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Effect of chemical admixtures on mortar's durability

A. Benouis[1*] and A. Maanser[2]

[1]Professor, Head of material's team
[2]Postgraduat student
Civil Engineering and Hydraulic Laboratory LGCH, (24000) University of Guelma,
Algeria. Benouis_h@yahoo.fr maansera@yahoo.com

ABSTRACT

The availability of chemical admixtures made conventional concretes and mortars easier to use. In this work, we propose to study the effect of some chemical admixtures on the durability of the mortars. Three indicators of durability were used through tests measurements of accessible porosity, water permeability and air permeability.
The chemical admixtures used are: two superplasticizers, a retardator, an accelerator, a waterproofing and an air-entraining agent. Three different dosages of each chemical admixture, recommended by the manufacturers, is examined to study the effects on the mortar's properties. They revealed that superplasticizers improved all the studied properties. The most fall performances are those of the mortar with the air-entraining agent. The results indicated that use of retarder agent had minor effect on the target properties, while incorporation of accelerator agent increased the permeability significantly. Incorporation of waterproofing agents increased the performance of mortars regarding the reference mortar.

Keywords. Mortar, Chemical admixtures, Porosity, Water permeability, Air permeability.

INTRODUCTION

The chemical admixtures are very important components of modern concretes and mortars, they make it possible to modify certain properties of the mortar in the fresh or hardened state. They are organic substances (plasticizers, superplasticizers, and air-entraining agents) or inorganic (setting accelerators and of hardening) who allow us to modify the rheology of the concretes with lower water, thus with not chemical admixtures. The availability of these products has made it possible a new generation of concretes and mortars easier to use. It is well known that the fluidity and other properties of fresh cement pastes are affected by the kind and the time (Aiad, 2003), type and proportions of addition of organic admixtures (Fukuda, 1990). If the effect of these chemical admixtures on strengths is well specified in the normative texts, their effect on the durability is much less investigated.

MATERIALS AND METHODS

Materials

The materials used are a sea sand, Portland cement CEM II-A and six types of chemical admixtures. The characteristics of the materials used were determined at of the Civil Engineering and Hydraulic Laboratory (LGCH-university of Guelma).

The physical characteristics of sand (NF EN, 1998 and NF EN, 1999) are given in the following table:

Table 1. Physical characteristics of sand

Apparent density (g/cm^3)		1.540
Absolute density (g/cm^3)		2.667
Equivalent Of sand	E. S.V (%)	93
	E.S (%)	92
Water content (%)		0.33

The sand equivalent was given according to standard NF In-933-8 (NF EN, 2006) ; the result indicates that it is a sand suitable with small percentage of clayey fines. The grain distribution of the sand is presented in table2.

Table 2. Granulometric analysis of sand

Diameter of meshs (mm)	Partial refusal (g)	Total refusal (g)	Total refusal (%)	Filtered (%)
5	0	0	00	100
4	0	0	00	100
2	1	1	0.05	99.95
1	14	15	0.75	99.25
0.50	180	195	9.75	90.25
0.250	1700	1895	94.75	5.25
0.125	95	1990	99.5	0.5
0.063	5	1995	99.75	0.25
< 0.063	5	2000	100	00

We should notice that 9.75 % of the sand grains have a diameter between 0.5 and 5 mm, it is a very fine sand. The percentage retained in weight between two sieves is higher than 40 %; sand does not have a uniform granularity. The percentage of fines (less than 0.08 mm) is 0.32 %, lower than 10 %. It is clean sand according to the standards.

The retarder, SIKA REARDER (SIKA) contains phosphates. Setting retard is directly proportional to proportioning used. It is of amber colour and mixed with water before introduction into the mixer. Recommended use is 0,2 % to 2 % of the weight of cement.

The concrete accelerator, SIKA PRISE SC 2 (SIKA), is recommended to a proportion from 0.2 to 0.34 % of the weight of cement.

The first superplasticizer is the GLENIUM 27 (BASF), it is an chemical admixture not chlorinated of a chemical new generation based on modified polycarboxylic ether. The optimal effect is obtained by incorporation of GLENIUM 27 in concrete after the addition of 70 % of mixing water in the mixer. It is used from 0.3 to 2.0 % of the weight of cement.

The second superplasticizer is the SIKA VISCOCRETE 2100 (SIKA) which is a synthetic polymer, it appears as a liquid ready for use, of brown colour.

The waterproofing (SIKA) is a liquid of white colour. The air-entraining agent is micro air 111 (BASF), it gives concretes and mortars a good protection by creating extremely stable, small and tight bubbles of air.

Composition of mortars

The various mortars have all the same composition of a normal mortar, which is composed in weight of one part of cement, three parts of sand and a half part of water. They are thus different only by the type of additive and its proportion.

The dimensions of samples are according to the type of test. Samples 4x4x16 cm were used for loss of mass, cubic samples 15x15x15 cm for the water permeability and cylindrical samples (diameters 15 cm and thickness 5 cm) for air permeability. Three different dosages (min., moy. and max.) correpond to minimal, medium and maximal dosage of each chemical admixture recommended by the manufacturers (table 3).

Table 3. Denomination of mortars and chemical admixtures proportions

Denomination of mortars	Proportions of chemical admixtures (%)		
	Min.	Moy.	Max.
M.T (witness mortar)	0.0	0.0	0.0
MRT	0.2	1.1	2
MAC	0.2	0.27	0.34
MSP1	0.3	1.15	2
MSP2	0.5	1.25	2
MHY	0.7	1.35	2
MMC	0.1	0.25	0.4

Porosity

The method mostly used is undoubtedly the measurement of porosity accessible to water and the apparent density by hydrostatic weighing. This simple, practical measurement is applicable on a variety of cement pastes, mortars and concretes. It is considered as the basis of any microstructural characterization or evaluation of the material's durability. It provides a total result ("total" porosity), an indicator of quality. Porosities, given according to the procedure recommended by the AFREM (AFREM, 1997), for different mortars tested are indicated in table 4. Samples were preserved in water during 28 days then heated in an electric oven to 105°C, until the stabilization of their masses.

Figure 1. Samples in oven

Water penetration test

Water is applied under pressure to the surface of the hardened mortar. Upon splitting the specimens, the water penetration is measured. The test must be carried out on of 28 days old samples and further. The water pressure should not be applied on the surface of the sample flushed by a trowel. Pressure of water is 500 ± 50 kPa. During test, we regularly observe the appearance of non exposed surfaces of the samples for noting a possible presence of water (NF EN, 2001).

Figure 2. Water permeability test equipment

Air permeability

It relates the displacement of a fluid without the effect of a pressure, it depends on the size of pores in which the fluid or the gas (Billard, 1997) moves. The equipment, a permeameter CEMBUREAU (Controlab, 2008), was conceived exclusively to determine the air permeability. It includes a measuring cell and a control unit (fig. 3).

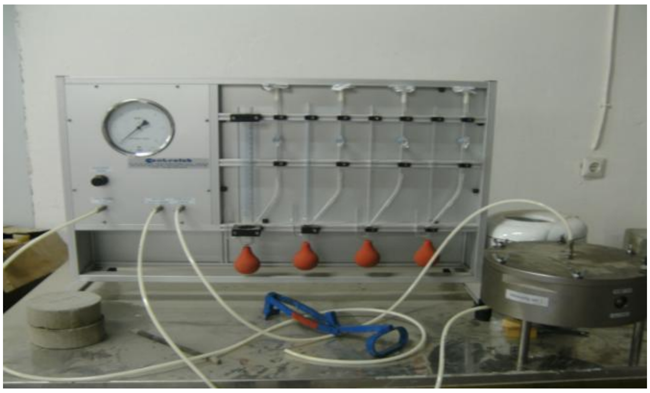

Figure 3. Air permeability test equipment

RESULTS

Accessible porosity

Table 4. Growing classification of mortar's porosity

N°	Mortar	Proportions of admixtures **Min.**	Mortar	Proportions of admixtures	
				Moy.	**Max.**
1	MSP2	3.45	MSP2	3.68	3.45
2	MSP1	4.06	MRT	5.07	4.06
3	MHY	4.55	MSP1	5.26	4.55
4	MRT	4.66	MHY	5.31	4.66
5	M.T	6.19	M.T	6.19	6.19
6	MAC	7.90	MMC	7.62	7.90
7	MMC	12.02	MAC	11.25	12.02

The temperature increase until 105°C causes evacuation of accessible free water, what causes a loss of mass, this represents accessible porosity.

The reference mortar has a porosity of **6.1%,** which has an acceptable accessible porosity (<than **10 %**).

Mortars with superplasticizers (**MSP1 and MSP 2**) present lowest porosities for the three proportions of additive. The lowest porosities for **MSP2 and MSP1** are respectively **3.45 %** and 4.06 **%**, they are obtained for **max.** proportions.

The same remark is to be made for the retarder. Porosities are lower than that of the witness mortar for three proportionings of additive. The less porosity (**4.6 %**) is obtained for the **max**. proportioning.

The waterproofing also causes lowest porosities than that of the witness mortar for the three proportions of additive. The lowest porosity (**4.55 %**) is obtained by the **max**. proportions.

The concrete accelerator led to porosities higher than the witness mortar. The most significant porosities were obtained for the mortar with air-entraining agent. They exceeded **12 %** for the **max.** proportioning.

Water permeability

The test of permeability described previously is conceived for concretes. After 72 hours of the testing, we note water penetration after rupture of samples by splitting, In the case of our study, some mortars break under the only the water pressure applied. To compare results, we proceeded differently for our tests. Methodology is divided into three stages of comparison of mortar's water permeability: the time of the total penetration of water (**h=150mm**), the time of the semi penetration of water (**h=75mm**) and penetration depth corresponding to a time of 3 mn (**t=3mn**). Tables 5, 6 and 7 summarize the results of the three types of measurements.

Table 5. Time of total water penetration (h=150 mm)

Proportions of admixtures	**Time (mn)**						
	Mortar						
	M.T	**MSP1**	**MSP2**	**MRT**	**MAC**	**MHY**	**MMC**
Min	5	397.42	-	2.83	2.00	10.17	16.33
Moy		1075.33	70.05	5.45	1.5	22.67	6.33
Max		696.75	1357.42	4.67	1	71.13	1.83

Table 6. Time of semi water penetration (h=75mm)

Proportions of admixtures	**Time (mn)**						
	Mortar						
	M.T	**MSP1**	**MSP2**	**MRT**	**MAC**	**MHY**	**MMC**
Min	2	70.33	-	1.70	0.90	5.75	10.50
Moy		440.25	26.83	3.27	0.67	10.83	2.83
Max		275.58	747.42	2.80	0.42	32.33	0.83

It is noted that important times of the two water penetrations (h=150mm and h=75mm) are those of the mortars with superplasticizers. This remark is valid for all proportionings.

The various mortars present certain proportionality between the proportioning and the time of penetration, except mortar **MMC**. In this last case, it is observed an opposite effect which is similar to the results of the porosity.

The retarder has less influence on the water permeability, while the concrete accelerator has a very harmful effect. They present very less times of all the mortars.

Mortar MSP1 presents an increase then a reduction in times of penetration with the increase in proportioning. What can imply that optimal proportioning, for permeability, is lower than proportioning **max**.

In end, we notice that times of the total penetrations (h=150 mm) and semi-penetrations (h=75mm) follow the same tendency.

Table 7. Water penetration at t = 3 mn

Dosage	**Water penetration (mm)**						
	Mortar						
	M.T	**MSP1**	**MSP2**	**MRT**	**MAC**	**MHY**	**MMC**
Min	85	10	-	-	-	17	80
Moy		5	24	65	-	20	-
Max		7	9	80	-	25	-

At **3 mn** of test, we note that the penetration is total in mortars with accelerator for all proportionings.

Mortars **MSP2** and **MRT** had the same result for proportioning **min**, while the mortar **MMC** present a total penetration for proportionings **moy.** and **max**. It should be also noted that all these mortars were broken during the tests under the only effect of the water pressure. These results confirm also total penetration of water where time necessary does not exceed 3mn **except** for the average proportioning **moy.** of mortar **MMC**.

Mortars with superplasticizers present the lowest penetrations. They correspond to 1/10 of reference mortar for proportionings max. The mortar with the retarder has a similar behaviour that witness mortar.

If the waterproofing confer to mortar impermeability better than the reference mortar (4 times less water penetration), there remains less performant than the superplasticizers.

Perméabilité à l'air

Air permeability is characterized by specific coefficient K, this coefficient is given by formula of Hagen-Poiseuille (Rilem, 1998 and Siad, 2011) :

$$K = \eta \frac{2 Q P_0 h}{A (P^2 - P_a^2)} \qquad (1)$$

Where:

- K: coefficient of permeability (m^2)
- h: height of sample in flow direction (en m)
- A: area of sample (en m^2)
- η: dynamic viscosity of gas test: air at 20°C $\eta = 1.82*10^{-5}$ (Ns/m^2)
- Q: gas flow in the direction of flow (m^3/s),
- P: absolute entry pressure (N/m^2),

- **P_a:** exit pressure (for this test, it corresponds to atmospheric pressure N/m^2),
- **P_0:** pressure with the which flow is measured in (N/m^2), here it is equivalent to the atmospheric entry pressure.

Table 8. Air permeability means coefficients of mortars

Proportioning	Permeability mean coefficient K (10^{-16} m^2)						
	Type of mortar						
	M.T	MSP1	MSP2	MRT	MAC	MHY	MMC
Min	37.66	4.53	4.15	40.43	54.97	22.04	66.08
Moy		1.21	0.34	38.63	59.47	3.01	74.15
Max		0.18	0.15	37.15	65.94	0.37	82.36

Permeabilities to air of mortars with superplasticizers are lowest for all proportionings. They are also influenced by proportioning where we notice a very significant decrease of permeability. Permeability with proportioning **max.** decreases until less than 4 **%** of that with proportioning **min**.

Mortars MSP1 and **MSP2 have** maximum permeabilities equivalent to **1/10** of that of the reference mortar. Mortar **MHY (**with waterproofing) has a permeability equal to 50**%** of that of reference mortar at **min.** proportioning and 1**%** at **max.** proportioning.

Mortars **MRT, MAC** and MMC **have** permeabilities more significant than that of reference mortar. Contrary to the other mortars, **MAC and MMC have** permeabilities which increase with proportioning. The effect of proportioning for these mortars is less significant than for the mortars with the superplasticizers and waterproofing. Mortar **MMC has** the important permeabilities to air.

DISCUSSION AND CONCLUSION

In this experimental study, we have quantified the effect of six types of chemical admixtures for some indicators of mortar's durability.

Superplasticizer 2 gives the less porous mortar. Accessible porosity is equal to **3.45%** for proportioning **max.,** where the reference mortar has a porosity of **6.19 %**. Chemical admixtures modifying the setting cause porosities more significant than that of the reference mortar.

But the most significant porosity is that of the mortar with the air-entraining agent, which is **12%** for proportioning **max**. The beneficial effect of superplasticizer 2 is confirmed with permeability tests to water, the total water penetration intervenes after **20 hours**. It intervenes after **5 minutes** of setting under pressure for the reference mortar.

The various mortars present certain proportionality between the proportioning and the time of water penetration except for mortar **MMC** where the tendency is reversed. If the retarder has only a less influence on the water permeability, the concrete accelerator has a very harmful effect. Time of penetration of **98%** compared to the witness mortar. The time of penetration falls of 98% compared to reference mortar.

The air permeability tests confirms beneficial effect of superplasticizers on the mortar's permeability. It presents the tenth of that of witness mortar for minimal proportioning. By increasing proportioning, the permeability strongly decreases compared to the witness mortar. The mortar with the waterproofing is much less permeable than the reference mortar especially with proportioning **max.**

The addition of the retarder does not have a notable influence on the air permeability as for the water permeability. The permeabilities of the mortars with concrete accelerator and air-entraining agent are higher than those of the witness mortar. This augmentation is proportional to proportioning. It varies from **46 % (**proportioning **min.**) to **75%** (proportioning **max.**) for concrete accelerator and from **75 %** (proportioning **min.**) to **218 %** (proportioning **max.**) for the air-entraining agent.

These results showed effect of the chemical admixtures tested on the properties of the mortars. This reveals that superplasticizers improved all the studied properties. The most falls of performances are those of the mortar with the air-entraining agent. If the retarder affects only very less properties of the mortars, the concrete accelerator especially has a negative role in term of permeability. The mortars with the waterproofing behave generally better than the witness mortar.

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