Effects of high temperatures on mortar containing Portland cement and an Air-Entraining Agent

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RÉSUMÉ. Les mélanges de mortier incorporant un agent entraînant l'air (AEA) n'ont pas gagné en popularité dans la construction accélérée. Lors d'un incendie, le béton est soumis à des températures très élevées pouvant entraîner un effondrement de la structure. Le but de cette recherche est d'étudier le comportement du mortier à base de ciment Portland et d'un agent entraînant l'air chauffé à 600 ° C. Les avantages obtenus lors de l'utilisation de l'AEA dans un mortier, tels que la durabilité, sont discutés. Les échantillons sont soumis à des essais de résistance à la compression et à la flexion, à la perte de masse et à l'absorption. Quatre mélanges de mortiers, à savoir M0, M0.01, M0.08 et M0.1 contenant de l'AEA à des niveaux de 20, 200, 400 et 600 ° C, ont été étudiés pour donner des indications sur leur utilisation dans la construction. Les prismatiques ont été testés à l'âge de 28 jours. Les résultats indiquent qu'un taux de mélange d'AEA dans le ciment de 0,08% donne des résistances à la compression qui, après chauffage à 400 ° C, sont proches des résistances initiales avant chauffage. Les plus grandes quantités de perte de masse n'étaient visibles qu'à 600 ° C. À 600 ° C, la forte dégradation de la microstructure conduit à des résistances inférieures à 23% des résistances initiales pour les échantillons avec ou sans AEA.

ABSTRACT. Mortar mixes incorporating an Air-Entraining Agent (AEA) has not grown popularity in fast track construction. During a fire, concrete is submitted to very high temperatures which can lead to structural collapse. The aim of this research is to study the behaviour of mortar made of Portland cement and an Air-Entraining Agent which are heated to 600 °C. The benefits that are obtained when using AEA in mortar such as durability are discussed. The samples are submitted to compressive and flexural strength tests, mass loss and the absorption. Four mixes of mortars i.e. M0, M0.01, M0.08 and M0.1 containing AEA at levels of 20, 200, 400 and 600 °C have been investigated to give guidance for their use in construction. The prismatic were tested at the age of 28-days. The results indicate that a mixes rate of AEA in cement of 0.08 % gives compressive strengths that, after heating to 400 °C, are close to initial strengths before heating. The greater quantities of loss's mass were only visible at the 600 ° C. At 600 °C, the strong degradation of the microstructure results in strengths of less than 23 % of the initial strengths for specimens with or without AEA.

MOTS-CLÉS : *Mortier, Entraineur d'air, Haute température, Résistance à la compression, maniabilité.*

KEY WORDS: *Mortar, Air –Entraining Agent, High temperature, mechanical resistance, workability.*

Introduction

Chemical admixtures are used in concretes to prove some properties at ambient temperature. The admixture concretes may present different behaviour at high temperature than at normal conditions. Such admixtures can provide several beneficial effects in concrete, though the effectiveness depends on factors such as the nature and dosage of the product, nature of cement and aggregates, water-cement ratio (*w/c*) and ambient temperature. The admixture type and its chemical composition, dosages and the molecular structure of the admixtures all of these parameters effect on workability of cement [MAA 18].

An earlier literature survey by the Beningfiel showed that the factors affecting the amount and type of air entrained and the effect of this air on the properties of mortar are rarely quantified in the literature. It has become practice to entrain a percentage of air in concrete (AEC) to improve its durability and in particular its resistance to frost attack [ABD 09]. Entrained air also improves the concrete workability and makes it easier to be compacted, placed and finished by the presence of minute air bubbles dispersed uniformly throw the cement-paste portion of the concrete. Air-entrainment usually reduces strength; the reduction is generally proportional to the amount of air entrained. The effects of high temperature on the mechanical properties of concrete have been investigated since the 1940s [MET 05]. These studies examined the behavior of cement paste, mortar, concrete samples and reinforced concrete members exposed to high temperature. The objective of this paper is to present the results of a research experimental data on the residual mechanical properties of MAE subject to heat which are important for the repair of concrete structures in case of fire.

1. Experimental program

1.1 Characteristics of the materials used

A study of air entrained and non-air entrained mortars of the ratio w/c = 0.50 was carried out.

Cement: This is a Portland cement (CEM II 42.5) has a Blaine specific surface area of 3585 cm^2 / g and a density of 3.2. Chemical and mineralogical composition is given by Bogue's formulas (Table 1).
Sand: The binary sand mixtures aggregates used in this study were SD (dune sand) and CS (crushed sand). The characteristics of binary sand mixtures are given in Table 2 The dune sand used with particles ranging from 0.08 mm to 5 mm in size. This natural sand was taken from Boussâada, Algeria. The granulometric study is performed according to standard NF P18-304. In this study the manufactured fine aggregate used is crushed sand generated by the quarry waste. An improvement of porosity of the binary mixture (crushed and dune sands) and correct the variation of the granulometric composition (particle sizes) using 1/3 of crushed sand blend.
The adjuvant: used is an air entraining agent (MEDA - AIR). It is a solution of pH =7 -8 and a density of 1± 0.01, with ions chlores ≤1 %. Its normal use scale is fixed by the manufacturer's recommendation of to 0.01 to 0.1 % of the cement weight. The percentage of the chemical admixture used was 0.08 % by weight of cement for all mixes.

Table 1. *Chemical and mineralogical composition of cement*

Chemical compositions (%)							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
18.48	4.51	3.21	61.04	2.16	2.18	0.56	0.13

Mineralogical compositions (%)				
C_3S	C_2S	C_3A	C_4AF	Gypsum
57	18	07	11	15

2. Experimental procedure

2.1 Formulation of Mortar

Fresh mortar mixes were prepared in modified laboratory mixer. Mixtures were prepared from dry aggregates. Cement and sand were dosed by weight, water and chemical admixtures were added by volume. The mortar formulation tested is performed by formulating's method mortar of the Skramataiv [KOM 78]. In the case of the use of adjuvants, the latter is diluted in the mixing water. The mortar specimens are preserved in their mould in wet place (20∘C, 95% HR) during 24 hours. Then they undergo immersed in the potable water tap. .

In order to investigate the influence of an air- entraining agent on the rheology of mortars, prisms samples with the dimensions of 7 cm x 7 cm x 16 cm, are produced. After 28 days curing conditions, the samples were used for the determination of the compressive strength. . The physical and mechanical characteristics of the mortars with and without air entrained agent have been compared. The air entrained agent is added at dosages of 0.08% and

0.1% of cement weight respectively. Table 2 present the complete formulation of the 02 mortar mixes for cement dosages of 400 kg / m and W / C = 0.5.

For all the mortar made, workability was measured by the Abrams cone slump test in accordance with NF P 18- 451. The axial compressive strength was tested at 28 days according to NF EN 12390 - 4 for the mortar at 20 °C that was not subjected to high temperatures. After 28 days, specimens are dried in an oven (at 100 °C), until stabilization of their mass. All specimens are subjected to high temperatures: 200 °C, 400 °C and 600 °C according to the time temperature schedule of ASTM E 119-00. After cooling, they were subjected to compression tests.

Table 2. *The mortar composition with AEA*

Mix (g)	M0	M0.08	M0.01	M0.1
AEA	-	0.36	0.045	0.45
Cement	450			
Sand dune	450			
Crush sand	900			
Water /Cement	0.50			

3. Results and discussions

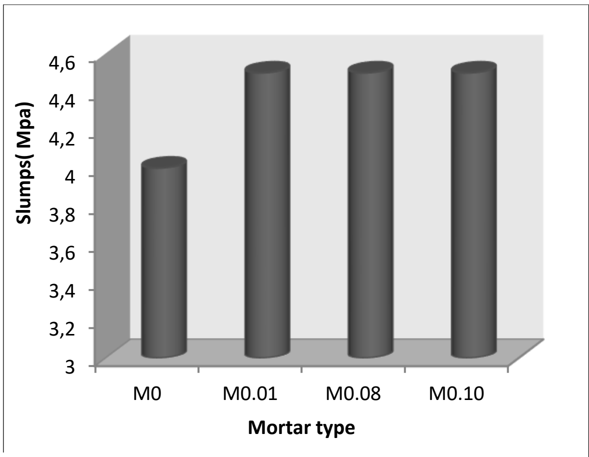

Figure 1: *Variation of slump of mortar with AEA and control mortar*

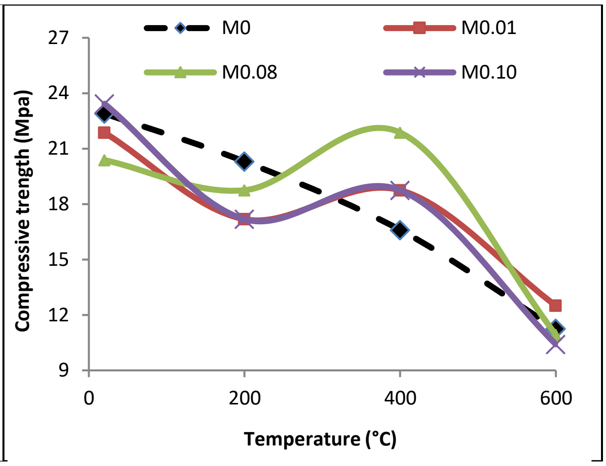

Figure 2: *Compressive strength of the different mortars as a function of temperature*

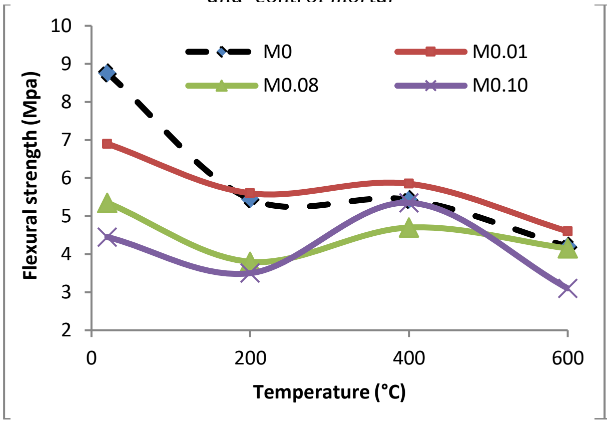

Figure 3: *Flexural strength of the different mortars as a function of temperature*

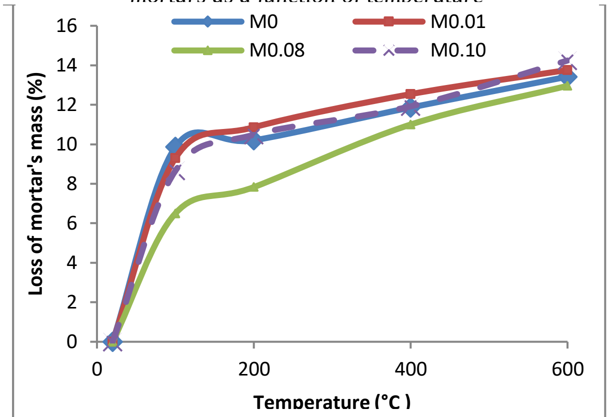

Figure 4: *Evolution of mass loss related to temperature*

- The effect of dosing AEA on mortar workability was evaluated by the Abram's cone immediately after mixing. Figure 3 shows the results of workability of mortar in which the air- entraining agent is added at dosages of 0.08%, 0.01% and 0.1% of cement weight. It seems that workability of mortar decreases as the AEA content decreases. Based on the experimental results presented in Fig. 1, the incorporation of chemical admixture affects the

workability of mortar negatively. Indeed, an air- entraining agent enhances the handling by making a more workable mix of a plastic mortar rheological behavior.
From Fig.1, it can be observed that all the mortar mixtures with adjuvant gave better workability compared to the control mix at the values ranging from 4.5 cm slump for the first one and to 4.53cm slump for the latter. This is in agreement with other results on the subject found previously where there was an improved fluidity of mortars at fresh state of these types with incorporation of blends [TEB 18].

- As concluded from Fig. 2 is can be seen that 0.08% AEA give more effective compressive strength in different temperature than the other mixes of mortar with AEA. It has been found that the compressive strength of the mortar mixes is decreasing with temperature increase. Also, found that the increases in temperature from 200 to 400°C, this gain was quite strange and may be attributed to some hydration of the cement paste at this temperature that did not occur at lower temperatures [PEN 05]. After 400 °C the compressive strength decreases for all mixes. According to the many researches, these gains at 400 °C are attributed to the increase in the forces between gel particles (Van der Walls forces) due to the removal of water content [CAS 90].

In the range of 400 - 600 °C, severe strength losses occurred in all mortar M0, M0.08, M0.01 and M0.10. In this range, cement paste contracts, whereas aggregates expand. So, the transition zone and bonding between aggregates and paste are weakened. After heating to 600 °C, the compressive strengths of M0 were lower than those of the mortar M0.08. This is due to the degradation of calcium-silica-hydrate (C-S-H). Second phase of the C-S-H decomposes in the temperature range from 600 to 800 °C, forming β-C_2S [TEB 17].
At 600 °C, one noticed that quick losses in compressive strength for M0.08 mortars are attributed to the process as well as chemical decomposition of hydration products causes severe deteriorations and strength losses in moratr after subjecting to high temperatures. The greatest strength losses of mortar 0.08%, 0.01% and 0.1% without AEA were observed at 600 °C, which were 21%, 32% and 46% respectively.
It appears that the dosage of AEA has no significant effect on the compressive strength at 200 °C. However, between 200 °C and 400 °C, the quantity of 0.08% AEA has significant effects on the residual compressive strength.

- The average tensile strength for different mixes is given in Fig. 4. The decrease in flexural strength in M0.08 compares with M0 caused by entrained air; voids caused by entrained air affect the tensile strength in the same way as compressive strength.

- Figure 4 shows the evolution of mass loss during the heating cycle of the studied specimens. The mass of mortars decreases with increasing temperature due to loss of moisture. Here are some facts for this:

- ✓ Before 200 °C, the mass change is very low. The mass loss in this temperature range corresponds generally to the water escape from concrete pores.
- ✓ Between 200 and 600 °C, a strong mass loss for all mortar specimens tested. All mortar maximum of water in each mortar specimen evaporated during heating between 200 and 400 °C.
- ✓ The decrease of resistance estimated at 51% for mortar with 0, 08% AEA exposed to a temperature of 600 °C. On the other hand, it is 2% for control mortar. During these processes, some cracks occur and mortar is crumbled and becomes porous material [KAN 16]. Aggregate's effect on mortar at high temperatures is related to their mineral structures. This process results in volume increase and damage [RAH 14].

4. Conclusion

From this study, one can conclude, that, when using HPC specimen, the speed of temperature rising, influences the decrease in strength between 400 and 600 °C.

- The compressive strength of mortar improved with additions of AEA at volume, the strength showed maximum at 0.08% proportion but decrease at 0.1% with AEA.
- The critical temperature, which causes maximum attenuation properties of different compressive strength, mass loss is between 400°C and 600 °C.
- Beyond 600 °C the mortar may lose the majority of these properties i.e there are properties that can cancel out .One can say that the mortar has become weak.
- The mortars with AEA are affected by high temperatures especially at 600°C and above compared with less than AEA dosage.

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