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Strength and hygric properties of ETICS applied at various temperature, using adhesives with different cellulose ethers

Strength and hygric properties of ETICS applied at various temperature, using adhesives with different cellulose ethers

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Abstract. The ETICS comprises a prefabricated insulation product bonded to the wall or a combination of adhesive and mechanical fixings. The insulation is faced with a rendering consisted of one or more layers (site applied), one of which contains a reinforcement. Adhesives used for bonding the insulation to the wall and base coat include cellulose ethers. These chemical compounds are used in building materials as thickeners, binders, film formers, and water-retention agents. Cellulose ethers influence on the physico-mechanical characteristics of a mortar. Temperature application and then conditioning of adhesives strongly affect the water retention. This paper presents a study on the impact of different temperatures on the setting and hardening adhesives with three types of cellulose ethers (HEC, HPMC and HEMC). The tests included water retention in freshly – mixed mortars and bond strength between the adhesive and substrate in mortars. Water transport in freshly-mixed mortars containing cellulose ethers were examined with classical and new methods Time Domain Reflectometry. During the laying and curing time the ambient temperature was hold on to 5±2 ºC (reduced), 23±2ºC (standard), 30±2ºC(increased) in the relative humidity 50±5% or 80±5%. Adhesives were cured for 4 weeks. The pull-off test was performed on the following samples: without supplementary conditioning (dry condition) and after immersion of the adhesive in water for 2 days and 2 h drying at laboratory conditions. The tests were performed on the substrates: a smooth concrete slabs and the expand polystyrene insulation boards. The hygric properties were measured in the sample thickness 12 mm and 9 mm during the first 24 hours.

1. Introduction

Mortars in ETICS systems contain the two most important admixtures: redispersible polymer powder and one of three types of cellulose ethers. The redispersible polymer powder primarily improves adhesion to the substrate. Cellulose ethers increase viscosity and water retention in thin layers of mortar. The evaporation of water in the materials depends on the temperature and the relative air humidity. The paper presents the influence of temperature on water retention during bonding of cement mortar.

2. Materials

A typical adhesive formulation was used to investigate the effect of three various types of cellulose ethers (HEC, HPMC and HEMC) on the physico-mechanical characteristics of a mortar. The following commonly applied materials were used in the investigations over adhesives for ETICS. Basic adhesive composition shown in table 1 did not contain cellulose ethers.

Table 1. Mix design for basic adhesive "0".

Component	Content (*% mass of dry mixture*)
Portland cement CEM I 42.5 R	20.0
Quartz sand with a grain size of 0.1–0.5 mm.	65.8
Calcium carbonate fine powder with a grain size below 0.1 mm.	12.2
Redispersible powder consisting of copolymer ethylene and vinyl acetate (VAC/Et)	2.0
Cellulose ether	-

The properties of the cellulose ethers depend on both the molecular weight of the polymer and on the degree of etherification. The mechanical properties of the ethyl cellulose are reported to be influenced more by the former, whereas other physical properties such as solubility and water absorption are influenced more by the latter [1]. This information is not usually provided as it is considered to be confidential by manufacturers. It has been demonstrated that the average molecular weight of the polymer is linked to its solution viscosity, when it is dissolved in water at a set concentration and reference temperature [2].

Three sets of cellulose ether were selected: hydroxyethyl cellulose (HEC), methyl hydroxyethyl cellulose (MHEC), hydroxypropyl methyl cellulose (HPMC). Data of the cellulose ether (viscosity - in solutions 2%, method Brookfield RV 20 rpm) and content in adhesive are summarized in table 2.

Table 2. Composition of adhesives with content of cellulose ethers and water.

Name	Component name (-)	Viscosity (*mPa·s*)	Content of (*% mass of dry mixture*)	Water/powder ratio (*% mass of dry mixture*)
Adh 0	-	-	0.0	16
Adh 1	HEC	20 000	0.2	20
Adh 2	MHEC	30 000	0.2	18
Adh 3	HPMC	7 000	0.2	18

3. Methods

3.1. Test condition and mixing of the adhesive

Standard conditions were maintained at (23 ± 2) °C and (50 ± 5) % relative humidity and a circulation of air in the testing area of less than 0,2 m/s. After application mortars were cured for 4 weeks at temperature 5±2ºC (reduced) in the relative humidity RH 80±10%, 23±2ºC (standard) in RH 50±5%, 30±2ºC (increased) in 50±5%. At the same temperature retention capacity and adhesion tests were performed. The samples were stored in three different climate chambers (Uni-Mors, Weiss Technik C1000, ITEPIB Radom).

The amount of water required for preparing the adhesive was stated in proportion to weight (e.g. the amount of liquid, in kilograms and the amount of powder, in kilograms). A minimum quantity of 2 kg of the adhesive was prepared in a mixer of the type described in 4.4 of EN 196-1 [3], using the slow speed settings, (140±5) r/min mix for 30 s; scrape down the paddle and pan within 1 min and next (62±5) r/min planetary movement for 1 min. The adhesive was left at rest for 5 minutes before a final 15 s homogenization.

3.2. Consistency
Water/powder ratio was established experimentally at level 120 – 140 mm by flow tables for mortar and building lime [4]. The flow was measured in two directions.

3.3. Water retention
The fresh mortar with accepted level of consistence was subjected to a suction treatment under defined conditions using filter paper as a substrate. The water retention of the mortar is the mass of water retained in the mortar after the suction treatment and is expressed as a percentage by mass of its original water content [5].

The adhesive was poured into ring previously placed on a filter paper and non-fibrous textile. The assembly was weighted and covered with a plastic plate, next left to stand for 5 minutes. Water retention capacity WRV (in %) was calculated according to Eq. (1)..

$$WRV = 100 - \frac{W_3}{W_2} \times 100 \tag{1}$$

where: W_2 - the mass of water in the mortar,
W_3 - the mass of water absorbed by filter paper as a substrate.

3.4. TDR method for the measurement of water content
The Time Domain Reflectometry (TDR) method for the measurement of soil water content becomes more and more popular because of its simplicity of operation, accuracy and non-destructiveness, as compared to other methods [6,7]. This measuring technique takes advantage of three physical phenomena characteristic to the materials, i.e.:

- in the frequency range of 1 GHz the complex dielectric constant of the material is reduced to its real value and the electromagnetic wave propagation velocity, v,
- a dielectric constant of the material liquid phase has much higher value than other phases, i.e., about 80 against 2÷4 for the solid and 1 for the gas phase;
- the relation between the material moisture and its dielectric constant is highly correlated [8,9].

TDR measurements were made using LP/ms Laboratory Operated Meter (LOM) probes and TDR/MUX Integrated Measuring Module produced by E-Test company under the license of the Institute of Agrophysics, Polish Academy of Sciences in Lublin. The measuring system was calibrated with water and ethocel as calibration media, according to the manufacturer instructions [10]. All samples were 9 mm thin and surface that allowed complete immersion needles length of 52 mm. The results were then correlated with the initial water content and after test with the adhesive dried to constant weight.

3.5. Bond strength test between adhesive and substrate
The tests were performed on the following substrates:

- A substrate consisting of a smooth concrete slab at least 40 mm thick. The water/cement ratio was contained in the range of 0.45 to 0.48. The tensile strength of the slab was at least 1.5 N/mm². The moisture content of the slab prior to the test was a maximum of 3 % of the total weight.
- A substrate consisting of expanded polystyrene (EPS) foam sheet at density 19,5 kg/m^3.

The adhesive was spread on the substrate to a thickness of 3 mm and with an area of 19,6 cm². After allowing the adhesive to cure at three temperatures and corresponding humidity for at least 28 days, metal plates of appropriate size were bonded to it using a suitable adhesive. The pull-off test was performed at a tensioning speed of 1 to 10 mm/minute on the following samples:

- without supplementary conditioning (dry condition),
- after immersion of the adhesive in water for 2 days and 2 h drying at (23±2)°C and (50±5)% RH,

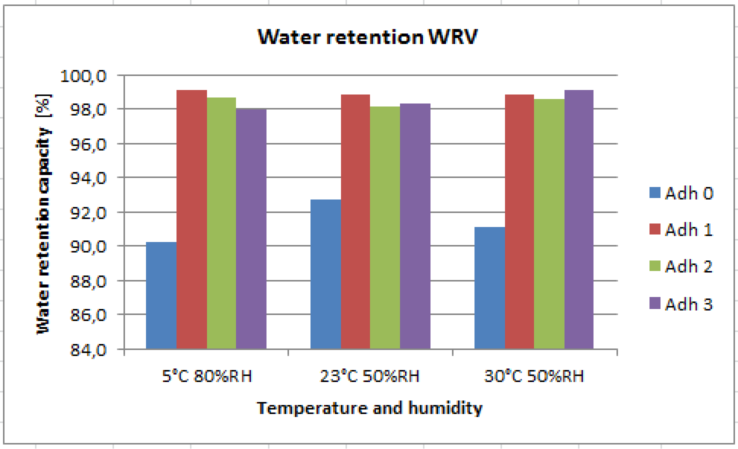
The individual and mean values were recorded and the results expressed in N/mm² [11].

4. Results

4.1. Water retention

Right amount of water is important for the proper setting of the cement in the adhesive. Water retention is essential especially if thin layers of mortar do not contain redispersible powder. The increase of water retention is interpreted as an increase of viscosity of the water phase in modified mortar. The standard EN instruct to the use of 12 mm thick discs. Result for adhesives are presented in figure 1.

Figure 1. Water retention capacity WRV (in %) at different temperatures and humidities.

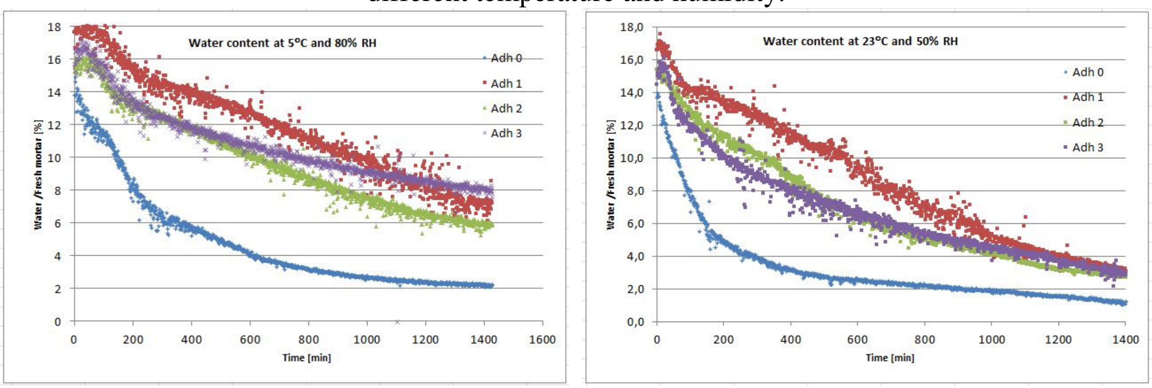


Before the test materials were stored in various appropriate conditions. Mortar without cellulose ethers kept the water at about 91% and the other materials at about 98%. At this thickness, in such a short time, the effect of temperature was small.

4.2. TDR method for the measurement of water content

The Time Domain Reflectometry was alternative method to weight method of water mass loss. One cannot use the precision balance in continuous measurement by vibration and low temperature in the climate chamber. The results of water content changes in the first 24 hours are shown in figure 2.

Figure 2. Changes in the content of water in the first 24 h at various temperatures and humidities.at different temperature and humidity.



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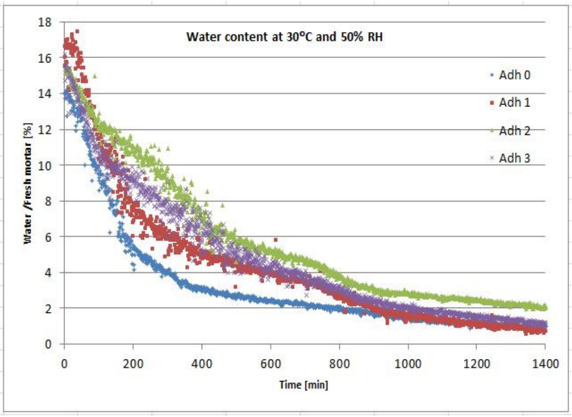


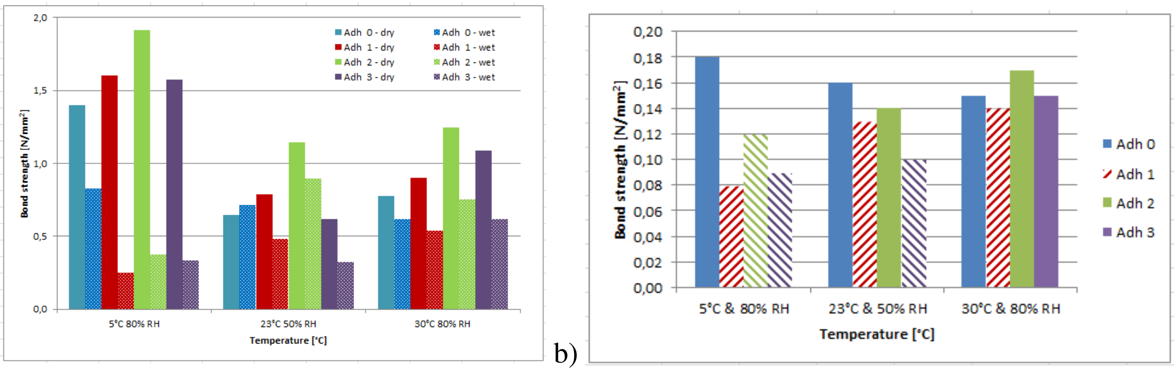
The initial water content in the mortar as wall as temperature and humidity had an impact on the obtained results. High humilities and low temperatures improved water retention in mortar. High temperature and low humidity increased water loss, but positive effects of the cellulose ethers were observed during the first six hours. The author observed effect of surface drying in adhesive with cellulose ethers. These admixtures sucked water from the surface to the interior of the mortar. Such a phenomenon was not observed in the mortar Adh 0, for which the surface remained wet for a long time.

4.3. Bond strength test between adhesive and substrate

Before applying the adhesive plate provided in appropriate chambers for 24 hours to obtain the desired temperature, one had to maintain a constant temperature and humidity; 5°C at 80±5% RH and 23°C or 30°C at 50±5% RH. After 28 days in dry condition and after immersion of the adhesive in water for 2 days and 2 h drying, samples were executed pull-off test (figure 3).

Figure 3. Bond strength adhesive to: (a) smooth concrete slab, (b) expanded polystyrene (EPS) foam sheet after immersion in water.

a) b)



Three types of failure were observed: Cohesive Failure within the Substrate (CF-S), Cohesive Failure within the Adhesive (CF-A), Adhesive Failure between adhesive and Substrate (AF-S). In the case of expanded polystyrene (EPS) in dry condition all damages were of type CF-S. The obtained results were contained in the range of 0,15 to 0,18 N/mm^2 and it was EPS tensile strength. In the case of the concrete slabs all failure types were CF-A. Hydration mortar after water immersion weakened adhesive but strength level is higher than EPS tensile strength. The situation was different when we had a wet mortar on EPS. Type of destruction depended on how much moisture was kept in the sample at the time of the test. Adhesive without cellulose ethers dried faster (method provides for two hours in a laboratory after removal from the water). In this case all destruction were of types of CF-S (solid fill in figure 3b). Lower temperature of storage caused destruction type AF-S (texture fill in figure 3b) for adhesives with cellulose ethers.

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5. Conclusions

Based on the results presented herein the following conclusions may be drawn:

- cellulose ethers change the plastic properties and consistency of the adhesive.
- temperature and humidity do not affect significantly on short time water retention WRV. Large differences are observed in mortars with or without cellulose ethers.
- TDR method allows the observation of changes in the amount of water in the long term. Character of change is strongly dependent on humidity and temperature in the first 24 hours. The hygral properties are especially important in thin layers of mortar. The pure cement mortar (without any chemical admixtures) quickly evaporates the water, lack of it later in the hydration process.

6. References

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