. On the other hand, the values provided by the Eurocode [23] rather represent average values. Above 300 °C, the results are all higher than the values given by the Eurocode [19, 23].

Mass loss in concrete allows porosity to be quantified, with increasing temperature, the mass loss ratio provides an assessment of progressive deterioration and damage to the microstructure increasing moisture loss, the lowest rates differentials depend on the density of the microstructure (Porosity), the union of hydrothermal processes and conditions [24]. The loss of mass observed throughout a heating cycle for all concretes begins at temperatures above 100 °C, and this mass loss begins with the loss of capillary water present in the material's outer layer. Then gradually, the gasses and fluids present in the material are set in motion [19]. Several studies [5, 19] reveal that the first mass loss occurs before the temperature reaches 100 °C, and this corresponds to the departure of free water. During the heating of the concrete, Khoury, et al. have shown that the mass of the concrete decreases due to the evaporation of the water and the progressive dehydration of the hydrates of the cement paste [18].

According to Maanser, et al. [2] concrete admixtures with air entrainer caused the highest reduction in strength and mass at a temperature of 300 °C when compared to other admixtures concretes. At this temperature, the biggest reductions are realized for concretes containing superplasticizers.

2. MATERIALS AND METHODS

2.1. Materials

The materials used were sea sand, Portland cement CEM II-A, and six different types of admixtures. The materials' characteristics were determined by the laboratory (LGCH, University of Guelma, Algeria). The physical characteristics of sand are listed in Table 1 [25]. The sand equivalent was calculated using the NF In-933-8 standard, and the result suggests that it is acceptable sand with a minor number of clayey particles [26].

The Portland cement used is manufactured from CEM II-A and has the following physical and mechanical properties: specific fineness of 3200 cm^2/g, bulk density of 1100 kg/m^3, and absolute density of 3100 kg/m^3 [2]. Phosphates are present in the setting retarder (RT), SIKA REARDER (SIKA). The proportioning employed is directly proportionate to the setting retarder. It has an amber color and must be blended with water before being added to the mixer; the recommended use ranges from 0.2 to 2.0 percent of the cement's weight. SIKA SC 2 is a brown liquid hardening accelerator that should be added to the cement at a rate of 0.2 to 0.34 percent by weight. GLENIUM 27, the first superplasticizer (SP1), is a new chemical generation's non-chlorinated chemical admixture. The best results are achieved by incorporating GLENIUM 27 into concrete after adding 70% of the mixing water in the mixer. It makes up 0.3 to 2.0% of the total weight of cement. The second superplasticizer (SP2) is SIKA Viscocrete 2100 (SIKA), a synthetic polymer that looks like a brown-colored liquid ready for usage. SIKA Liquid Hydrofuge, a white liquid, is used as a mass water repellent (HY). It is utilized in amounts ranging from 0.7 to 2.0 percent of the cement's weight. Micro air 111 (BASF) is an air entrainer (MC) that protects concrete and mortar by forming exceptionally stable, small, and tight air bubbles [27].

Table 1. Physical characteristics of sand

Apparent density (g/cm³)		1.540
Absolute density (g/cm³)		2.667
Equivalent of sand	E.S.V (%)	93
	E.S (%)	92
Water content (%)		0.33

2.2. Experimental Study

The varied mortars are all built up of one part cement, three parts sand (sea sand), and half a part water (W/C = 0.50) [28]. They simply differ in terms of admixture type and percentage (Min, Med and Max, respectively), which correspond to the minimum, medium, and maximum dosages of each chemical admixture (Table 2).

Table 2. Proportions of chemical admixtures and mortar denomination

Mortars Denomination	Proportions of chemical admixtures (%)		
	Min	Med	Max
M.T (Mortar control)	0.00	0.00	0.00
MRT	0.20	1.10	2.00
MAC	0.20	0.27	0.34
MSP1	0.30	1.15	2.00
MSP2	0.50	1.25	2.00
MHY	0.70	1.35	2.00
MMC	0.10	0.25	0.40

Setting retarders (MRT), hardening accelerators (MAC), first superplasticizers (MSP1), second superplasticizers (MSP2), water repellents (MHY), and air entrainers are all used in these mortars (MMC). For the strength and mass loss tests, 4×4×16 cm samples were used.

In the fresh state: sagging was measured (Abram's cone test) (Figure 1). In the hardened state: The experimentation that we have carried out consists of carrying out tests of tensile and compressive strength on specimens in cement mortar, at ambient temperature, and at 105 ° C and tests for the evaluation of the loss of mass (accessible porosity) (Figure 2).

Figure 1. Abram's cone slump tests

To assess the porosity accessible to water and the apparent density, the most frequent method is to use hydrostatic weighing. This simple calculation can be used on a variety of cement pastes, mortars, and concretes. Any microstructural characterization required to measure the material's durability is built on top of it. It produces a total result "Total", which is a quality indicator [27]. The AFREM recommended method for administering porosities [29]. The samples were maintained in water for 28 days (Figure 3) before being roasted at 105 °C in an electric oven until their masses stabilized (Figure 4) [27].

On the ambient air-cooled test specimens, tensile tests (by bending) were performed using a press capable of applying stresses up to 150 KN (Figure 5). The loading speed chosen is 0.05 MPa/s, which is standard. Three specimens were tested for each component. After failure in bending, the half-prisms of the test specimen will be fractured under compression (Figure 6).

Figure 2. Evaluation of mass loss

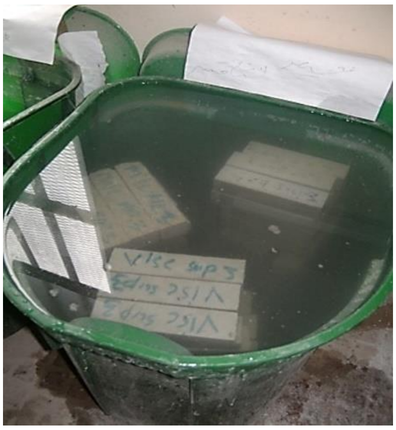

Figure 3. Preservation of the test specimens in water

Figure 4. Samples in oven at T= 105 °C

Figure 5. Tensile strength tests (by bending)

Figure 6. Compressive strength tests

3. RESULTS AND DISCUSSIONS

3.1. Workability

This test is recommended for concrete; in our study its use will only serve a comparative purpose as to the effect of admixtures (Table 3).

Table 3. Slump evolution for various admixtures mortars

Dosage			Min	Med	Max
Slump (mm)	Admixtures mortar	MSP1	3	7	12
		MSP2	3	7	11
		MRT	2	4	6
		MAC	0	0	0
		MHY	0	0	2
		MMC	35	72	108
	Control mortar	MT	2		

It is about evaluating the plasticity and knowing the quality of a mortar which allows its workability while maintaining its homogeneity. On a practical level, this translates into the ease of implementation and of obtaining an acceptable raw facing, whether in the horizontal or vertical plane. So, the condition of workability is fixed by the plasticity of the concrete or the mortar.

All the mortars exhibited greater subsidence than those of the control mortars except the MAC and MHY mortars (Table 3). This remark is valid for the three dosages used. This increase in sag is proportional in dosage. The maximum values are ensured by the max dosage (Figures 7 and 8). Both superplasticizers (SP1, SP2) have the same beneficial effect on sagging mortar. Their values are identical to the dosages. It's only natural that the setting retarder (RT) produces more sags than the hardening accelerator (AC). The air entrainer (MC), which is known to improve workability [2], produces extremely high sag values. These measurements range from 35 mm to 108 mm, confirming the mortar's minimal resistance. As a result, additional caution should be exercised when using this combination [2].

3.2. Tensile Strength at Ambient Temperature (20 °C)

Figure 9 depicts the results of the tensile strengths at room temperature, which are presented in Tables 4 and 5.

Mortars mixed with superplasticizers give the greatest tensile strengths. VISCOCRET 2100 (MSP2) appears to be better in terms of improving strength and this for the three dosage ranges tested.

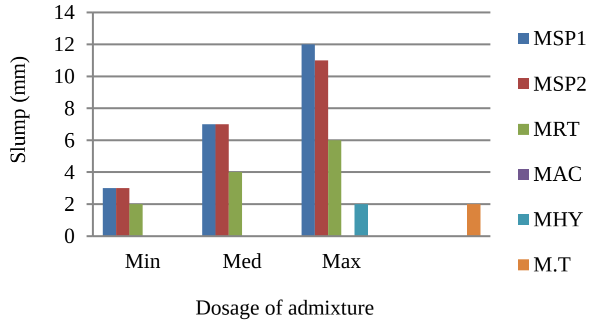

Figure 7. Comparison of slump of different mortars (MT, MSP1, MSP2, MRT, MAC, MHY)

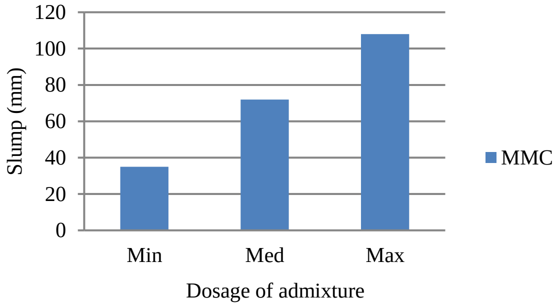

Figure 8. Comparison of slump of mortar MMC

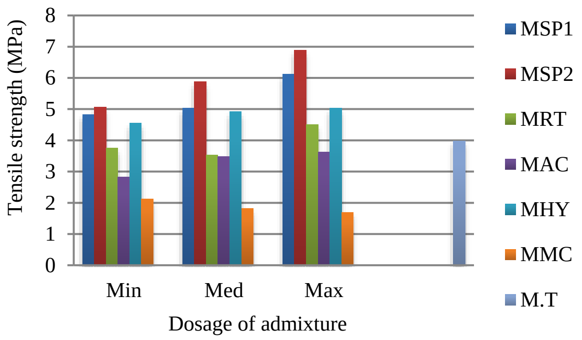

Figure 9. Tensile strength of different mortars at T = 20 °C

Table 4. Tensile strength of different mortars

Dosage			Min	Med	Max
Tensile strength (MPa)	Admixtures Mortar	MSP1	4.825	5.032	6.113
		MSP2	5.069	5.887	6.889
		MRT	3.762	3.530	4.512
		MAC	2.832	3.476	3.625
		MHY	4.547	4.929	5.038
		MMC	2.121	1.822	1.692
	Control mortar	MT	3.986		

Table 5. Decreasing the ranking of the tensile strength of the different mortars

No	mortar	Dosage		mortar	Dosage
		Min	Med		Max
1	MSP2	5.069	5.887	MSP2	6.889
2	MSP1	4.825	5.032	MSP1	6.113
3	MHY	4.547	4.929	MHY	5.038
4	MT	3.986	3.986	MRT	4.512
5	MRT	3.762	3.530	MT	3.986
6	MAC	2.832	3.476	MAC	3.625
7	MMC	2.121	1.822	MMC	1.692

In all cases, the resistances are always higher than that of the control mortar. This confirms the known results on the use of superplasticizers when looking for high resistance. The use of water repellent also improved the tensile strength of the mortar (MHY). This improvement is less than that of superplasticizers.

Water repellent is often used as a sealant, so it fills in voids, which in turn increases tensile strength. The tensile strengths of the mortars added by the setting accelerator are lower than those of the mortars added by the setting retarder for the three dosages tested. But the two types of mortar have lower tensile strengths than that of the control mortar except the mortar (MRT) with the max. Mortars with an air entrainer (MMC) have the lowest tensile strengths. This decrease is even more marked with increasing dosage. It reached a 58% drop for max dosage.

3.3. Compressive Strength at Ambient Temperature (20 °C)

Figure 10 depicts the compressive strength results at room temperature, which are presented in Tables 6 and 7 (Appendix 1).

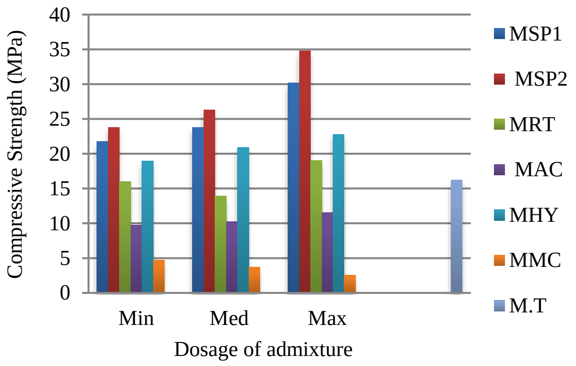

Figure 10. Different mortars' compressive strength at T = 20 °C

First, we see that the evolution of compressive strengths correlates perfectly with the evolution of tensile strengths, depending on the type and dosage of rope admixture. The compressive strengths of the mortars admixed with superplasticizers indicate this agreement. The MSP2 mortar provides the most essential values where the resistance is doubled [2]. The setting retarder produces values that are similar to those of the control mortar and are compliant with the regulations (80 percent of the control mortar's resistance). With the water repellent, we see an increase in the mortar's resistance. The surge becomes more pronounced as the dosage is raised. The setting accelerator provides lower resistances than the control mortar. The dosage (min) is reduced by 40%, while the dosage (maximum) is reduced by 29%. (max). The values are outside the range allowed by the rules (a reduction of 20% of the control mortar's resistance). Due to the composition examined, this implies that the manufacturer's maximum dosage recommendation is insufficient. With the introduction of an air entrainer, the negative impact on compressive strength is substantially greater. The resistance of this mortar ranges from 29 percent (for the lowest dosage) to 15.62 percent (for the highest dosage) of the control mortar's resistance. As a result, caution should be exercised when employing this combination [2].

3.4. Evolution of Residual Tensile and Compressive Strengths at Temperatures T = 105 °C

In Figures 11 and 12, and Tables 11 and 12, depict the evolution of residual tensile and compressive strengths at temperatures of 105 °C (Tables 8a, 8b, 8c, 9a, 9b, 9c in Appendix 2).

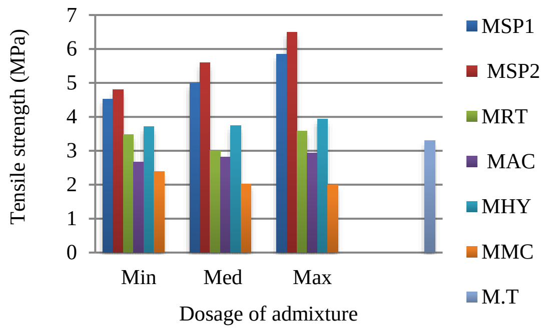

Figure 11. At T=105 °C, the tensile strength of various mortars varies

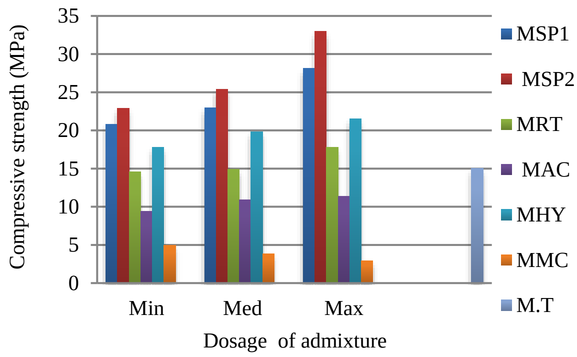

Figure 12. At T = 105 °C, the compressive strengths of various concretes changed

When temperatures were raised from 20 °C to 105 °C, all mortars showed a reduction of strength Tables 10 and 11, [2, 14]. Except in the case of mortar admixed with an air entrainer, where resistance (tensile and compressive strengths) increases [30].

The maximum drop in tensile strength is obtained by the mortar with water repellent (MHY) dosed at Max. It is around 22%. The lowest falls are those of mortars with superplasticizers (≤ 6%). Note that the gain in tensile strength, obtained by the mortar with air entrainer, (MMC) reaches 18% for the max dosage. Heating the mortar, therefore, evacuates the air and allows the continuation of the chemical reaction of the setting, facilitating contact between the water (still present) and the cement. The same observation is made for compressive strengths [20]. However, we note less strength losses than in traction. These drops remain less than 10%. Mortars (MMC) show, as in traction, gains in resistance to compression. The largest increase is obtained for the max dosage, with 14%.

Table 10. At temperatures of 20 and 105 °C, the relative residual tensile strengths of admixtures mortar evolved ((-) corresponds to loss, and (+) corresponds to gain)

Dosage	$\frac{R_c\,(105\,°C) - R_c\,(20\,°C)}{Rc\,(20\,°C)}$						
	Admixtures mortar						Control mortar
	MSP1	MSP2	MRT	MAC	MHY	MMC	M.T
Min	-6.2	-5.3	-7.4	-5.5	-18.4	+12.8	-17.3
Med	-0.8	-5.1	-14.9	-19.1	-24.1	+11.0	
Max	-4.3	-5.7	-20.6	-19.0	-22.0	+17.8	

Table 11. Evolution of the relative residual compressive strengths of admixtures mortar at temperatures 20 and 105 °C ((–) corresponds to loss, and (+) corresponds to gain).

Dosage	$\frac{R_c\,(105\,°C) - R_c\,(20\,°C)}{R_c\,(20\,°C)}$						
	Admixtures mortar						Control mortar
	MSP1	MSP2	MRT	MAC	MHY	MMC	M.T
Min	-4.3	-3.7	-9.2	-3.9	-6.3	+5.9	-7.3
Med	-3.2	-3.4	+7.6	-5.1	-5.3	+4.8	
Max	-6.9	-5.2	-6.5	10.5	-5.6	+14.4	

3.5. Mass Losses at 105 °C (Accessible Porosity)

Free water evacuation occurs when the temperature rises to 105 ° C, resulting in the mass loss Tables 12 and 13. The latter is the porosity that can be accessed. [2] The control mortar has a porosity of 6.19% and a mass loss (porosity less than 10%). As a result of the nature of the same sand, it has a relatively low resistance (siliceous end). For the three quantities of admixture [2 and 27], the super plasticizer- admixtures mortar (MSP1 and MSP 2) had the lowest mass losses (porosities). Which backs up the resistance results [2]. The lowest losses for MSP2 and MSP1 are 3.45% and 4.06%, respectively, and they are obtained at maximum dosage. The same can be said about the usage of a setting retarder (RT). For the three admixture dosages, the losses are lower than for the control mortar, confirming the resistance results. The largest dosage results in the smallest loss (4.66%). For the three quantities of admixture, the water repellents (HY) induce smaller mass losses than the control mortar. Which confirms the resistance's results? The max proportions [2] achieve the lowest loss (4.55%). When compared to the control mortar, the hardening accelerator (AC) generates more losses. The admixtures mortar suffers the most significant losses due to the air entrainer (MC). The maximum dosage causes them to lose more than 12% of their weight (Figure 13).

Table 12. Mass losses of different mortars

Dosage	Mass loss (%)						
	Admixtures mortar						Control mortar
	MSP1	MSP2	MRT	MAC	MHY	MMC	M.T
Min	5.33	4.42	5.28	7.95	5.97	6.29	
Med	5.07	3.68	5.31	7.62	5.26	11.25	6.19
Max	4.06	3.45	4.66	7.90	4.55	12.02	

Table 13. Growing classification of mortars mass loss (porosity)

No	Mass loss at 105 °C (%)				
	mortar	Dosage Min	mortar	Dosage Med	Max
1	MSP2	4.42	MSP2	3.68	3.45
2	MRT	5.28	MSP1	5.07	4.06
3	MSP1	5.33	MHY	5.26	4.55
4	MHY	5.97	MRT	5.31	4.66
5	MT	6.19	MT	6.19	6.19
6	MMC	6.29	MAC	7.62	7.90
7	MAC	7.95	MMC	11.25	12.02

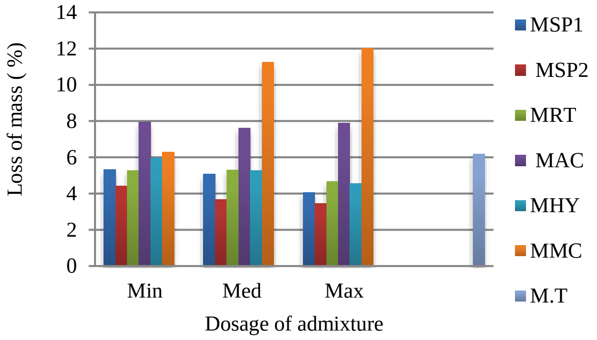

Figure 13. Variation of the mass of the mortars at 105 °C

5. CONCLUSIONS

The influence of six types of chemicals admixtures on the evolution of mass losses and resistance of mortars subjected to a temperature of 105 °C was evaluated in this experimental investigation. The following conclusions can be deduced from this experimental investigation:

● Introducing admixtures has been beneficial for the workability of the mortars. The Max sags are obtained by the Max dosages. Note the importance of the air entrainer (MC) on the sag, where it is reached 108mm for the max dosage. The setting retarder (RT) and hardening accelerator (AC) as well as the water repellent (HY) lead to a slump close to that of the control mortar (MT). The two superplasticizers had the same effect on workability, by improving the latter. Sag varies in a ratio of 3 to 12 for min to max dosages.

● At ambient temperature (20 °C), the greatest tensile strengths are obtained by superplasticizers Viscocrete 2100 (MSP2) gives the maximum strengths for the three dosages. Resistance gains of 27% for the Min dosage and of 73% for the Max dosage are achieved, compared to the reference mortar (MT). The admixtures setting retarder (RT) and hardening accelerator (AC) led to lower strengths (less than 30% for the min dosage), this drop decreases with increasing dosage. The most detrimental effect on resistance is obtained by the air entrainer (MC). The drop in resistance increases with dosing and reaches 58% for max dosing. The evolution of compressive strengths confirms that observed during tensile tests. The MSP2 mortar gives the maximum values; the gain varies from 47% (min dosage) to 114% (max dosage). If the setting retarder (RT) gives values close to that of the control mortar, those obtained by the setting accelerator (AC) are lower.

This drop-in resistance exceeds that authorized by the standards (20%). The water repellent improves resistance up to 40% at the max dosage. The air entrainer is the most detrimental resistance adjuvant; its usage has resulted in compressive resistances that are only 29% (min dose) to 16% (max dosage) of the control mortar's resistance (MT). This decrease in resistance was enhanced as the dosage was increased.

- Except for the resistances of the mortar with the air entrainer, the increase in temperature causes a loss of resistance at 105°C (MMC). Its maximum drop in traction is obtained by water repellency (max dosage) exceeding 20 %. Super plasticizers (SP1, SP2) have low falls, less than 6%. The air entrainer (MC) provides a gain in tensile strength of up to 18% for the max dosage. Residual compressive strengths follow the same evolutions as those in tensile. However, we note the less significant drops, they remain below 10%. At 105 ° C, mortars (MMC) give strengths greater than those of the ambient state of 14% with the maximum dosage.
- When the temperature rises over 105 °C, the available free water evaporates, resulting in mass loss in all mortars tested. The uses of different types of admixtures have a variable effect on reducing mass loss. MSP1, MSP2, MRT and MHY mortars lead to lower mass loss than the reference mortar; it is almost half in the case of MSP2 superplasticizer (max dosage). The super plasticizer 2 leads to the least porous mortar. For the maximum test, the mass loss (accessible porosity) is 3.45%, while the control mortar shows a loss of 6.19%. Admixtures (RT and AC) generate larger mass losses than the control mortar. But the most important loss is that of the air drive mortar (MT) which is 12% for max. Thus, the correlation between the resistances and the mass losses is coherent, which confirms the known results.

APPENDICES

Appendix 1. Compressive Strength at Ambient Temperature (20 °C)

Tables 6 and 7 show the Compressive Strength at temperature (20 °C).

Table 6. Compressive strength of different mortars

Dosage			Min	Med	Max
Compressive Strength (MPa)	Admixtures Mortar	MSP1	21.759	23.768	30.218
		MSP2	23.775	26.331	34.763
		MRT	16.040	13.891	19.018
		MAC	9.771	10.283	11.522
		MHY	18.975	20.915	22.801
		MMC	4.688	3.673	2.534
	Control mortar	MT	16.215		

Table 7. Decreasing ranking of compressive strength of different mortars

No	mortar	dosage		Mortar	Dosage
		Min	Med		Max
1	MSP2	23.775	26.331	MSP2	34.763
2	MSP1	21.759	23.768	MSP1	30.218
3	MHY	18.975	20.915	MHY	22.801
4	MT	16.215	16.215	MRT	19.018
5	MRT	16.040	13.981	MT	16.215
6	MAC	9.771	10.283	MAC	11.522
7	MMC	4.688	3.673	MMC	2.534

Appendix 2. Evolution of Residual Tensile and Compressive Strengths at Temperatures *T* = 105 °C

Tables 8 (a, b, c) and 9 (a, b, c) show the Compressive Strength at temperature (105 °C).

Table 8. (a, b, c) Evolution of the tensile strengths of concretes with temperature (20 °C and 105 °C)

Table 8a

Dosage			Min	
Temperature (°C)			*T*= 20	*T*= 105
Tensile strengths (MPa)	Admixtures mortar	MSP1	4.825	4.525
		MSP2	5.069	4.799
		MRT	3.762	3.485
		MAC	2.832	2.676
		MYH	4.547	3.712
		MMC	2.121	2.392

Table 8b

Dosage			Med	
Temperature (°C)			*T*= 20	*T*= 105
Tensile Strength (MPa)	Admixtures Mortar	MSP1	5.032	4.992
		MSP2	5.887	5.589
		MRT	3.530	3.003
		MAC	3.476	2.812
		MYH	4.929	3.743
		MMC	1.822	2.022
	Control mortar	MT	3.986	3.295

Table 8c

Dosage			Max	
Temperature (°C)			*T*= 20	*T*= 105
Tensile strengths (MPa)	Admixtures mortar	MSP1	6.113	5.850
		MSP2	6.889	6.497
		MRT	4.512	3.584
		MAC	3.625	2.938
		MYH	5.038	3.932
		MMC	1.692	1.993

Table 9. (a, b, c) Evolution of the compressive strengths of concretes with temperature (20 °C and 105 °C)

Table 9a

Dosage			Min	
Temperature (°C)			*T*= 20	*T*= 105
Compressive strengths (MPa)	Admixtures mortar	MSP1	21.759	20.832
		MSP2	23.775	22.892
		MRT	16.040	14.559
		MAC	9.771	9.390
		MYH	18.975	17.778
		MMC	4.688	4.965

Table 9b

Dosage			Med	
Temperature (°C)			*T*= 20	*T*= 105
Compressive Strength (MPa	Admixtures mortar	MSP1	23.768	23.002
		MSP2	26.331	25.423
		MRT	13.891	14.947
		MAC	11.522	10.937
		MYH	20.915	19.797
		MMC	3.673	3.849
	Control mortar	MT	16.215	15.025

Table 9c

Dosage			Max	
Temperature (°C)			*T*= 20	*T*= 105
Compressive strengths (MPa)	Admixtures mortar	MSP1	30.218	28.122
		MSP2	34.763	32.963
		MRT	19.018	17.791
		MAC	10.283	11.365
		MYH	22.801	21.529
		MMC	2.534	2.898

NOMENCLATURES

1. Acronyms

MRT Mortars with setting retarders
MAC Mortars with hardening accelerators
MSP1 Mortars with first superplasticizers
MSP2 Mortars with second superplasticizers
MHY Mortars with water repellents
MMC Mortars with air entrainers (MMC)

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