



Behavior Analysis of One-Component Waterproofing Mortars by Mechanical and NMR Investigations

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Abstract. Waterproofing mortars are used for many applications in the field of construction. The behavior of waterproofing mortars, after application on surface, is different due to the use of aggregates and polymers from different sources, even if it satisfies the waterproofing needs of the substrate and meets quality standards. Measurements performed at 3, 7 and 28 days by mechanical tests combined with Nuclear Magnetic Resonance (NMR) relaxometry highlight the physical and mechanical properties of the mortar in relation to the presence of hydration water and water in small, medium and large pores. During the 28 days of hydration, the size and homogeneity of the pores change radically so that the mortar becomes more resistant to compression and flexural tensile.

Keywords: One-component · NMR · Waterproofing

1 Introduction

On the market of building materials there is an important category of mortars that provide protection against water, this is represented by waterproofing mortars. The recipe of such a mortar is similar to that of a classic mortar, the difference is the type of polymer used and the method of application on the designated surface. Depending on the application method, waterproofing mortars can be classified as one-component or two-component.

This paper presents the characterization of one-component mortars by traditional methods complemented by NMR investigations. The samples are prepared on site by adding water according to the statements of each producer.

They were chosen from three one-component waterproofing mortars, currently sold on the Romanian market and which are used for protection against moisture of surfaces where water comes from outside to inside (positive pressure), applying only on mineral substrates (concrete, masonry bricks or cement-based plasters). Typical examples of use of waterproofing mortars are: drinking water tanks, foundation walls, wet areas, elevator shafts, underground passages, irrigation canals.

Through the investigations carried out for this study, three objectives were pursued. The first objective was to analyze the evolution of the mechanical strengths of the mortars during 28 days in relation to the amount of hydration water of the aggregates. The second objective was to characterize the distribution of water in the pores by observing the changes of the distribution of transverse relaxation times (T_2). The third objective was to extract from the homogeneity of the pores the best receipt to obtain the waterproofing effect of the mortar.

2 Materials and Methods

2.1 Materials

The materials used are one-component waterproofing mortars. These are based on Portland cement, fine aggregates, additives and polymers in the form of redispersible powder. Each of the components of the waterproofing mortar has a very important role in the workability required during application or in ensuring the protection against water.

Unlike a classic mortar, the waterproofing mortar is applied in thin layers, of maximum 2 mm, so that the size of the aggregates used must be less than 0.5 mm. The chosen additives are stabilizers or emulsifiers of mortars and are in the form of antifoaming or surfactant agents. In all of three types of investigated waterproofing mortars, the type of polymer used was based on latex, in an elastomeric or thermoplastic redispersible form. The role of the polymer is i) to prevent the formation of cracks due to the agglomerated structure of calcium silicate hydrates and calcium hydroxide bound together by the weakest van der Waals forces [1], ii) to have adhesion and iii) to form a matrix structure that stops water infiltrations.

Table 1 presents the three waterproofing mortar recipes analyzed in this paper. An equal amount of powder and water were used to perform the tests, according to the specifications of each mortar.

Table 1. Type of mortars.

Type of mortar	Powder [kg]	Water [l]	Water/Powder ratio
C65	1.8	0.446	0.248
P88	1.8	0.396	0.22
AQ	1.8	0.594	0.33

2.2 Methods

The time evolution of the waterproofing mortar's physical properties was investigated using modern ^1H NMR relaxometry methods to get the distributions of transverse relaxation times which were associated with various pores [2].

NMR measurements were performed with the low-field NMR Bruker Minispec spectrometer working at the proton frequency of 19.69 MHz. The transverse relaxation time (T_2) was measured by the CPMG (Carr-Purcell-Meiboom-Gill) pulse sequence [3–5] with 3000 echoes and 0.07 ms echo time. To enhance the signal-to-noise ratio, the number of scans was set at 1024. For the determination of the T_2 transverse relaxation time distributions, the acquired CPMG decays were analyzed using a Laplace inversion algorithm. This technique was developed for the characterization of relaxation in porous materials [6–10].

The mechanical strengths were determined on prismatic specimens ($40 \times 40 \times 160$ mm) using a hydraulic press, according to [11]. This were determined at 3, 7 and 28 days. The NMR measurements were performed on the same samples (or part of samples) subjected to flexural tensile and compressive strengths measurements, procedures which leads to the sample's failure [2].

3 Results and Discussions

The distribution of relaxation times T_2 for waterproofing mortars is presented in Fig. 1. At a first analysis it can be seen that all three types of waterproofing mortars have the distribution composed by 4 peaks. The amplitude, shape and linewidth of each peak provide information about the position and amount of water chemically bound to the

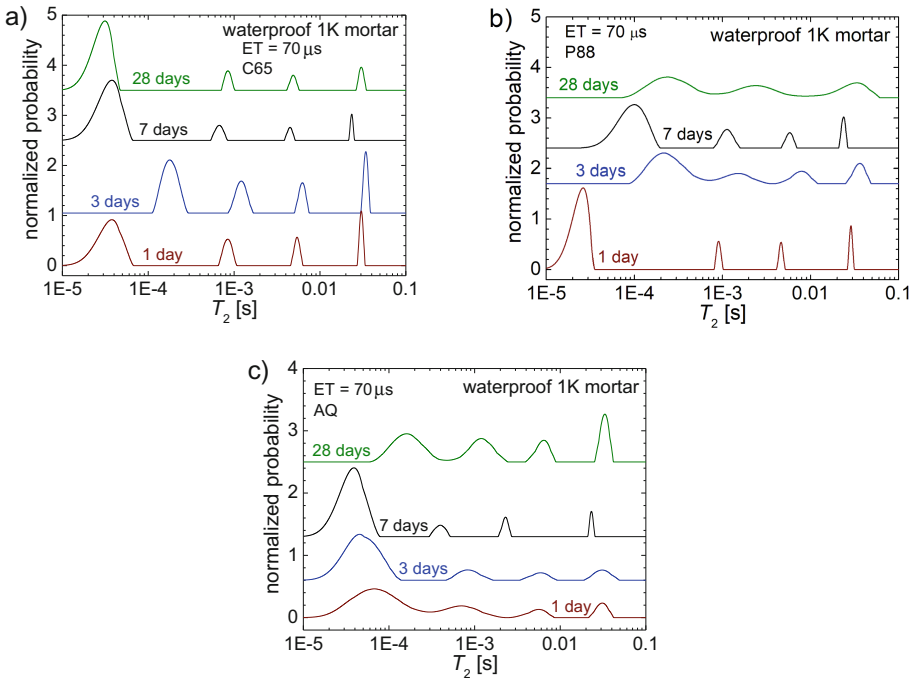


Fig. 1. Normalized probability of transverse relaxation time at 1, 3, 7 and 28 days after preparation for samples of waterproof 1K mortars: (a) C65; (b) P88 and (c) AQ.

aggregates and about the amount of water in the small, medium and large pores as well as their homogeneity and mobility. Although the general behavior is similar, the values of the relaxation times for each mortar show differences that are due to the amount of water used for preparation but also to the own recipe.

In Fig. 1a mortar C65 at 1 day after preparation has the highest amount of ^1H located as hydration water of the aggregates. At 3 days after preparation the distribution of T_2 relaxation times changes significantly, which can be associated with changes in the distribution of water in the pores. At 7 days after preparation the amounts of water are much smaller in small, medium and large pores, they change very little from day 7 to day 28.

Figure 1b presents the mortar P88 which, at first day after preparation, has quite rigid components, with homogeneous and well-defined pores. At 3 days, the distribution of relaxation times shifts to higher values, both for those associated to the hydration water and for pores. At 7 days, the mortar presents an increased rigidity, observed from the decreases of the T_2 -values associated to the hydration water and to the pores. Large pores are more homogeneous than medium and small pores. At 28 days, only 3 peaks are observed. Probably the small pores were merged with medium pores, phenomena observed from the wide measured distributions.

In Fig. 1c it is observed that at the first day after preparation, the AQ mortar show wide peaks, meaning a high heterogeneity for water used for the hydration of mortar's components and to fill the pores. At 3 days, the increase in homogeneity is observed by decreasing the width of the peaks, which leads also to an increase in stiffness. At 7 days after preparation the homogeneity and rigidity are increasing. At 28 days the distributions of relaxation times are very different compared to those measured previously, this is interpreted by a decrease in stiffness and increase in porosity of the mortar.

Figure 2 compares the distributions of the measured relaxation times for C65, P88 and AQ mortars at 28 days, when theoretically it is assumed that the mortar is hardened and with maximum qualities to ensure protection against water, so that no subsequent

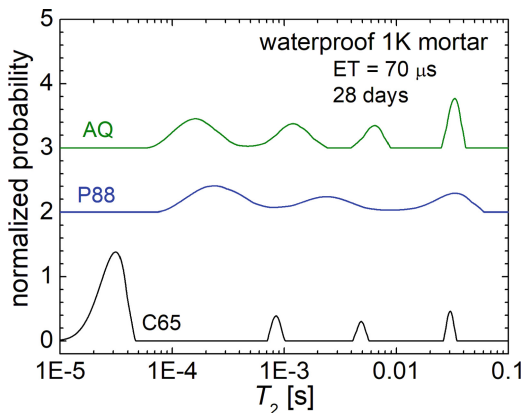


Fig. 2. Normalized probability of transverse relaxation time at 28 days after preparation for samples of waterproof 1K mortars.

evolution is expected. Even if the position and linewidth of the peaks is different for each mortar, the amounts of water in the integral areas are relatively the same.

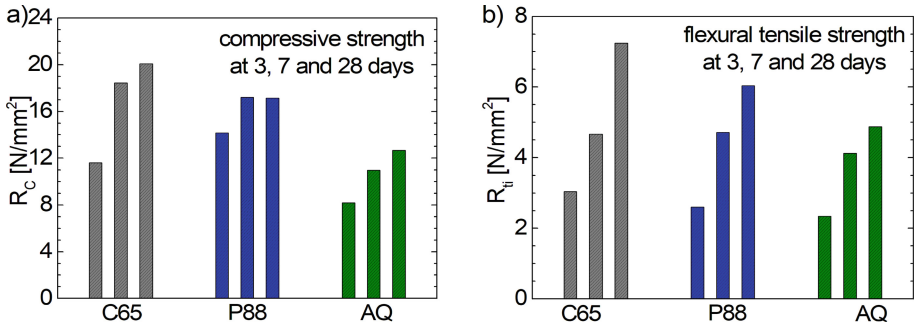


Fig. 3. a) Compressive strength measured for samples of waterproof 1K mortars at 3, 7 and 28 days after preparation; b) Flexural tensile strength measured for samples of waterproof 1K mortars at 3, 7 and 28 days after preparation.

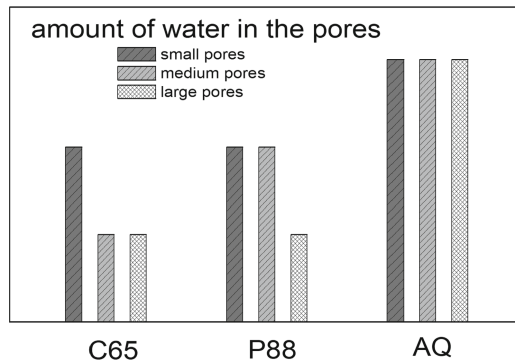


Fig. 4. Amount of water in the pores for samples of waterproof 1K mortars.

Compressive strength and flexural tensile strength were investigated starting with day 3 after preparation. The increasing evolution of the resistance to both compressive (Fig. 3a) and flexural tensile (Fig. 3b) can be observed at the three measured intervals. The mechanical properties of the mortars change less in the interval of 7–28 days compared to the changes measured for the interval 0–7 days. The most relevant mechanical parameter is the compressive strength. By comparison, at 28 days, the mortar C65 has the best compressive strength, followed by the mortar P88 and then the mortar AQ.

The evolution of the amount of water in the pores was measured by the method of NMR relaxometry at intervals of 1, 3, 7 and 28 days. The results show how the amount of water decreases the most in the first 3 days. In the interval of 3–28 days the amount of water is too small to change its proportion considerably.

In Fig. 4 is presented a comparison, at 28 days after the preparation of the samples. It is observed that there is a larger amount of water in the large, medium and small pores in the AQ mortar, followed by the P88 mortar and the C65 mortar.

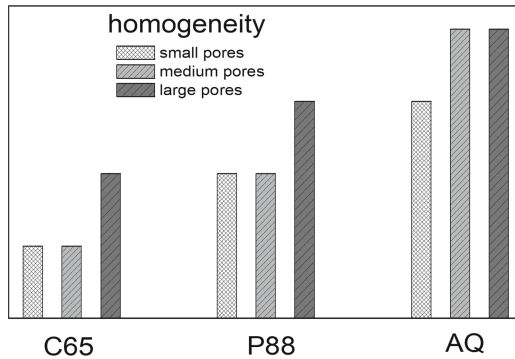


Fig. 5. Homogeneity for samples of waterproof 1K mortars.

The diversity of homogeneity in each type of investigated mortar within 28 days of preparation can be seen in Fig. 5. The most important information provided by this measurement is that the homogeneity at 28 days is less than that measured in the first day.

4 Conclusions

Carrying out investigations on waterproofing mortars and interpreting the results led to the following conclusions:

Both, the amount of hydrating water and the amount of water in the small, medium and large pores have an effect on the compressive strength of the mortar. As the amount of water decreases the compressive strength increases inversely proportionally.

The distribution of T_2 transverse relaxation times showed a change in pore size and homogeneity in all four-time intervals. The pore size changes due to the amount of water that decreases over time and the homogeneity differs quite a lot at the same interval for each mortar.

The lack of homogeneity at the end of the hardening period of the mortar may suggest that it has the desired waterproofing effect, due to the hydrating effect of the cement and the formation of the sealing matrix. For a more advanced analysis of this sealing effect, it is necessary to carry out investigations using SEM (Scanning Electron Microscope), this being one of the future objectives of the research team.

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