

The Dimensional Stability and Durability of Acrylic Resins for the Injection of Cementitious Systems

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Abstract

The dimensional stability and durability of Acrylamide- and Methacrylate-based acrylic resins have been studied. The dimensional stability was characterized by measuring the volume expansion of samples immersed in water for a period up to 240 days or by exposing the samples to 23°C and 50 %, 90 % relative humidity and by monitoring the shrinkage. The durability was investigated by exposing the resins to cyclic variations of temperature in air and in water. The resins generally exhibit a significant volume change up to 160 % of the initial volume when immersed in water or exposed to a relatively dry atmosphere (23°C and 50 %). A general increase in the material stiffness and/or crack formation on the surface of the resin is observed. On a long-term basis, the durability of the resins may significantly vary with occasionally a partial or complete deterioration of the some resins. A general better dimensional stability and durability is observed for the Methacrylate-based resins as compared to the Acrylamide-based resins.

Keywords: dimensional stability, durability, acrylic resins, injection

Introduction

Injection grouts are extensively used in the construction field for above- and underground applications, in particular to stabilize or strengthen soils or weak materials or to increase the water tightness of structures. The most common grout materials are cement-based. In the recent years, the rapid development of the material technology in the cementitious field, promoted the use of ultrafine and special cements and the addition of different materials such as filler and additives to the cement-based mixtures [1]. The advent of chemical additives significantly changed and improved the properties of the fresh and hardened injection materials. Superplasticizers [2], accelerators, air entraining agents and other additives and in general polymer modified cementitious

materials [3] significantly improved the properties of the injected mixtures. Among the different types of injection systems [1-3], polymer modified gouts, i.e. latex modified, appear to promote an increase in tensile and flexural strength, thus improving the cement-aggregate bond [4, 5].

To reduce or stop the water loss throughout a structure, acrylic resins are also used as one of the main injection materials. In this concern, modified grouts consisting of cement, clay, water, acrylic resins or methyl methacrylate co-polymer emulsions were recently investigated [6]. The addition of latexes improved, among other properties, the compressive strength, the shear bond strength and the resistance to wet-dry cycles [6]. Nevertheless, a lack of information exists on the dimensional stability and on the long-term behaviour of acrylic resins used as injection system in cementitious material.

The goal of this work is to study the dimensional stability and durability of different types of commercially available acrylic resins used to restore the water tightness of concrete structures.

Experimental

The acrylic resins either acrylamide or metacrylate – based, consisted of two main components. The single components prepared with the additive, were supplied ready to mix, in most of the cases, or required additional mixing according the mix proportions on the resin data sheets provided by the suppliers. The single components were then simultaneously mixed and poured in cylindrical plastic mould with a diameter of 5 cm.

RESIN	TYP OF RESIN
Resina A	Acrylamide-based resin 1 Components A, B – Producer 1
Resina B	Acrylamide-based resin 2 Components A, B – Producer 1
Resina C	Methacrylate-based resin 1 Components A, B – Producer 1
Resina D	Methacrylate-based resin 2 Components A, B – Producer 2
Resina E	Methacrylate-based resin 3 Components A, B – Producer 3
Resina F	Methacrylate-based resin 4 Components A, A'' Component A* Component B Component B' – Producer 3

Table 1. Type of acylic resins.

The dimensional stability of the resins during the time, in particular after water storage, was investigated by alternatively weightening the samples in air and in water followed by the calculation of the volume change similarly as described in the norm EN 14498 [7].

Three samples for each type of resin were measured. The dimensional change with time caused by the storage of the resins in a dry atmosphere (23°C and 50 % relative humidity) and in a water semi-saturated atmosphere (23°C and relative humidity > 90 %) was studied by measuring the shrinkage. The measurements were carried out for both atmosphere on two samples pro type of resin. The shrinkage was measured by placing the cylindrical plastic moulds on a metal plate and controlling the vertical length change with a length comparator. In this concern the measuring procedure was taken from the norm EN 12637-3, even though the measurements concerned the shrinkage [8].

The durability tests were carried out according to the norm EN 13687-3 with the following exposure conditions: 2 hours in water at 21°C ± 2°C, 4 hours in air at - 15°C ± 2°C, 2 hours in water at 21°C ± 2°C and 16 hours in air at 60°C ± 2°C [9]. In this concern, the visual aspect and the mass loss after the cycles were examined on three different samples pro type of resin.

Results and Discussion

The dimensional stability

The acrylic resins own their capability of sealing cracks to the volume expansion when in contact with water. Most of the investigated resins immersed in water exhibit a relatively rapid increase in the volume during the first 30 days. Afterwards the expansion levels off until 240 days. The volume remains relatively constant on a long-term basis for the resins E, F /AII + B, F /AII+BI, F/A+BI, A and C, while the resin D exhibits a volume decrease (Fig. 1 A). On the other hand, the resins F/A*+BI, F/A*+B and B, exhibit a continuous increase in the volume during time up to 200-250 % of the initial volume (Fig. 1A). A detail investigation at a early stage up to 30 days indicates a relatively limited volume increase for the resins C, F/A+BI and A as compared to the other resins (Fig. 1 B). The latter resins also exhibit a reduced increase in the volume on a long-term basis (Fig. 1A).

The resins exhibit a relatively high shrinkage in a dry atmosphere up to 30 days. The shrinkage values vary from 100 % up to 160 % (Fig. 2A). In a more water saturated atmosphere (23 °C / > 90 % relative humidity), the shrinkage up to 30 days is reduced for most of the resins to values around 5 %. Only the resin E reaches values up to 20 % (Fig. 2 B). Resins such as for instance F/A*+B, which exhibits a high volume expansion when immersed in water, indicates a general reduced shrinkage. That means, only a slight general correlation exists between the capability of the resins to adsorb water, i.e volume expansion, and the shrinkage.

Interestingly the different type of resins used in this study, i.e. Acrylamide or Methacrylate-based, exhibit a significant difference in the capability of adsorbing water and shrinkage. This significant difference in the stability is also observed within the Acrylamide or Methacrylate-based groups.

A visual inspection indicates that the resins immersed in water relatively maintain their original stiffness, except for the samples E and F/A*+B, where a significant reduction of stiffness is observed (Fig. 3-7). A significant colour change after immersion in water is observed for the resins B, C, D, F/A*+BI, F/A+BI, F/AII+BI. The resins subjected to shrinkage in a dry atmosphere do not generally exhibit a significant change in the colour. Nevertheless some resins, in particular the samples A and C exhibit the formation of cracks, and the resin E indicates a reduction in the stiffness (Fig. 3-7).

The durability

The durability of the resins investigated by cyclic exposure to different temperatures has been evaluated by visual inspections and by measuring the mass loss. The resins A, (Fig. 3), C (Fig. 4), E (Fig. 5) exhibit a significant deterioration after 24 cycles of exposure. The other samples (resins B, D, F/A*+B, F/A*+BI, F/AII+B, F/AII+BI) exhibit a general shrinkage as compared to the reference samples (Figs. 3-7). A general increase in the stiffness as compared to the reference samples is also observed for this latter resins and occasionally, small surface cracks are observed for the resins B, D, F/AII+BI, F/A*+B, F/A*+BI. Most of the resins exhibit a significant mass loss after 6 cycles of exposure (Fig. 8). In this concern, the main loss of mass is present at a early stage, while on a later stage, the mass loss is largely reduced. The resin A exhibit a decreased mass loss at a early stage, but at a later stage, the mass loss is large and the resin is almost completely deteriorated.

General remarks

Generally it can be stated that, the formation of small cracks during shrinkage or the partial deterioration of some resins after the durability tests cannot be directly correlated with a performance decrease in terms of sealing cracks in cementitious systems. Nevertheless, the advanced stage of deterioration, in particular for the resins A and C after the durability tests, makes this performance largely questionable. Furthermore, the volume expansion of the resins when in contact with water should be limited. A unlimited expansion within the cracks may cause an increase of pressure within the cracks, which may reduce the sealing performance of the resins.

Thus, the general dimensional stability of the resins, in terms of a controlled volume change when the resins are in contact with water or exposed to a dry atmosphere, appear to be generally high for the methacrylate-based resins D, F/A+BI, F/AII+B, F/AII+BI. Concerning the capability to withstand cyclic exposures to different temperatures in air and in water, these latter resins (except the resin F/A+BI, which exhibits an increased deterioration) exhibit a very limited deterioration.

On the other hand, the acrylamide-based (acrylamide: carcinogenic component) resins A and B exhibit a general reduced dimensional stability and durability, in particular with respect to the resistance to the cyclic exposure to the climatic conditions, to the cracks

formation within the resin during shrinkage (resin A), and to the expansion of the resin when in contact with water (resin B).

Conclusions

The resins in contact with water exhibit a relatively rapid volume increase within the first 30 days, which in some cases reach 160 % of the initial volume. Similar volume reductions are observed when the resins are exposed to a dry atmosphere.

The volume changes are occasionally associated with a change in the stiffness and/or the formation of surface cracks on the resins.

The cyclic exposure to different temperatures in air and in water may cause a general increase in the stiffness of the resins and in some cases an almost complete deterioration.

The Methacrylate-based resins exhibit a general higher dimensional stability and durability as compared to the Acrylamide-based resins.

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