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INFLUENCE OF PREPARATION METHOD OF POLYMER COATINGS ON THEIR MECHANICAL PROPERTIES

WPŁYW SPOSOBU PRZYGOTOWANIA POWŁOK POLIMEROWYCH NA ICH WŁAŚCIWOŚCI MECHANICZNE

A b s t r a c t

In order to prolong concrete durability, polymeric coatings are commonly used. The coatings protect concrete against ingress of hazardous media. The coatings have to be characterized by long-term weathering resistance, good adherence to concrete substrate and appropriate elasticity to have crack bridging ability. Ensuring appropriate homogeneity of the material is very important for obtaining high quality of hardened coating, especially while comparing some features of the material under laboratory conditions. The paper deals with comparison of some properties of acrylic coating such as displacement and damage energy depending on a preparation method (with and without deaerating) and a type of a agitator used.

Keywords: *concrete durability*, *concrete protection*, *polymeric coatings*

S t r e s z c z e n i e

W celu przedłużenia trwałości betonu powszechnie stosuje się powłoki polimerowe. Powłoki chronią beton przed wnikaniem niebezpiecznych mediów. Materiały te muszą charakteryzować się długotrwałą odpornością na starzenie, dobrą przyczepnością do podłoża betonowego i odpowiednią elastycznością, żeby posiadać zdolność mostkowania rys. Zapewnienie odpowiedniej jednorodności powłoki jest bardzo ważne dla uzyskania wysokiej jakości utwardzonej powłoki, zwłaszcza porównując różne cechy w warunkach laboratoryjnych. W artykule przedstawiono porównanie właściwości powłoki akrylowej, takich jak naprężenie, przemieszczenie oraz energia zniszczenia w zależności od metody przygotowania (z i bez odpowietrzenia) oraz rodzaju użytego mieszadła

Słowa kluczowe: *rwałość betonu*, *ochrona betonu*, *powłoki polimerowe*

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1. Introduction

Concrete is a very durable material if it is well designed and produced. Nevertheless, there are some environments in which concrete may deteriorate. In consequence, some properties of concrete may reach an unacceptable level faster than its assumed design life. Deterioration of concrete may be caused by different physical and chemical processes. They include cycles of freezing and thawing, leaching, carbonation, chloride penetration and sulfate attack. Acid attack can also lead to deterioration of concrete. In the presence of moisture, concrete can deteriorate by an alkali-silica reaction (ASR) if the aggregate is reactive. Mechanical or thermal stress as well as drying shrinkage can also cause concrete to crack. Moreover, cracks in concrete can appear due to improper structural support, movement of a building and/or motion of soil [1–3].

In order to prolong service life of reinforced concrete structures, some polymeric coatings are commonly used. Currently various materials are available for concrete protection such as polyurethane, epoxy and acrylic resins, silicones, silanes, latexes and chlorinated rubbers [3–6]. The type of materials has to be chosen depending on various exposure conditions, type of a structure etc. Before depositing coatings on concrete substrate, it should be cleaned in order to remove dust, partly old paint and ensure good adherence of the materials. Usually the surface is prepared using high-pressure water jetting or sanding. Then coatings are applied by brush, roller or spray gun. After applying and seasoning, the adherence of the materials to concrete should be at least 1 [MPa]. Moreover, they ought to be elastic enough to accommodate movement of cracks in concrete [7].

The paper deals with comparison of two methods used to mix water-borne acrylic coating by means of two different types of agitators. Previous author's experience with some acrylic coatings show that preparing material having homogeneous surface by means of a roller was not an easy task. After depositing a coating on a surface by means of a roller or a brush, the hardened material showed some irregularity. One of the factors influencing the above problem of the hardened coatings is mixing of liquid coatings. During the process some air is introduced into the bulk of the liquid. In consequence, the hardened material may possess worse parameters than expected due to a greater number of pores [8]. Hence, a choice of the mixing process and an appropriate agitator are very important. They both influence the properties of a hardened coating.

2. Experimental part

Two methods were used to prepare the specimens. One of them consisted in applying a vacuum pump and in case of the second method; the samples were prepared under standard pressure conditions. Regardless of the method used, the following procedure was applied: Liquid coating was poured into a tank and mixed mechanically for three minutes. Two different agitators were applied. Fig.1 shows pictures of both mixers used. One of them was a typical agitator used to mix coatings (a) and the second one had a shape of a spoon (b). The diameters of (a) and (b) were 5.8 cm and 5.0 cm, respectively.

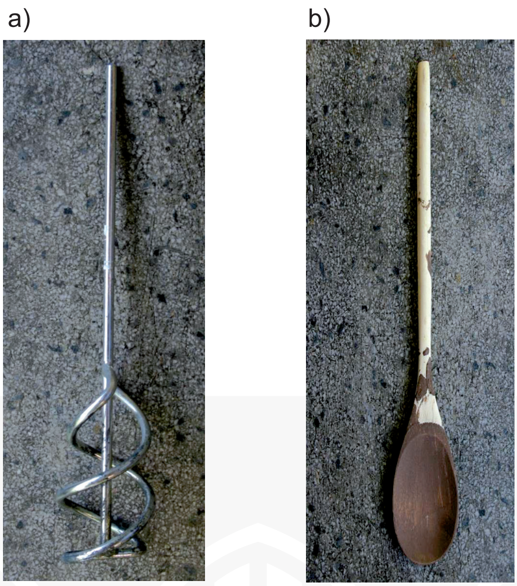

Fig. 1. Picture of two agitators used

The agitators were placed centrally in the tank (1 cm above its bottom) while mixing. The vessel was in the shape of a cylinder and was 10 cm in diameter. The agitation frequency was the same for both agitators used and was 60 rpm. Viscosity of the coating was 9000 [mPa·s] and temperature in the lab was 20°C ± 2°C. In order to determine a regime of agitation an impeller Reynolds number N_{Re} was calculated. It was 0.52 for the agitator (a) and 0.39 for the agitator (b), hence flow in the tank was laminar for both cases [9]. In case of a method using the vacuum pump, soon after mixing the coating, the vessel was covered with a cover in which the polymeric pipe was installed and connected to the pomp. In order to remove as much air bubbles as possible, the tank was put on a vibrating table while applying the vacuum of 1 bar. Then, the coating was placed in a mould covered with polymeric anti--adhesive agent and left for seven days at around 20°C for seasoning. Then the sheet of the hardened coating was taken away from the mould and dumb-bell specimens were cut out of the sheet by means of a special device. Fig. 2 shows the procedure of a sample preparation.

An elongation and a stress were determined according to PN-EN ISO 527-3 standard using Zwick 1445 universal machine. All specimens were tested with the same displacement

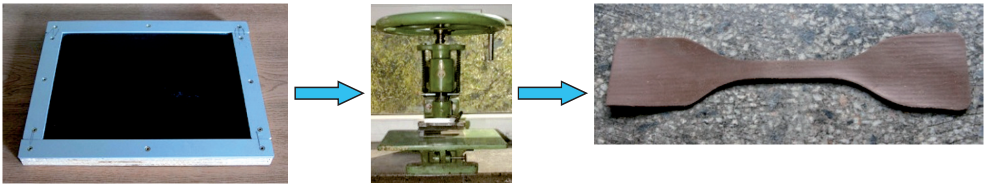

Fig. 2. Procedure of a sample preparation

control at rate of 50 mm/min. Total length l_3 of the dumb-bell sample was 115 mm, width of narrow parallel-sided portion b_1 and gauge length l_0 were 6mm and 25 mm, respectively. The Fig. 3 shows the shape of the dumb-bell specimen for mechanical tests.

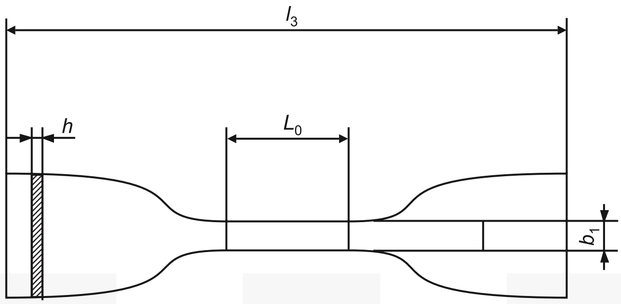

Fig. 3. Dumb-bell sample

During the tension test specimens were tested up to damage. Based on a relationship between stress and displacement damage energy was calculated by integrating the area under stress-displacement curve [10].

3. Test results

The specimens, which were mixed using the standard agitator and the spoon–shaped one were marked 1 and 2, respectively. Letters "a" and "b" describe the samples prepared without and with an application of vacuum, respectively. Table 1 shows values of maximum stress of the samples.

Table 1

Values of maximum stress of samples

	Maximum stress [MPa]			
No.	1a	1b	2a	2b
1	0.98	0.90	1.87	1.87
2	0.99	0.97	1.62	1.78
3	0.98	0.96	1.65	1.80
4	0.89	1.00	1.75	1.70
5	0.90	0.98	–	1.69
Mean	**0.95**	**0.96**	**1.72**	**1.77**

Test results show that an application of the spoon–shaped agitator has allowed obtaining much higher values of maximum stress. Fig. 4–7 show the graphs of force-displacement for samples 1a–1b and 2a–2b.

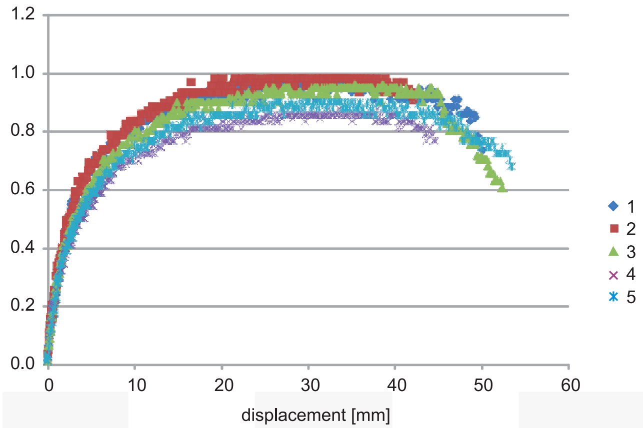

Fig. 4. Nominal stress-displacement relationship for samples 1a

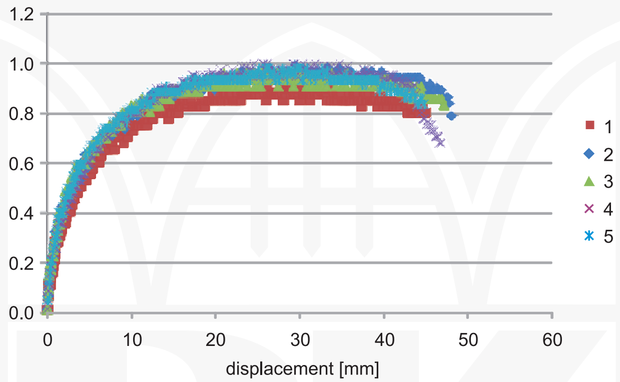

Fig. 5. Nominal stress-displacement relationship for samples 1b

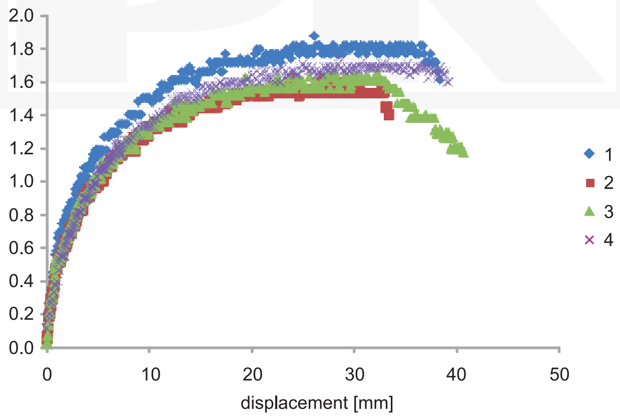

Fig. 6. Nominal stress-displacement relationship for samples 2a

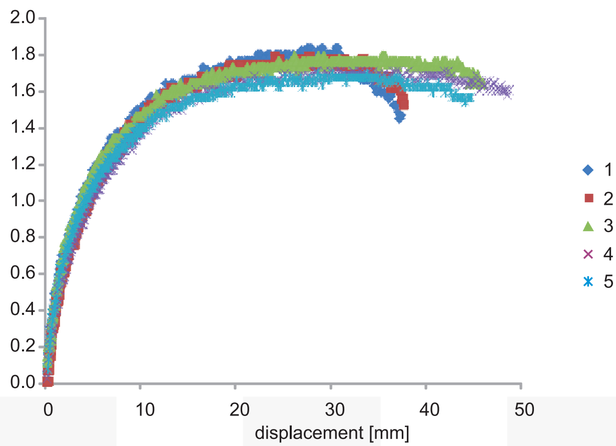

Fig. 7. Nominal stress-displacement relationship for samples 2b

Damage energy was determined based on integrating surface area under the nominal stress-displacement curves. Table 2 shows values of damage energy of the specimens. The energy shows how much energy has to be added to destroy the sample. The quantity is useful, since it gives some information on collaboration between a coating and surface. The higher energy, the more durable coating is.

Table 2

Values of damage energy of samples

	Damage energy [N/mm]			
No.	1a	1b	2a	2b
1	43.0	35.0	60.1	56.6
2	36.6	41.1	44.4	56.0
3	43.1	39.7	55.3	71.1
4	33.8	39.7	56.7	72.0
5	42.0	38.0	–	65.2
Mean	**39.7**	**38.7**	**54.1**	**64.2**

4. Discussion and conclusions

Test results showed that application various types of agitators influenced the mechanical properties of the coating tested. While mixing with a standard agitator, some air was introduced to the liquid material leading to a formation more pores and worsening of the properties of hardened coatings, which is illustrated by the maximum stress and the calculated damage energy. Application of vacuum has not improved the properties, which were within experimental error with samples prepared without vacuum. Much better results were obtained when spoon-shape agitators were used. In this case both maximum stress and damage energy were much higher whether the vacuum was used or not. Application of deaerating allowed improving damage resistance even more. It seems that the shape of the agitator had significant influence and the final results. Even though the properties of fresh materials fulfill requirements concerning the coatings applied on concrete using standard agitator, it appears that for the long run the coating can be less durable. Ensuring right homogeneity is especially crucial while comparing some properties of the materials under laboratory conditions. In some cases depositing coatings by means of the special machines is done according to PN-EN ISO 527 standard, but in this case properties of the materials can be compared only under laboratory conditions, since in situ the materials are applied usually by a roller or brush.

References

[1] Taylor H.F.W., *Cement chemistry*, 1997.

[2] Kurdowski W., *Chemia cementu i betonu*, 2010.

[3] Bassi R., Roy S.K., *Handbook of coatings for concrete*, 2002.

[4] Smith L. M., *Generic coating types. An introduction to maintenance coating materials*, 1996.

[5] Harwood P.C., *Surface coatings – specification criteria*, Protection of concrete. Proceedings of the international conference. University of Dundee, Scotland, UK. E & F.N., Spon 1990, p. 201-215.

[6] Hewlett P.C., *Methods of protecting concrete-coatings and linings*, Protection of concrete, Proceedings of the international conference. University of Dundee, Scotland, UK, E & F.N., Spon 1990, p. 105-134.

[7] Czarnecki L., Emmons P.H., *Naprawa i ochrona konstrukcji żelbetowych*, Wyd. Cement Polski, 2002.

[8] Sisti M.J., La Plante J. EN., *Process Performance: Effect of Agitation, Loading and Stabilizer Level*, EN Conference Proceedings, 1999.

[9] Perry R.H., Green D.W., *Perry's Chemical Engineers's Handbook* (7th Edition), 1997.

[10] Kozak A., Kwiecień A., Zając B., *Accelerated weathering tests of polyurethane mass for flexible joint to repair concrete and Masory structural elements*, 7th International Conference AMCM 2011, 13–15 June 2011, Kraków, Poland.