

7th Scientific-Technical Conference Material Problems in Civil Engineering (MATBUD'2015)

Determination of tensile properties of selected building sealants in combination with High-pressure Compact Laminate (HPL)

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Abstract

One of the current issues in the Czech building industry is an efficient implementation of seal joint between constructions. An undesirable penetration of water, moisture or air between structural elements may have a negative effect on their reliability and may also affect the length of expected service life. This issue is addressed in detail in the following paper. The experimental part of the research is aimed at ascertaining the technical properties of sealants and on verification of their potential usage in practise. Furthermore, this article focuses on the preparation and subsequent production of test specimens, and also on the experimental verification of their tensile properties at a temperature of $(20 \pm 3)^\circ\text{C}$ and $(-22 \pm 2)^\circ\text{C}$. For the tests, composite high pressure laminates (i.e. HPL Trespa Meteon) are chosen for the cladding. In order to find the best solution ten types of commonly manufactured industrial sealants is selected. At the same time the emphasis was on representation of sealants in various price categories. The main conclusion of tests is the fact that it is not possible to responsibly choose a suitable material without taking appropriate measurements or having previous experience. A secondary conclusion to this article is the fact that there are significant differences between individual sealants in the results they provide in combination with selected cladding material. Moreover, the method also suggests that the use of the most expensive sealant does not always provide the best results.

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Peer-review under responsibility of organizing committee of the 7th Scientific-Technical Conference Material Problems in Civil Engineering

Keywords: Adhesive Failure; Cladding tile; Cohesive Failure; Sealant, testing

1. Introduction

In civil engineering, sealants are used often and are widespread. Most frequently, they are used for filling of joints in structures. Even if it is not a load bearing structural joint but only sealing, the suitable performance is important for the proper function of the whole structure as described by Pocius [3]. For efficient sealing of the joint, the most important qualities of sealants are adhesion and durability. Failure of the joint tightness may be caused both by the use of incorrect sealant depending on the cladding material and the quality of execution. In addition, such factors as incorrect hardening of the sealant, aging or climatic conditions have high impact. Although the cladding material selected by ourselves is suitable for application on façade with the use of sealants, producers do not specify further under which conditions. Thus, there exists any amount of combinations of cladding materials, sealants, and application conditions. For this reason, it is not possible that producers compass the whole

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area. This fact has taken us to the idea of experimental testing of specific cladding material in combination with a selected group of sealants.

2. Literature review

Silicone sealants and adhesives as used e.g. in the construction industry were introduced approximately forty years ago. Their commercial importance lies mainly in their unique combination of material properties, which allow them to satisfy important needs in a broad variety of markets. The most important properties of silicone sealants for construction are durability and adhesion. The effect of weather changes on the degradation of sealant joints has been studied and discussed in detail in the literature as described by Wolf [4]. The cause of sealant failure on a building facade depends on the type of sealant used and the quality of installation. Sealant material can fail due to improper curing, aging, and weather exposure. Failure can also occur if large joint movements take place before the seal is fully cured according [1]. Aging tends to manifest itself in the surface section of the test specimen instead of within the interior as described by Chew [1]. It has also been shown that long-term exposure to water and heat has an influence on the adhesive and cohesive failure of polyurethane sealants according to Šlanhof [2].

3. Methodology

Methodological procedure of sealants testing that is production of samples, their conditioning, testing as well as subsequent evaluation of results is described in detail in Czech technical standards. The selected method of testing is completely in harmony with EN ISO 8339 [5] and EN ISO 11600 [6].

3.1. Selection of sealant and cladding material

The attention of authors is focussed on the possibilities of sealing of high-pressure laminate that is selected as the underlying material. Its production consists of the use of layered paper impregnated with resins, which is pressed under a high temperature and high pressure in a homogenous hard board with a thickness of 8 mm. Its use may be both for interior and exterior according to manufacturer Trespa [7]. The product is known under the trade name HPL Trespa Meteon.

For the test, we have selected ten commonly available sealants from three producers so that sealants of different material composition and different price were included. All sealants may be used for the exterior climatic conditions. The set of the selected sealants is captured in Tab. 1.

Based on the fact that the tested group of selected sealants have very similar material properties, the authors of this article considered it necessary to distinguish the differences between them. For this reason, the names of sealant manufacturers published. However, there are no intentions to harm a good name of all manufacturers.

Table 1. Overview of selected sealants.

Type of Sealant	Soudal	Lučební závody Kolín, Czech Republic	Silco
Silicone acetate	Universal silicone (SO-U)	Lukopren UNI A (LU-U)	Universal silicone (SL-U)
Neutral silicone	SILIRUB N (SO-N)	Lukopren UNI N (LU-N)	Neutral silicone (SL-N)
Polyurethane	25D (SO-PU)	-	PU 40 (SL-PU)
MS polymer	Soudaseal 215LM (SO-MS)	-	MS 60 (SL-MS)

3.2. Production of samples

The test specimen is combined of two facade cladding substrate bodies with dimensions 30 x 50 mm. Between them, sealant is applied with a dimension 12 x 12 x 50 mm as shown on Fig. 1. For each sealant used, three samples are needed according to EN ISO 11600 [6].

For the production of the selected structure of the sample it is necessary to use lining elements of dimensions 9 x 12 x 50 mm. These shuttering elements are used for the option to shape the sealant between two substrate bodies. Due to the taking these shuttering elements out a potential removal of their planking must be ensured. For this, a stripping product could be used that is directly intended for this. Since the product is not functional for all types of sealants, their stripping must be done by other means. Alternatives are parchment paper and polypropylene. Before the sealant is applied, the adhesion properties of the substrate bodies surface must be improved by degreasing. The samples are filled with a manual caulking gun to the cartouches on the front side. To ensure the identification during subsequent operations, individual samples must be precisely marked.

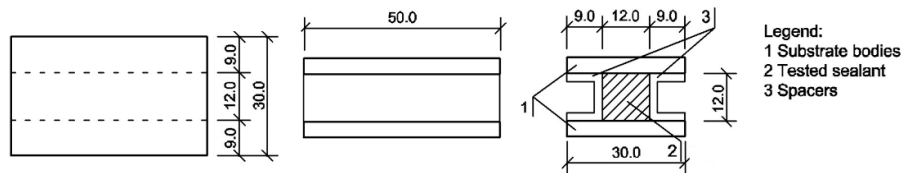


Fig. 1. Test specimen according to [2].

3.3. Maturing

Based on the statutory requirements samples are left to mature in a dry and clean environment for 28 days. That is at average air temperature of $(23 \pm 2) ^\circ\text{C}$ and relative humidity $(50 \pm 5) \%$.

3.4. Conditioning

After the passing of 28 days, samples undergo three cycles of conditioning that consist of the following steps:

- 3 days in a drying oven at a temperature of $(70 \pm 2) ^\circ\text{C}$,
- 1 day in distilled water at a temperature of $(23 \pm 2) ^\circ\text{C}$,
- 2 days in a drying oven at a temperature of $(70 \pm 2) ^\circ\text{C}$,
- 1 day in distilled water at a temperature of $(23 \pm 2) ^\circ\text{C}$.

For better handling of more samples, it is suitable to use a made-to-measure mould. Samples are soaked in a water bath. Samples are dried in electric drying oven with forced circulation of air in a chamber.

3.5. Testing of the samples

The basis of test is stressing of the testing sample by stretching until damage occurs. Before testing, the testing samples must be stored for 24 hours at a temperature of the air $(23 \pm 2) ^\circ\text{C}$ with relative humidity $(50 \pm 5) \%$.

At a temperature of $(23 \pm 2) ^\circ\text{C}$, the testing samples will be placed into a specially produced mould that allows fixing of the testing sample into the testing equipment as shown in Fig. 2. Samples fixed in this manner are stretched at the temperature of $(23 \pm 2) ^\circ\text{C}$ with the speed of $(5.5 \pm 0.7) \text{ mm} \cdot \text{min}^{-1}$ until their damage occurs. A diagram of stretching depending on the applied force is recorded.

Another set of samples is tested at the temperature of $(-22 \pm 2) ^\circ\text{C}$. Before testing, the testing samples are deposited for at least 4 hours at the temperature of $(-22 \pm 2) ^\circ\text{C}$ into a freezing device. Subsequently, the testing specimens are taken out and placed into the testing equipment, they are elongated at the temperature of $(-22 \pm 2) ^\circ\text{C}$ with speed of $(5.5 \pm 0.7) \text{ mm} \cdot \text{min}^{-1}$ until their damage occurs. A diagram of stretching depending on the applied force is recorded.



Fig. 2. Testing of specimens in testing equipment.

4. Results

A result of this test method is a secant tensile modulus (σ), which expresses tension at the given deformation calculated according to (1).

$$\sigma = \frac{F}{s} \quad (1)$$

where,

F is the force at the chosen elongation, in Newtons. There is chosen elongation 100 %, i.e. 12 mm,
s is initial cross – section area of test specimen, in square millimetres, i.e. 600 mm².

Further, for each testing sample the value of elongation is calculated upon tearing/breaking (E_b) in per cent according to (2).

$$E_b = \frac{\text{extension}}{\text{initial length}} \cdot 100 \quad (2)$$

The result is a deformation course of elongation dependence at force, as it can be seen in Figures 3 and 4 both with Lukopren UNI A.

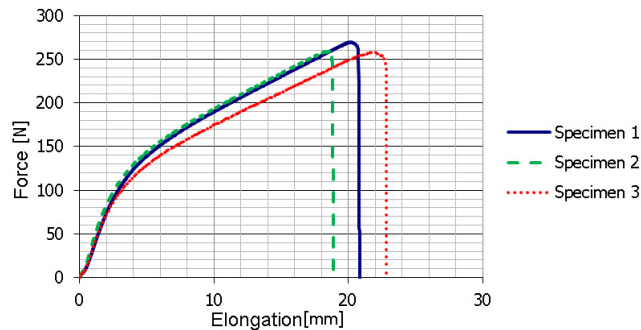


Fig. 3. Test procedure at temperature $(23 \pm 2)^\circ\text{C}$ with Lukopren UNI A.

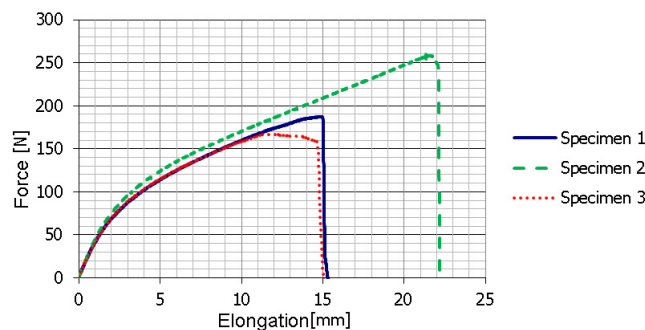


Fig. 4. Test procedure at temperature with $(-20 \pm 2)^\circ\text{C}$ with Lukopren UNI A.

It is clear from Fig. 1 and Fig. 2 that after the maximum strength is achieved, immediately a rupture occurs.

Tab. 2 and Tab. 3 give arithmetic averages of forces (F) at elongation 100 % i.e. 12 mm at the temperature of testing (23 ± 2) and $(-20 \pm 2)^\circ\text{C}$. Also, they give related secant tensile moduli (σ), their determinative deviations (SD) and elongation at break (E_b).

Table 2. Tensile properties of test specimens at temperature $(23 \pm 2) ^\circ\text{C}$.

Marking of sealant	F at 100% [N]	σ [$\text{N}\cdot\text{mm}^{-2}$]	SD [$\text{N}\cdot\text{mm}^{-2}$]	Elongation at break [mm]	E_b [%]	SD [%]
SO-U	316.196	0.527	0.017	45.058	375	24.672
SO-N	154.233	0.257	0.110	35.445	295	14.078
SO-PU	338.490	0.564	0.026	42.414	353	12.624
SO-MS	269.850	0.450	0.024	33.497	279	54.161
LU-U	202.317	0.337	0.014	23.088	192	13.353
LU-N	111.733	0.186	0.015	54.975	458	80.550
SL-U	122.661	0.136	0.106	21.663	181	94.363
SL-N	296.390	0.494	0.026	15.582	130	18.836
SL-PU	557.676	0.929	0.056	29.153	243	19.016
SL-MS	703.291	1.172	0.108	31.449	262	34.724

Table 3. Tensile properties of test specimens at temperature $(-20 \pm 2) ^\circ\text{C}$.

Marking of sealant	F at 100% [N]	σ [$\text{N}\cdot\text{mm}^{-2}$]	SD [$\text{N}\cdot\text{mm}^{-2}$]	Elongation at break [mm]	E_b [%]	SD [%]
SO-U	196.905	0.328	0.044	47.444	395	16.985
SO-N	117.138	0.195	0.100	39.093	326	42.662
SO-PU	491.821	0.820	0.168	35.002	292	29.148
SO-MS	231.777	0.386	0.049	36.595	305	24.534
LU-U	175.420	0.292	0.014	18.001	150	26.500
LU-N	92.655	0.154	0.026	54.572	455	33.816
SL-U	153.461	0.256	0.063	37.461	312	21.626
SL-N	235.164	0.392	0.096	15.732	131	31.162
SL-PU	677.614	1.129	0.126	33.057	275	111.169
SL-MS	526.567	0.878	0.353	30.365	253	63.339

5. Analysis

It is evident that best results with respect to the secant tensile modulus σ are achieved by sealants manufactured by a company SILCO. Namely, this is a polyurethane sealant SILCO PU 40 and MS polymer SILCO MS 60. Further, polyurethane sealant SOUDAL 25D also achieves very good results.

With respect to elongation at break, the best results are achieved in neutral silicone produced by a company Lučební závody Kolín, Lukopren UNI N. Its elongation against the original width amounts over 450 % before a total rupture occurs. However, it has the lowest counteract in testing.

In most cases, the adhesion of the sealant to the cladding material was damaged. In many tested cases the sealant did not stick to one or both substrates, as it can be seen in Fig. 5. The destruction of the tested joint by the sealant cohesive failure, which means that the sealant shows a rupture or tear within its boundaries as opposed to where it sticks to the substrate. Cohesive failure can occur as a result of sealant deterioration. This type of defect occurred already during the maturing of test samples, as can be seen in Fig. 6. The series of tests proved the fact that the sealant incompatibility have to be considered because the selected materials might degrade one another, or fail to adhere to one another, or prevent the cure of one or both materials.



Fig. 5. Specimen after testing with Lukopren UNI N.



Fig. 6. Specimen after testing with SOUDASEAL 215LM.

6. Discussion

Knowledge of the sealant behaviour on a concrete base material in the whole interval is a good piece of information for its selection even if results do not bring any fundamental findings on the behaviour of the sealant before the damage of its primary function that is tightness. In a more significant elongation the stressed sealant is gradually destroyed which will show in its partial detaching, partial tear or breaking. However, the test continues further until the complete detaching or breaking but the sealant damaged in this way would not fulfil its function of the joint sealing any more. However, the course expressed in the form of a graph will show well by the change of the curve each more significant damage of the sealant and immediately it is obvious at which stress and elongation this happened. Therefore, this test may be considered important for the general idea of the sealant properties. The calculated values of the secant tensile moduli and elongation at break, however, may not be used for mutual comparison of the individual products. Although a higher value of the secant tensile modulus means the achieving of a higher strength it may not be the criterion of quality. The same applies to the size of elongation at break that does not specify exactly which product is better or worse. Both these parameters, though, may be applied in the case when more suitable sealants are suggested by other tests performed.

From the concrete results of the arithmetic averages of the secant tensile moduli σ at elongation of the sealant by 12 mm (100 %), as specified in Tab. 2 and Tab. 3 it is clear which sealants are able to resist higher strength. In addition, it may be observed that the scatter of values expressed in a determinative deviation SD is in most cases quite small. From values given in Tab. 2 and Tab. 3 there further follows a significant difference in the elongation abilities of the individual types of the tested sealants. The parameter E_b specifies what is the average elongation of the sealant in per cent in comparison to the original width of 12 mm. Here, the scatter of values is considerable.

7. Conclusion

Based on the present results from the experimental measurement it may be noted that sealants may be applied on the tested cladding material.

Three testing specimens for one test are an absolute minimum. The purpose of these tests, however, is not to exclude all the evaluated sealants but to find differences among them. This means to identify those that have the best preconditions for the reliable fulfilling of the function to seal off joints. This objective may be considered completed. From the presented results, it may be detected that there exist very significant differences between the selected sealants. Together with other tests it shows that using the most expensive sealant does not always lead to the best results.

Acknowledgement

This research was carried out as part of project MPO FR - TI4/332 New Technologies of Bonded Facade Cladding with Anchor Elements with Increased Resistance to Corrosion.

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