Properties of Selected Polyurethane Sealants in the Sealing of Cement-based Materials

Adam Boháček

Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, Brno 602 00, Czech Republic
bohacek.a@fce.vutbr.cz

Abstract: Since the rise of cement-based building elements, there has been a need to seal these materials. Therefore, this article deals with the sealing of cement-based materials, specifically glass cement. The aim of this work is to find a sealant for sealing this problematic substrate, to verify its suitability and to show that polyurethane sealants are also important in the construction market. The problem of a cement-based substrate lies mainly in the dustiness of its surface, where there are always small dust particles on its surface. The main method for testing these sealants is the tensile test, which checks both the properties of the sealant itself and the contact joint between the sealant and the base material. Tensile test specimens are made of glass-cement plates and three representatives of one-component flexible polyurethane sealants are selected as the sealing material. From the results of the tensile test, it can be concluded that, with the appropriate choice of sealant and primer, problematic cement-based materials with good results can be sealed, provided that the grinding is carried out correctly.

1. Introduction

Our society has been cementing materials practically since the beginning of construction history. We still need to bond various materials together today, and we can see cemented joints virtually everywhere. Naturally, cemented joints have developed over time, but now we have shifted from the original natural materials to the area of the chemical industry. Due to the significant expansion of the chemical industry, great advances have been made in the development and application of sealants in the field of cemented joints over the last two decades [1].

Cement joints are now a common part of the building industry, and we could not imagine modern construction without them. Their main aim is to prevent substance exchange between the construction materials and external environment. They also ensure thermal and sound insulation, and some even contribute to the construction’s fire resilience [2]. We can find them virtually in all parts of building constructions, for example between prefabricated concrete elements in façades, around windows and doors, in the joints between floors and walls etc. Even though we can find cemented joints in various places, it is evident that different demands are imposed on different joints. So obviously there are significant differences between the individual cemented joints [2,3].

And as a result of the different demands on cemented joints, when designing a cemented joint, we have to take into account all the variables which might negatively influence the cemented joint. To the
greatest extent these variables include external climatic influences [3]. If we assume that a cemented joint will be exposed to external climatic influences, it is necessary to select a sealant where the manufacturer states that it is resilient to negative climatic phenomena [4-6]. On the Czech market, there is really a huge number of different sealants from different manufacturers, which differ in terms of quality and price. This can make it difficult for the regular user to navigate such an extensive offer and choose the right sealant. And this situation is also complicated by the fact that the manufacturer’s recommendations concerning resilience of the sealant do not always correspond with reality [7-10]. This is another reason why the following research was undertaken, which is intended to compare the regular sealants available on the Czech market [11-13] and their properties after exposure to negative climatic influences.

2. Material
For the purposes of this research, it is necessary to select the base material, sealant recommended by the manufacturer for the needs of cementing the selected base material, and a suitable primer.

The decisive factor for choice of the material used in this survey is how difficult the material is for the creation of cemented joints and its availability on the Czech market. Glass reinforced concrete was selected as the base material based on these criteria. This material has a large number of dust particles on its surface which greatly weaken the cohesion between the sealant and its surface layer. This property should be in part improved by the application of a primer before the actual sealant.

As far as the actual sealants are concerned, consideration is given to the availability for the regular user and the optimum price offer as well as recommendation of the manufacturer that the sealant is suitable to use for cementing the base material chosen by the author. Following a careful survey of the Czech market, three polyurethane sealants from three different manufacturers in various price categories were chosen. Three primers were then selected for these sealants. These primers were selected at the recommendation of the manufacturer.

Selected sealants (Table 1) and primers (Table 2) are further specified in the tables below.

| Properties                        | Sealant A | Sealant B | Sealant C |
|-----------------------------------|-----------|-----------|-----------|
| Density [g/cm³]                   | 1.23      | 1.3       | 1.39      |
| Tensile strength [N/mm²]          | 1.4       | 1.5       | 3.8       |
| Consistency                       | Thixotropic paste | Thixotropic paste | Thixotropic paste |
| Elastic modulus of elasticity [N/mm²] | 0.7     | 0.6       | 0.7       |
| Hardness according to Shore A     | 40        | 37        | 40        |

| Properties                        | Primer A  | Primer B  | Primer C  |
|-----------------------------------|-----------|-----------|-----------|
| Density [g/cm³]                   | 1.01      | 1.0       | 1.05      |
| Consistency                       | Low viscosity liquid | Liquid | Liquid |
| Dry matter content [%]            | -         | 34        | 70        |

3. Methodology
The test methods described in this article are based on the valid Czech technical standard ČSN EN ISO 8340 Building construction - Sealants - Determination of tensile properties at maintained extension [14]. This standard gives a precise definition of the test body and a precise tensile test procedure. But it does not precisely define the test rig.
The test body consists of two base boards of precisely defined dimensions, but there can be changes as long as the dimension of sealant and adhesion area remain the same. It also consists of two spacers and the actual sealant. A test body was designed consisting of 50 x 30 mm base boards where the thickness of the base boards was 12.5 mm. In order to ensure that the cemented joint is properly exposed to the air, the spacers are made of wood, are 50 mm high and have plan dimensions of 12 x 12 mm. The base boards (along with two wooden spacers) define the boundary of the applied sealant and together make up these individual parts of the test body. The standard also gives the minimum number of test bodies for one test (three test bodies). But for the purposes of this test, five test bodies were used in order to provide a better evaluation of the test results. The test bodies were constructed at a constant temperature of sealant and test boards (23 ± 2) °C, and the instructions of the sealant manufacturers were adhered to. These may include a condition to use a base coat, so-called primer. And according to the standard it is necessary to adhere to the designated conditions: to ensure that there are no air bubbles, to press the sealant onto the contact areas of the base bodies, and to smooth the surface of the sealant to the level of the test bodies and spacers.

Before the actual test it is necessary to cure the test bodies, i.e., to store them according to the procedure defined by the Czech standard. The test bodies are first of all left at a temperature of (23 ± 2) °C and relative humidity of (50 ± 5) % for 28 days so that the applied sealant can cure properly, and then they undergo the following storage cycles three times:

1. 3 days in drying room at the temperature of (70 ± 2) °C
2. 1 day in distilled water at the temperature of (23 ± 2) °C
3. 2 days in drying room at the temperature of (70 ± 2) °C
4. 1 day in distilled water at the temperature of (23 ± 2) °C

The standard defines the procedure of the test for determining tensile properties at maintained extension used for the given survey, but as already stated it does not define the actual test rig to be used. For this reason the test rig shown in figure 1 was built as part of the preceding research into the sealants. This tensile test is performed in two variants - at the temperature of (23 ± 2) °C and (-20 ± 2) °C. The principle of the test is that the test bodies which have undergone the prescribed cycles are exposed to the prescribed temperature and then stretched at a rate of (5.5 ± 0.7) mm/min to 25 % more than their original length.

The first variant is the performance of a tensile test at temperature of (23 ± 2) °C where the test body is stored for 24 hours at the temperature of (23 ± 2) °C and relative humidity (50 ± 5) % after cycling. After this period the test bodies are put in the test equipment shown in figure 2 and stretched at a rate of (5.5 ± 0.7) mm/min to 25 % more than their original length at a temperature of (23 ± 2) °C. This extension is maintained for 24 hours at a temperature of (23 ± 2) °C. After this there is a visual inspection of defects in adhesion and cohesion, which are then measured with a calliper.

The second variant is performance of a tensile test at the temperature of (-20 ± 2) °C where the test bodies are kept at the temperature of (-20 ± 2) °C for at least 4 hours. The following procedure is similar to the first variant. The test bodies are put in the test device and stretched at a rate of (5.5 ± 0.7) mm/min at a temperature of (-20 ± 2) °C to 25 % more than their original length. This extension is maintained at a temperature of (-20 ± 2) °C for 24 hours. Then defects in adhesion and cohesion are identified and measured with a calliper. In this case the defects are identified after the test bodies have been taken out of the cooling chamber and thawed out [14].
Tests were performed on five test samples of each sealant. The evaluation of the test results was performed by a visual inspection of the test sample and then measuring using a calliper. For greater transparency of result evaluation, the testing is divided into two sections - testing at the temperature of \((23 \pm 2) \degree C\), the results of which are given in table 3, and testing at the temperature of \((-22 \pm 2) \degree C\), the test results of which are recorded in table 4. Both tables contain an evaluation of the joint between the sealant and the base material, and any breakage is described.

A joint evaluated in the tables as Failed following the visual inspection and calliper measurement displays signs of breakage. Such a joint is shown for testing at temperatures \((23 \pm 2) \degree C\) in figure 2, and for testing at temperatures \((-22 \pm 2) \degree C\) in figure 4.

In contrast a joint evaluated as Did not fail after inspection does not display signs of breakage. For the purposes of clarity, an unbroken joint after testing at the temperature \((23 \pm 2) \degree C\) is shown in figure 3, and joint after testing at temperature of \((-22 \pm 2) \degree C\) in figure 5.

If the tested samples display breakage, the sealant has separated from the base material on one side.

As you can see from the table of results, it does not contain test results for the third sealant. It was not possible to test and measure this sealant because all the samples disintegrated during cycling.

Figure 1. Test rig for maintained extension.
### Table 3. Test according to ČSN EN ISO 8340 at temperature of (23 ± 2) °C.

| Type of sealant | Polyurethane sealant | Sealant A | Sealant B |
|-----------------|----------------------|-----------|-----------|
| Base material   |                      | No Joint  | No Joint  |
| 1               | Failed               | one-sided separation | one-sided separation |
|                 |                      | when stretched by 25 % | when stretched by 25 % |
| 2               | Failed               | one-sided separation | one-sided separation |
|                 |                      | when stretched by 25 % | when stretched by 25 % |
| Glass reinforced concrete | 3 Failed | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
|                 |                      | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
|                 |                      | Did not fail | none |

#### Figure 2. Sealant A, sample No 3.

#### Figure 3. Sealant B, sample No 4.

### Table 4. Test according to ČSN EN ISO 8340 at temperature of (-22 ± 2) °C.

| Type of sealant | Polyurethane sealant | Sealant A | Sealant B |
|-----------------|----------------------|-----------|-----------|
| Base material   |                      | No Joint  | No Joint  |
| 1               | Failed               | one-sided separation | one-sided separation |
|                 |                      | when stretched by 25 % | when stretched by 25 % |
| 2               | Failed               | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
| Glass reinforced concrete | 3 Failed | did not fail | Did not fail |
|                 |                      | none | none |
| 4               | Failed               | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
| 5               | Failed               | Did not fail | none |

| Type of sealant | Polyurethane sealant | Sealant A | Sealant B |
|-----------------|----------------------|-----------|-----------|
| Base material   |                      | No Joint  | No Joint  |
| 1               | Failed               | one-sided separation | one-sided separation |
|                 |                      | when stretched by 25 % | when stretched by 25 % |
| 2               | Failed               | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
| Glass reinforced concrete | 3 Failed | did not fail | Did not fail |
|                 |                      | none | none |
| 4               | Failed               | one-sided separation | Did not fail |
|                 |                      | when stretched by 25 % | none |
| 5               | Failed               | Did not fail | none |
5. Analysis of results
As can be seen from the above table of results, during the testing of samples at the temperature of (23 ± 2) °C and temperature of (-22 ± 2) °C the test samples displayed only one defect - a one-sided separation of the sealant from the base material. There were varying values for this separation, but even at low values such a sealant must be evaluated as non-compliant.

In the case of testing at the temperature of (23 ± 2) °C we can see in the table of results that sealant A displays far worse cohesion between the sealant and base material than sealant B. In the case of the first of the sealants, all the tested samples displayed signs of breakage.

There is also clear breakage of the cemented joints in all the tested samples of sealant A at the temperature of (-22 ± 20) °C. Thus, in general terms sealant B displays better results in this specific testing than sealant A.

6. Conclusion
It is evident from the author’s measurement that each of the tested sealants displays shortcomings when used for cementing the selected base material. As a result it must be stated that in spite of the recommendations given by the manufacturer and specified suitability of the sealant for cementing glass reinforced concrete base materials, none of the tested sealants can really be recommended as suitable for cementing.

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