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ORIGINAL PAPER

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INFLUENCE OF THE CONDITIONS USED TO TEST THE CRACK BRIDGING ABILITY OF WATERPROOFING COATINGS ON THE ASSESSMENT OF THEIR DURABILITY

Barbara Francke[1]✉, Jarosław Siwiński[2], Volodymyr Trach[3], Mykola Khoruzhyi[3], Eugeniusz Koda[1]

[1] Faculty of Civil Engineering, Environmental Engineering and Architecture, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
[2] Faculty of Civil Engineering and Geodesy of the Military University of Technology, Military University of Technology, Warsaw, Poland
[3] Institute of Construction and Architecture, The National University of Water and Environmental Engineering, Rivne, Ukraine

ABSTRACT

The paper analyses the crack bridging ability of waterproofing coatings used beneath ceramic tiling bonded with adhesives in tests carried out using the test method specified in EN 14891. The study examines 11 products divided into 3 material groups: water dispersions, resin and cement-polymer coatings. The highest resistance in this respect is shown by resin coatings; the least effective are water-dispersion-based coatings. Unfortunately, most tested products do not guarantee waterproofing durability under the climatic conditions of Poland, cracking at elongations of less than 0.75 mm. In addition, it was established that a change in the test speed of the concrete-coating sets from 0.05 mm·min^{-1} (according to EN 1062-7) to 0.15 mm·min^{-1} (according to EN 14891) does not significantly affect the elongation at which the first damage occurs, especially at sub-zero temperatures. It is also not possible to draw conclusions about the ability of the coatings to bridge cracks in concrete from the results of mechanical tensile tests performed on thin films, e.g. in accordance with EN ISO 527-1 and EN ISO 527-3.

Keywords: crack bridging ability, waterproofing coatings, water dispersions, resin and cement-polymer coatings, research methods according to EN 14891 and EN 1062-7

INTRODUCTION

Most processes that destroy building materials occur in the presence of water or moisture, which is why structures must be protected against the ingress of rainwater and water accumulated in the soil (Henshall, 2016; Klem et al., 2026). The application of such protection helps ensure comfort in indoor spaces, which, in the case of buildings, indirectly affects the health and lives of their inhabitants. Each building should be protected against unwanted rainwater, water accumulated in the ground or on the surfaces of terraces and balconies, and water splashed onto the floors of 'wet' rooms and supplied by the plumbing system (Francke, 2022; Klem et al., 2026).

Barbara Francke https://orcid.org/0000-0001-9525-5468; Jarosław Siwiński https://orcid.org/0000-0003-4805-166X; Volodymyr Trach https://orcid.org/0000-0003-2409-4913; Mykola Khoruzhyi https://orcid.org/0000-0002-5314-0483; Eugeniusz Koda https://orcid.org/0000-0002-3895-960X
✉barbara_francke@sggw.edu.pl

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This article is devoted to assessing the durability of waterproofing in one of the above-mentioned areas of application, i.e. waterproofing layers on terraces and balconies, as the durability of this part of the covering determines the proper protection of the structure against water and moisture. Waterproofing layers can be made of various materials, including products applied in liquid form after drying to form continuous coating layers, which are the subject of the manuscript. On terraces, waterproofing coatings are usually installed beneath the ceramic tile layers as additional under-tile insulation, with the appropriate waterproofing layer placed below in the covering layers. They are only finishing layers that help drain some rainwater flowing onto the terrace's ceramic tiles; however, they do not guarantee watertightness or moisture resistance. Such coatings are applied mainly to concrete surfaces, and the interaction between the waterproofing layers and the substrate is also a major concern. So, during construction, such coatings are exposed to both the formation of shrinkage cracks in the concrete substrate and the expansion and closure of these cracks as thermal and humidity conditions change. Concrete has low tensile strength and tensile strain capacity, and cracking initiates at a tensile strain of about 0.1 $mm \cdot m^{-1}$, which is comparable to the drying shrinkage of concrete, about 0.6 $mm \cdot m^{-1}$ to 0.8 $mm \cdot m^{-1}$ (Dimmig-Osburg et al., 2006). Hence, cracks are almost unavoidable. Large crack widths are not aesthetically pleasing and may also lead to accelerated corrosion of reinforcement in severe environments, leakage in water-retaining/resisting structures, in sanitary conditions, or obstructions and interruptions in production processes. Cracking may be caused by externally applied forces, imposed deformations, shrinkage or thermal strains which are externally and/or internally restrained, or by a combination of these (Tonoli et al., 2011; Wetzel et al., 2012a; Zurbriggen & Herwegh, 2016). Cyclic movements of concrete cracks and/or joints can subject the waterproofing material to concentrated strain at the adhesion interface over time (Löfgren, 2007; Oh & Kim, 2021). For concrete structures, the design guide indicates a high probability of waterproofing failure at the movement joint (Löfgren, 2007; Oh & Kim, 2021). Furthermore, water migration through cracks in waterproofing coatings may lead to a gradual reduction in the durability of the concrete structure (Papadakis et al., 1991; Zhang et al., 2017). EN 14891 (European Committee for Standardization [CEN], 2017) is widely used to assess the crack bridging ability of waterproofing coatings used beneath ceramic tiling bonded with adhesives, at temperatures of 23 ±2°C, a relative humidity of 50 ±5% and an air speed in the working area of less than 0.2 $m \cdot s^{-1}$, as well as at temperatures in the range from −5°C to −20°C. The smallest crack width assumed for the assessment at which no damage to the waterproofing coating should have occurred by the end of the test should not be less than 0.75 mm, according to EN 14891. The authors' previous research experience indicates that only a few coating products meet the above requirement at sub-zero temperatures, raising doubts about the legitimacy of the test assumptions adopted in the standard (Francke, 2022). The value of the test speed adopted in EN 14891 for the assessment of crack bridging ability is particularly puzzling, as this value differs from the value adopted in EN 1062-7 (CEN, 2004a) for the assessment of the ability of concrete surface protection products to bridge cracks in the concrete substrate; these products are also intended to protect it against moisture. This fact may be the reason for negative results in tests of crack bridging ability in accordance with EN 14891, especially at sub-zero temperatures. In both research methods, only the area of the coating lying over the test crack formed in the rigid substrate (concrete) is exposed to tensile stresses. The two test methods mentioned are often used by manufacturers to evaluate the same coating products when declaring their performance properties, especially for cement-polymer products. The test speed specified in EN 14891 is on the order of 0.15 $mm \cdot min^{-1}$, whereas in EN 1062-7 for concrete repair products of Classes A2 and A3 – according to EN 1504-2 (CEN, 2004b) – it is three times lower at 0.05 $mm \cdot min^{-1}$. According to the classification in EN 1504-2, Class A3 products should effectively cover cracks wider than 0.50 mm. This class was adopted for comparison because, for products included in the higher class, i.e. A4, the requirement in this respect is much higher, at more than 1.25 mm. On this basis, Class A3 products should effectively cover cracks wider than 0.5 mm but not exceeding 1.25 mm, a range that includes the limit value adopted in EN 14891 of 0.75 mm. Based on the above values,

it was considered advisable to compare the test speeds used to assess crack bridging ability, since the standard requirements are similar (i.e. Class A3). Of course, when analysing the above research assumptions, it should be emphasised that the results of the assessments according to both of the above-mentioned standards can only be used for product characterisation, because the assessment is carried out for a single exposure to the relevant factors, while under operating conditions these factors act repeatedly on the applied coating, alongside the effects of other service conditions (Wetzel et al., 2012b).

Considering the mentioned limitations, in the first stage of the tests, an attempt was made to classify the product groups included in EN 14891 based on their susceptibility to damage caused by cracking of the concrete substrate on which they are laid. For research purposes, coating products were grouped into three types, in accordance with the classification (CEN, 2017; Francke, 2022) given in the harmonised standard EN 14891, i.e. dispersion (DM, dispersion liquid-applied water-impermeable products), cementitious (CM, cementitious liquid-applied water-impermeable products (Fu, 2011; Jiang, 2015), and reaction resin-based (RM, reaction resin liquid-applied water-impermeable products). In the second stage of testing, the results obtained were compared with the results of the crack-bridging test performed in accordance with the test methodology included in EN 1062-7, for selected polymer-cement products, to determine the differences in the test results of what would appear to be the same parameter, depending on different test speeds, and with the mechanical tensile properties determined on thin films of coatings removed from the release substrate, this time at much higher tensile speeds, i.e. 100 ±10 mm·min^{-1}. The examination of tensile mechanical properties at significantly higher tensile speeds than in the two above-mentioned crack bridging tests was aimed at checking whether the values obtained in this test can be used to draw preliminary conclusions about the suitability of the above-mentioned products for bridging substrate cracks. This test is typical of those performed by most laboratories, whereas the other two test methods require additional specialised equipment.

It has been established that under-tile coatings are, in most cases, resistant to cracking over cracks in the substrate slabs at positive temperatures but are not resistant to such loads at sub-zero temperatures. The highest resistance is shown by resin coatings, while the lowest is shown by coatings made of water dispersions. The resistance of coatings over the cracks of concrete slabs shows similar values when tested at different speeds below 1 mm·min^{-1}. It is not possible to draw conclusions about the ability of the coatings to bridge cracks in concrete from the results of mechanical tensile tests performed on thin films, e.g. according to EN ISO 527-1 (CEN, 2019) and EN ISO 527-3 (CEN, 2018). Due to the limited number of samples tested, these conclusions represent a preliminary assessment of the problem and set the direction for further research. To sum up, the main aim of the research presented in the manuscript was to set directions for further tests to assess the crack bridging ability of under-tile waterproofing coatings on terraces and balconies.

MATERIAL AND METHODS

Materials

After initial screening tests on different waterproofing coatings from the same three groups, i.e. dispersion liquid-applied products, reaction resins, and cementitious mortars, we selected 11 materials with technical characteristics common to the represented material groups. The product sets were numbered from 1 to 11 for the test, and their characteristics are presented in Table 1.

The tested products can be characterised as follows:

– CM – cementitious liquid-applied water-impermeable products (so-called cementitious thin-layer waterproofing mortars) – these polymer-cement mortars include cement, selected mineral aggregate with a grain size selected according to a specially developed screening curve, fibres, and specific additives (specially modified resins, hydrophobic compounds, etc.). This composition provides effective

waterproofing even in thin layers. Added to this is a water-polymer dispersion (or redispersible copolymer) that provides significant flexibility to the mortar after drying. An additional advantage of cement mortars is that they can be applied to wet substrates. These mortars set by hydration and drying.

– DM – liquid-applied water-impermeable products; they are solvent-free, consisting of water dispersion of polymers. They provide complete moisture protection and surface coverage even at layer thicknesses of 1.0 mm. They are characterised by good adhesion to various substrates and considerable flexibility. They dry through water evaporation.
– RM – reaction resin liquid-applied water-impermeable products; these are one- or two-component, solvent-free resins, consisting of synthetic resin components (usually based on polyurethanes), with the addition of fillers, pigments and modifiers; they provide substrate protection and watertightness when exposed to moisture and water in the presence of aggressive media. They are characterised by flexibility and very good adhesion to the substrate.

Table 1. Summary of the characteristics of the products used in test sets determined according to EN 14891

Set	Waterproofing coating type	Adhesion to concrete substrate [MPa]	Watertightness at 150 kPa for 7 days	Water absorption of coating after 7 days, weight increase [g]
1	DM	0.60	no leakage	6.33
2	DM	1.61	no leakage	2.80
3	DM	1.40	no leakage	0.55
4	DM	1.33	no leakage	1.00
5	RM	0.97	no leakage	0.15
6	RM	1.20	no leakage	0.16
7	RM	0.84	no leakage	0.47
8	CM	1.03	no leakage	0.49
9	CM	0.70	no leakage	0.70
10	CM	1.29	no leakage	11.60
11	CM	0.81	no leakage	10.50

DM – waterproofing coating made of dispersion liquid-applied products, RM – waterproofing coating made of reaction resins, CM – waterproofing coating made of cementitious mortars.

Source: own work.

All coatings for test samples consisted of two layers. Sets 8, 9, 10 and 11 were made of two-component products and Sets 1, 2, 3, 4, 5, 6, and 7 were made of one-component products. For two-component products, the ingredients were thoroughly mixed before applying the coating.

The test samples were divided into two groups:

1. In the first stage of the evaluation, according to EN 14891, samples consisting of 11 materials were used. Three separate sample batches (each consisting of three samples) were prepared from each tested material to test three exposure temperatures. Each of the test samples was composed of the following layers (in order of their arrangement):
   – Test substrate, i.e. mortar prisms (Fig. 1), made of CEM I 52.5R, silica sand, a high-range water-reducing admixture added to the mixing water at 0.5% of the cement mass, and mixing water. The binder-to-sand ratio in the mixture was 1 : 2 (by mass); $w/c = 0.45$. The test surface on which the coating was applied had the following dimensions: 40 ±1 × 132 ±1 mm.

– Waterproofing coating made of a liquid-applied waterproofing product, applied as described above on the two longer opposite surfaces of each sample.

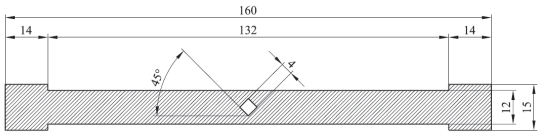


Fig. 1. Crack bridging ability test sample

Source: own work.

2. In the second stage of the research, two polymer-cement products (marked with numbers 8 and 11) were evaluated, from which the following were made:
   – Coatings applied to one side of concrete tiles with dimensions of 75 × 50 × 20 mm. The concrete met the requirements of EN 1766 (CEN, 2000) using the MC (045) standard mortar, with aggregate grains ranging from 0 mm to 8 mm. The test surface on which the coating was applied measured 75 × 50 mm. These samples were intended for crack-bridging tests in accordance with EN 1062-7.
   – Thin films formed on a release medium for testing the mechanical tensile properties according to EN ISO 527-3 and EN ISO 527-1.

Test methods

The purpose of the research was to assess the crack bridging ability of coatings at different temperatures and tensile speeds. The selected coatings were subjected to the following factors:

– Tensile strength of a coating applied to a concrete substrate (with a crack in the central part of the sample) at the test speed of 0.15 mm·min^{-1}, at temperatures of 23 ±2°C, −5 ±1°C and −20 ±2°C, according to EN 14891.
– Tensile strength of a coating applied to a concrete substrate (with a crack in the central part of the sample) at the test speed of 0.05 mm·min^{-1}, at temperatures of 23 ±2°C, −5 ±1°C and −20 ±2°C, according to EN 1062-7.
– Mechanical tensile properties of thin films removed from the non-stick substrate, as specified in EN ISO 527-3 and EN ISO 527-1 at a temperature of 23 ±2°C.

Crack bridging ability according to EN 14891 (Method A). The crack bridging test according to EN 14891 was performed under standardised conditions, i.e. at 23 ±2°C, and at sub-zero temperatures: −5 ±1°C and −20 ±2°C. The tests began with the assessment of the crack bridging ability, in accordance with point A.8.1 of the EN 14891 standard, on a computer-controlled Zwick Roell strength testing machine with a 10 kN load capacity head, with a tensile function operating at a speed of 0.15 mm·min^{-1}, without twisting or bending, using the samples described in point 1 (Fig. 1). The tested coatings were applied to two opposite surfaces of the substrates, in accordance with the manufacturer's recommendations, and then conditioned for 28 days under standardised conditions. After the conditioning was completed, the beams were pre-scored on the mortar wall above the square hole, without damaging the coating, and then placed in the holders of the testing machine (Fig. 2). The first stage of the test was to apply an initial tensile load of 20 N, set the elongation to zero position and then start tensile loading. The test was completed when the first damage occurred on the coating surface, as evidenced by a sudden drop in force on the computer monitor. The elongation was read with an accuracy

of 0.01 mm. The result is the average of three measurements. The test of the ability to bridge cracks at low temperatures, in accordance with Clause A.8.2 of EN 14891, was carried out at a temperature of −5°C and at a very low temperature of −20°C. The test substrates and sample preparation were identical to those used in the crack bridging method under standardised conditions. The difference was that the samples were tested in an additional chamber, an attachment to the testing machine that maintained sub-zero temperatures during the test. Prior to the test, the samples were additionally conditioned at the test temperature for at least 2 hours.

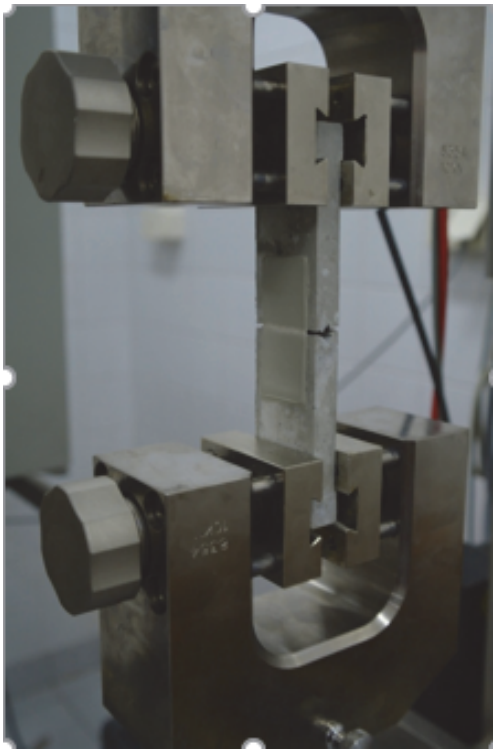


Fig. 2. Sample during crack bridging testing

Source: own work.

Crack bridging ability according to EN 1062-7 (Method B). The crack bridging ability test according to EN 1062-7 was performed under standardised conditions, i.e. at 23 ±2°C and at sub-zero temperatures: −5 ±1°C and −20 ±2°C. The test was performed using the static method (Method A) at 23 ±2°C, −5 ±1°C, and −20 ±2°C at a speed of 0.05 mm·min^{-1} in the prototype test device shown in Figure 3. The tested coatings were applied to one surface of the substrates, in accordance with the manufacturer's recommendations, and then conditioned for 28 days under standardised conditions. After conditioning was completed, the beams were pre-scored on the mortar wall along the transverse axis of the plate, without damaging the coating, and then placed in the testing machine's holders (Fig. 3). The crack width was up to 100 µm. The shorter edges of the plates were fixed in the test apparatus and conditioned at the test temperature for at least 2 hours before the test began to ensure that the specified temperature was reached. After the samples were fixed in the device's holders, the crack was widened in the horizontal plane without twisting at a constant speed of 0.05 mm·min^{-1} until the first cracks appeared. The width of the crack was measured with a micrometre magnifying glass

to an accuracy of 1 μm. The test was repeated three times for each test set and for each test temperature. For the purposes of these comparisons, the test result was reported as the average of the three results rather than the class of the repair product, which represents a deviation from the standard.

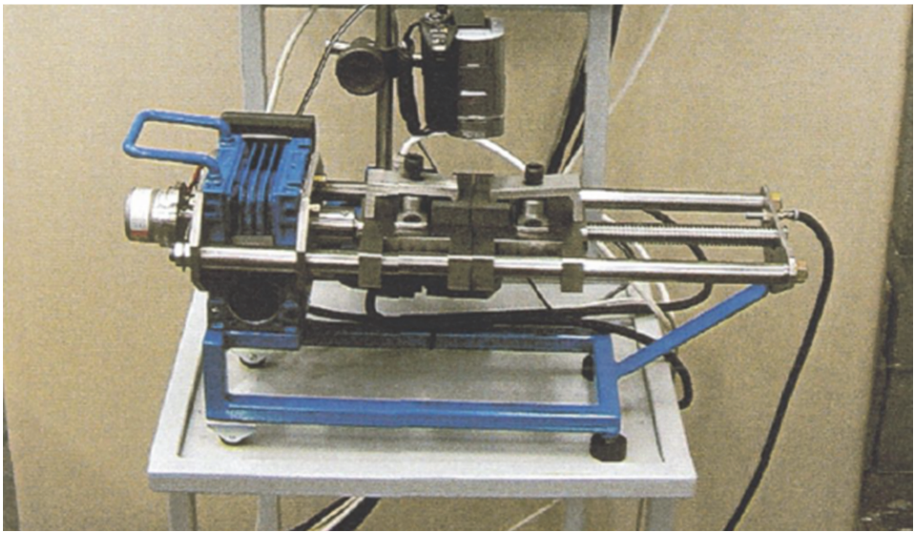


Fig. 3. Device for testing crack bridging ability

Source: own work.

Tensile properties (Method C). The test was performed at a temperature of 23 ±2°C according to the test methodology included in EN ISO 527-3 and EN ISO 527-1, on coating samples after the conditioning period at 23 ±2°C and a relative humidity of 50 ±5%, i.e. after 28 days. After removing the coatings from the non-stick substrates, type 5 samples were cut from them and tested at 100 $mm \cdot min^{-1}$ on a computer-controlled Zwick Roell strength testing machine with a 10 kN capacity head and an optical extensometer for elongation measurements. For each set, the results were the maximum tensile stress, expressed in megapascals, and the elongation at maximum stress, expressed as the average of five measurements and reported as a percentage, with the following accuracy: stress to the second decimal place; elongation to the nearest unit. The elongation measurement was performed with an extensometer; the distance between the jaws was 80 mm, and the test section was 25 mm long.

RESULTS AND DISCUSSION

In the tests carried out in accordance with EN 14891, the crack bridging ability test was performed on all sets at a standardised temperature; for sub-zero temperatures, the evaluation of this parameter was performed at the manufacturer-declared temperature. For five of the tested products, the assessment of crack bridging ability was conducted at both sub-zero temperatures to assess whether there is any numerical regularity in the variability of crack bridging ability among randomly selected samples as temperature decreases. The results of crack bridging tests for 11 different waterproofing coating sets are presented in Table 2 and Figure 4.

Table 2. Summary of the results of crack bridging tests according to EN 14891 for 11 coating sets

Set/Coating type	First damage (mean values) at temperature		
	23°C	−5°C	−20°C
1/DM	1.19 mm (CV 0.04)	0.98 mm (CV 0.10)	0.74 mm (CV 0.11)
2/DM	1.64 mm (CV 0.03)	0.44 mm (CV 0.07)	0.18 mm (CV 0.43)
3/DM	1.07 mm (CV <0.01)	0.52 mm (CV 0.05)	0.28 mm (CV 0.03)
4/DM	4.36 mm (CV 0.04)	–	2.27 mm (CV 0.02)
5/RM	4.90 mm (CV 0.03)	–	4.79 mm (CV 0.02)
6/RM	3.36 mm (CV 0.03)	–	3.21 mm (CV 0.03)
7/RM	2.26 mm (CV 0.04)	–	1.97 mm (CV 0.01)
8/CM	1.16 mm (CV 0.06)	0.31 mm (CV 0.36)	–
9/CM	0.91 mm (CV 0.06)	0.93 mm (CV 0.06)	–
10/CM	1.50 mm (CV 0.01)	1.24 mm (CV 0.03)	0.19 mm (CV 0.09)
11/CM	0.97 mm (CV 0.05)	0.27 mm (CV 0.12)	0.14 mm (CV 0.08)

DM – waterproofing coating made of dispersion liquid-applied products, RM – waterproofing coating made of reaction resins, CM – waterproofing coating made of cementitious mortars; CV – coefficient of variation.

Source: own work.

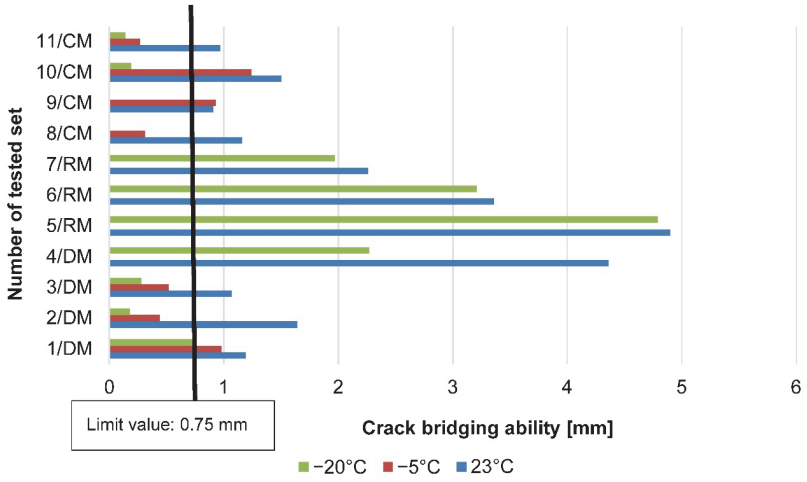


Fig. 4. Comparison of the crack bridging ability of different coating products at temperatures of 23°C, −5°C and −20°C

Source: own work.

In accordance with the technical requirements, it was assumed that the crack bridging ability, at both standard temperature and sub-zero temperatures, should be at least 0.75 mm. Figure 4 shows this limit value with a black vertical line. As shown, all eleven randomly selected test products meet this requirement at temperatures above zero, thereby qualifying them for further analysis. Unfortunately, at sub-zero temperatures, most of the tested products showed a significantly reduced ability to bridge cracks. Only coatings based on reaction resins transfer the loads resulting from possible cracks in the substrate, both at standard temperatures and at very low temperatures, i.e. at −20°C, as shown in Figure 4.

Figure 5 compares the crack bridging ability of reaction resins at standard temperature and at very low temperatures (−20°C).

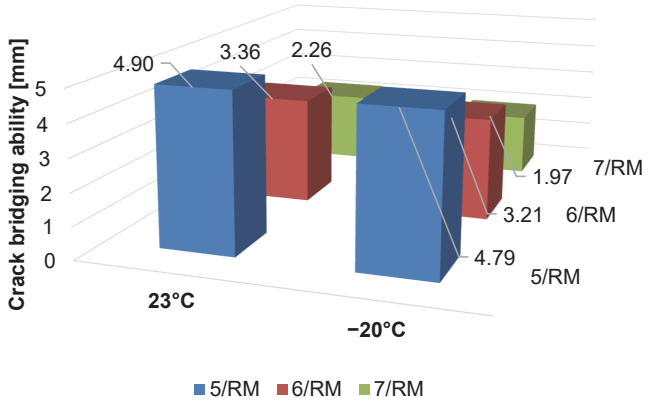


Fig. 5. Comparison of the crack bridging ability of randomly selected coating products based on reaction resins at temperatures of 23°C and −20°C

Source: own work.

Unfortunately, according to prior research by the authors, these products show a significant deterioration in their properties upon contact with water (Francke & Piekarczuk, 2020), which means that their high tensile adhesion strength is not accompanied by resistance to water and moisture, as assessed by measuring changes in adhesion to the substrate after exposure to ageing factors. Moreover, in Poland, these products are the least frequently used group of coating products on terraces and balconies. Most often, dispersion liquid-applied water-impermeable products are selected for use beneath ceramic tiling, and in this group a clear spread of results can be seen, as shown in Figure 6. Unfortunately, the product with the best properties in terms of crack bridging ability at both high and very low temperatures (marked 4DM) shows a significant decrease in performance in the presence of water and moisture, according to previously conducted research (Francke & Piekarczuk, 2020), and it detaches from the substrate under alternating sub-zero and above-zero temperatures. The other two dispersion products do not meet the requirements for crack bridging ability at low temperatures, thereby disqualifying them from use in external waterproofing on terraces and balconies.

Regarding cement-based products (Fig. 7), the results are unfortunately no more encouraging. Only two out of four tested products maintain the required crack bridging ability at –5°C; none of them show crack bridging ability at −20°C (Fig. 7).

In the present case, the effectiveness of the above-mentioned products used as waterproofing beneath ceramic tiling in the climatic conditions of Poland is questionable, as winter temperatures can fall below −17°C, and temperatures between −14°C and −15°C are recorded across almost all of Poland. From the point of view of crack bridging ability, products based on reaction resins are definitely the most advantageous, but, taking into account previous analyses of the durability of adhesion under the effects of water and moisture, these products may also prove to be a questionable solution in terms of durability. Due to their chemical compatibility with mineral substrates, coatings based on polymer-cement products would be expected to perform best on these substrates at both above-zero and sub-zero temperatures, even when simultaneously exposed to water and moisture. It turns out that these products also have a problem with bridging cracks in the substrate at sub-zero temperatures. Although this problem can be solved by placing reinforcing tapes

over the thermal expansion joints in the coating layers, it increases the cost of making such a layer and makes applying it to the substrate more difficult. Dispersion liquid-applied products exhibit similar problems in bridging substrate cracks to those of polymer-cement coatings, despite their considerable flexibility, which is observed in thin films but, unfortunately, is not confirmed in substrate-coating systems. To sum up, the studies carried out only confirm the existing requirements, stating that the under-tile waterproofing coating can only be an additional moisture-protection layer in terrace and balcony coverings, working in conjunction with the effective underlying waterproofing layer.

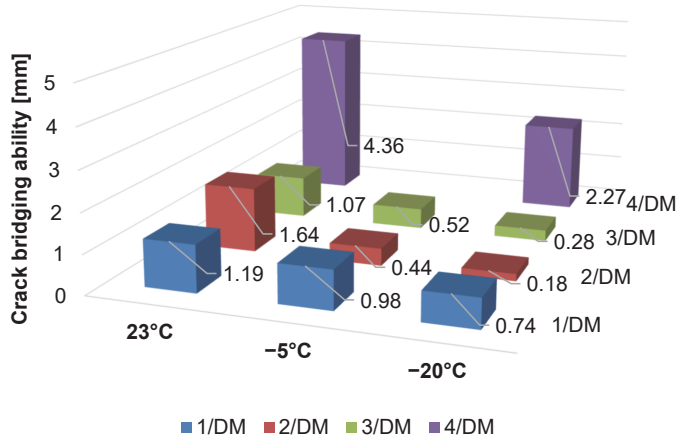


Fig. 6. Comparison of the crack bridging ability of randomly selected coating products based on dispersions at temperatures of 23°C, −5°C and −20°C

Source: own work.

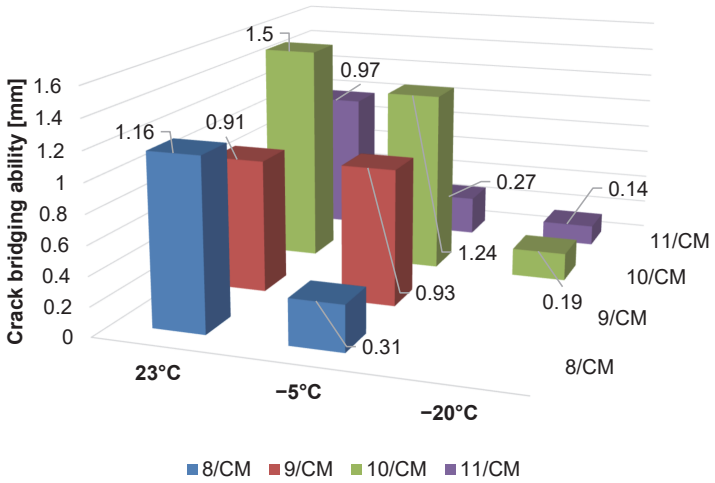


Fig. 7. Comparison of the crack bridging ability of randomly selected cement-based coating products at temperatures of 23°C, −5°C and −20°C

Source: own work.

To address the doubts raised at the beginning of the article regarding the test speeds and evaluation criteria adopted for assessing crack bridging ability, the values obtained for two test sets (8 and 11) at a tensile speed of 0.15 mm·min^{-1} were compared with the crack-bridging values in the test performed according to EN 1062-7 at a tensile speed of 0.05 mm·min^{-1}. In the case of the product marked with the symbol 8, the crack-bridging test at −20°C was not continued due to the lack of a manufacturer declaration of suitability for use at this temperature. These results were supplemented by tensile property values for coatings prepared as thin films at a tensile speed of 100 mm·min^{-1}. The results obtained are presented in Table 3.

Table 3. Comparison of the values of elongation of the coatings at first failure, determined at different sample elongation rates

Tested property	Set 8	Set 11	Test method
Crack bridging ability, expressed as the width of the crack at which the first damage occurred, at the following temperatures:			EN 1062-7
a) 23°C	1193 µm/1.193 mm (CV 0.231)	433 µm/0.433 mm (CV 0.033)	
b) −5°C	430 µm/0.430 mm (CV 0.042)	377 µm/0.377 mm (CV 0.025)	
c) −20°C	–	261 µm/0.261 mm (CV 0.012)	
Crack bridging ability, expressed as the width of the crack at which the first damage occurred, at the following temperatures:			EN 14891
a) 23°C	1.16 mm (CV 0.06)	0.97 mm (CV 0.0)	
b) −5°C	0.31 mm (CV 0.36)	0.27 mm (CV 0.1)	
c) −20°C	–	0.14 mm (CV 0.08)	
Tensile properties			
Maximum tensile stress	0.35 MPa (CV 0.11)	0.70 MPa (CV 0.23)	EN ISO 527-3 + EN ISO 527-1
Elongation at maximum tensile stress	27% (CV 2.0)	18% (CV 1.0)	
Elongation at maximum tensile stress with respect to the test section	6.8 mm (CV 0.5)	4.5 mm (CV 0.6)	

CV – coefficient of variation.

Source: own work.

It seems that despite the test speed adopted in EN 1062-7 being one third of that described in the EN 14891 standard, i.e. 0.05 mm·min^{-1} and 0.15 mm·min^{-1}, respectively, the values obtained at sub-zero temperatures are at a similar level but differ significantly at a temperature of 23°C for one product. Unfortunately, due to the small number of samples evaluated using the test method in the EN 1062-7 standard, the presented results should be treated as preliminary findings that provide directions for further analyses. In the authors' view, a significant increase in speed to 100 mm·min^{-1}, combined with a change from testing substrate-coating systems to testing the mechanical tensile properties of thin films made from coating products, does not allow conclusions to be drawn about the crack bridging ability of coatings applied to substrate slabs.

CONCLUSIONS

This article presents test results related to the functional property of crack bridging ability of coatings used beneath tiling bonded with adhesives. Due to the limited number of samples tested, these conclusions represent a preliminary assessment of the problem and set the direction for further research. The results of these studies allow for the following conclusions for the tested representatives of the three product groups:

– Products based on reaction resin liquid-applied water-impermeable products are the most advantageous. In the three investigated cases, cracking of the coating above the simulated crack in the substrate occurred

at a temperature of 23°C at substrate crack widths of 2.26 mm to 4.90 mm. These widths did not decrease significantly at a temperature of −20°C, with values ranging from 1.97 mm to 4.79 mm.
– Significantly less favourable values were obtained for water-dispersion-based coatings at a temperature of 23°C, within the range of 1.07–1.64 mm; only in a single case did this value rise to 4.36 mm. At sub-zero temperatures, the values decreased below the limit value specified by the standard, i.e. 0.75 mm, or remained slightly above this value.
– For polymer-cement coatings, the values are also in the range of 0.97–1.5 mm: at a temperature of 23°C, they range from 0.97 mm to 1.5 mm; at sub-zero temperatures, they fall below the limit value specified by the standard, i.e. 0.75 mm, or, in individual cases, remain slightly above this value.
– In the crack bridging ability test, the influence of coating tensile speed appears to be negligible when the speed does not exceed 1 mm·min^{-1}; a slight change in this parameter does not significantly affect the final test result. This conclusion is only indicative, as it was based on a small number of samples tested.
– A significant increase in the tensile speed and a change in the method of sample preparation, i.e. an increase to 100 mm·min^{-1} and testing thin films rather than in a system with a coating applied to a concrete substrate, significantly interfere with the ability to draw conclusions about the potential ability of coatings to bridge cracks in concrete substrate slabs and are therefore not recommended for such inferences.

All the above conclusions should be treated as tentative, given the small number of samples tested and the ongoing progress in coating production technology, which is driven by changes in the raw materials used in their production. According to the authors of the article, these factors may significantly affect the results of the research presented and the resulting evaluations.

Authors' contributions

Conceptualisation: B.F., J.S., V.T. and E.K.; methodology: B.F.; validation: B.F.; formal analysis: B.F.; investigation: B.F. and M.K.; writing – original draft preparation: B.F., J.S., V.T. and E.K.; writing – review and editing: B.F.; visualisation: B.F.; supervision: B.F. and E.K.

All authors have read and agreed to the published version of the manuscript.

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WPŁYW WARUNKÓW BADANIA NA OCENĘ ZDOLNOŚCI DO MOSTKOWANIA PĘKNIĘĆ POWŁOK HYDROIZOLACYJNYCH

STRESZCZENIE

W artykule przeanalizowano zdolność do mostkowania pęknięć warstw hydroizolacyjnych stosowanych pod płytkami ceramicznymi mocowanymi klejami, ocenianą zgodnie z metodyką badawczą ujętą w normie EN 14891. Przedmiotem badań było 11 wyrobów podzielonych na 3 grupy materiałowe: powłoki wykonane z dyspersji wodnych, powłoki żywiczne i powłoki polimerowo-cementowe. Największą odporność w tym zakresie wykazują powłoki żywiczne; najmniej skuteczne są powłoki z dyspersji wodnych. Niestety większość badanych powłok nie gwarantuje szczelności w warunkach klimatycznych Polski, ponieważ pęka przy wydłużeniu poniżej 0,75 mm. Ponadto ustalono, że zmiany prędkości badawczych w zakresie 0,05 $mm \cdot min^{-1}$ (zgodnie z EN 1062-7) i 0,15 $mm \cdot min^{-1}$ (zgodnie z normą EN 14891) dla zestawów powłok naniesionych na podłoża betonowe nie wpływają istotnie na powstanie pierwszych pęknięć podczas rozciągania, zwłaszcza w temperaturze poniżej 0°C. Nie jest również możliwe wnioskowanie o zdolności powłok do mostkowania pęknięć podłoży betonowych na podstawie wyników badań właściwości mechanicznych przy rozciąganiu na cienkich filmach, np. zgodnie z normami EN ISO 527-1 i EN ISO 527-3.

Słowa kluczowe: zdolność do mostkowania pęknięć, powłoki hydroizolacyjne, powłoki z dyspersji wodnych, z żywic reaktywnych i polimerowo-cementowe, metodyki badawcze zgodne z EN 14891 i EN 1062-7