Effect of cellulose ethers on water retention in freshly-mixed mortars

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The Effect of Cellulose Ethers on Water Retention in Freshly-Mixed Mortars

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Abstract

Cellulose ethers are polymers frequently introduced into mortar formulations in order to improve water retention capacity and workability of the freshly-mixed materials. Physico-chemical parameters of these admixtures (molecular weight, granulometry, substitution degrees, etc) seem to have a strong influence on mortar water retention capacity. In this paper, the influence of cellulose ether molecular weight on mortar water retention and its consistency was studied. Moreover, a new method was used to evaluate mortar consistency, named Consistor Baronnie method. This method was confirmed with rheological measurements.
Keywords: cellulose ethers, consistency, mortar, water retention

Introduction

The factory made mortar industry produces today more than 100 types of mortars in Europe. These mortars are found in different forms and offer chemical and mechanical properties and characteristics specially fitted to very differing building and civil engineering constructions. Depending on the applications, factory-made mortars are mainly composed of mineral binders (cement, lime and/or gypsum), sands, aggregates and additives (e.g. fillers). To these major ingredients, different kinds of admixtures, mostly organics, are added in order to bring some particular properties to the mortar, from the fresh paste to the hardened material [1-5]. Water retention is the property of a mortar that prevents the rapid loss of water to masonry units of high suction and prevents "bleeding" or "water gain" when the mortar is in contact with relatively impervious substrate. Water retention is an important property of mortar and affects workability and bond (durability, completeness, and strength) between mortar and masonry units. Water retention is affected by the formulation of the mortar (both cementitious and aggregate) and may be increased through the use of some organic admixtures. Cellulose is a common material in plant cell walls and it is the most abundant form of living terrestrial biomass. These polymers are widely used in many fields of application. The hydroxyl groups of cellulose can be partially or fully reacted with various chemicals to provide derivates, such as cellulose ethers, with useful properties. Among them, hydroxyethyl methyl cellulose (HEMC) are widely used in food industry, pharmaceutical industry and building materials. These admixtures constitute one of the most suitable molecules to improve mortar water retention [6, 7], and its workability while they induce hydration delay. The mechanism by which the cellulose ethers affect the cement hydration was reported in literature [8, 9]. However, the effect of such polymers on the mortar properties at the fresh state (water retention and consistency) is not well understood.

The objective of this paper is to evaluate the effect of HEMC on mortar water retention and its consistency. The consistency was assessed using Consistor Baronnie method and steady rate rheology. A correlation between both methods was attempted.

Experimental

Materials

Experiments were performed using a laboratory-made mortar, called "CEReM mortar", composed of Portland CEM I 52.5 R cement (30% wt.), siliceous sand (65% wt.) and calcareous filler (5% wt.), to which CE was added (0.27% wt. in addition to the above dry mix). Cellulose ethers (CE) are water-soluble polymers derived from cellulose. Nowadays, they are systematically introduced into mortar formulations, in order to improve both water retention and workability of the fresh paste. Among the wide variety of existing CE, three types are mainly used in mortar manufacturing: hydroxypropyl-methyl cellulose (HPMC), hydroxyethyl-methyl cellulose (HEMC) and hydroxyethyl cellulose (HEC). Such polymers are characterised by three parameters: the molecular weight (noted as Mw) and two substitution degrees: DS (degree of substitution, the average number of hydroxyls substituted per anhydroglucose units) and MS (molecular substitution, the average mole substituents per anhydroglucose units). In our paper, eleven CE have been studied: four HEMC, noted as C and seven HEC, noted as H. Their molecular weights and the contents of substitution groups are detailed in Table 1.

Table 1 Molecular parameters of the selected cellulose ethers.

Cellulose ether	Mw (KDa)	DS	MS
MHEC C1	80	1.8	0.15
MHEC C2	180	1.7	0.15
MHEC C3	310	1.7	0.15
MHEC C4	380	1.7	0.15
HEC H1	45	-	1.9
HEC H2	140	-	2.0
HEC H3	275	-	2.2
HEC H4	430	-	2.3
HEC H5	720	-	2.4
HEC H6	770	-	2.4
HEC H7	790	-	2.4

Water retention measurements

Water retention was measured following two different standards: DIN 18555-7 Standard [10] and ASTM C91 Standard [11]. For the first one, experiments had to be performed 5 minutes after mixing and consisted in measuring the lost water of a mortar in contact with a filter paper. For the second one, the test was performed using the apparatus described in the ASTM C.91 Standard. 15 minutes after mixing, the mortar was subjected to vacuum (50 mmHg) for 15 minutes (Fig. 1).

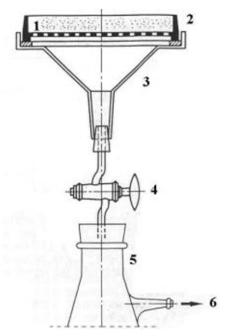

Fig. 1 ASTM test device to determine water retention of mortars. 1: fresh mortar; 2: perforated dish; 3: funnel; 4: tap; 5: flask; 6: to air vacuum.

Consistency measurements

Mortar consistency was assessed by two methods: the Consistor Baronnie method [12] and the steady rate rheology. The first one consisted in 10 stainless tubes with diameters ranging from 10 to 55 mm. They were marked from 1 to 10 and the aim of the experiment was to find the largest tube for which the paste did not slide before 5 seconds. Mortar consistency was given by the number which corresponded to the largest tube. This method need to be confirmed with more rigorous rheological measurements. For the rheometry tests, experiments were carried out with a Rheometrics Fluid Spectrometer RSFII with Vane geometry [13]. Rheograms represented the evolution of shear stress (τ) versus the shear rate (γ), and were fitted with Herschel Bulkley model [14]:

$$\tau = \tau_0 + K \cdot \dot{\gamma}^n \qquad (1)$$

where: K represents the consistency coefficient, τ_0 the yield stress and n is the flow behaviour index. When $n = 1$, the formula reduces to the Bingham model. The shear-thinning behaviour associated with $0 < n < 1$, and the unusual shear-thickening behaviour with $n > 1$.

Results and Discussion

First, a correlation between the results from two standards was established (Fig. 2). CE improved mortar water retention. Indeed, the ASTM retention capacity of the non-admixed mortar in next to 65%. Both methods were well correlated (r^2 = 0.99). Moreover, the results obtained with ASTM method slightly overrated the DIN ones.

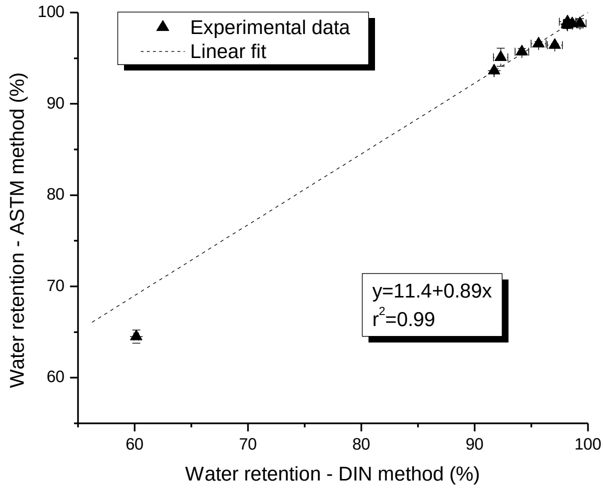

Fig. 2 Correlation between water retention standard methods.

Then, the effect of molecular weight was studied using two different panels of molecules. For HEMC C, substitution degrees were roughly constant among the group, thus only one parameter varied: Mw. For HEC H, we consider that MS variations were less important than the Mw variations. Therefore, with this group, the water retention was also studied as a function of CE molecular weight. For HEMC C, while Mw increased from 80kDa to 380kDa, mortar water retention increased from 93.6% to 98.3% and mortar consistency increased from 1 to 3. As a result, for HEMC, an increase in polymer molecular weight leads to an improvement of both mortar water retention and consistency. Concerning HEC family, when Mw increased from 45kDa to 790kDa, mortar water retention increased from 95.1% to 98.8% and mortar consistency was improved. Consequently, for both CE families, the higher polymer molecular weight, the better the mortar water retention and its consistency. This can be explained by the CE capacity to form with water an aqueous phase with a higher viscosity [7, 15], [16]. Consequently, a high molecular mass admixture would lower the water mobility with the result that the water retention would be increased.

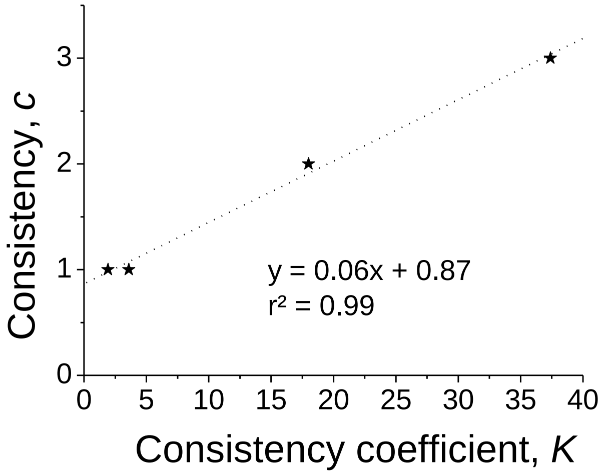

Fig. 3 Correlation between Consistor Baronnie method and rheometry.

A correlation was attempted between Consistor Baronnie results and consistency coefficient obtained with rheometry (Fig. 3). With Consistor Baronnie method (CBM), the consistency c ranged from 1 (for C1) to 3 (for C4), while the consistency coefficient K varied from 1.92 (for C1) to 37.4 (for C4). Variations of the consistency c and the consistency coefficient K were similar, thus confirming the validity of the use of our method, CBM. Moreover, the correlation between both methods was established and the correlation coefficient was equal to 0.99 (Fig. 3). Consequently, BCM can be used to estimate mortar consistency. Besides, this method is very easy and quick to set up.

Conclusions

This paper reviewed the effect of cellulose ether molecular weight on mortar water retention and its consistency. The results demonstrated that the molecular weight is a crucial parameter in a given polymer family. It was noted that, as the molecular increased, both water retention and consistency were improved. Moreover, it has been shown that consistency assessed with the Consistor Baronnie method was well-correlated to the rheological parameter (more particular, to the consistency coefficient).

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