International Scientific Conference *People, Buildings and Environment 2014* (PBE2014)
15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE

SEALING POSSIBILITIES FOR WOOD ELEMENTS

Jiří Šlanhof[1]*, Pavel Liška[1], Martina Šimáčková[1], Barbora Nečasová [1]

[1] Brno University of Technology, Veveří 95, Brno 602 00, Czech Republic

Abstract

The authors focus on the possibility of sealing wooden elements. Wood appears to be a problematic substrate, and in some cases it could be necessary to solve problems through the use of sealants. The research is based on the test procedure for the determination of tensile properties during maintained extension according to the European standard EN ISO 8340.

Facade wood has been selected as a substrate: specifically, heat-treated Finnish pine, has been used. A group of ten commercially available industrially produced sealants, including polyurethane, silicone and MS Polymer sealants, have been selected. The aim of the research was to discover any differences that might appear in their resistance against maintained extension as well as their durability when variable temperatures are applied. The test results were evaluated and stated in a table that defines main adhesive and cohesive failures at 23 ° C and -20 ° C. The research proved the possibility of sealing wood substrates but only if the correct sealant is chosen. Also significant differences between individual sealants in the results they provide in combination with wooden cladding material were observed. Of all the tested sealants only two products passed.

Key words

Adhesive failure; extension; maintained extension; seal; sealant

To cite this paper: *Šlanhof, J., Liška, P., Šimáčková, M., Nečasová, B. Sealing Possibilities for Wood Elements, In the conference proceedings of People, Buildings and Environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp. 439-447, ISSN: 1805-6784.*

*Corresponding author: Tel.: +420-541-147-979, Fax: +420-541-147-967
E-mail address: slanhof.j@fce.vutbr.cz

1 INTRODUCTION

Wood is a traditional building material used in the construction industry since time immemorial. In the 20th century, the limitations of this renewable material became obvious, and in many applications its use gave way to that of ceramic or concrete masonry elements, leaving wood to be employed mainly in the areas of roof structures or interior cladding. Over the last approx. 15 years, a significant increase in the popularity of wood with designers as well as builders has become apparent in Central Europe, and this is clearly visible in the rapid increase in the amount of wooden buildings constructed. Wood is once again perceived as a suitable alternative for the load-bearing structures of buildings, and in well designed structures it allows designers to comply with all statutory technical requirements for building structures.

Currently, wooden buildings occupy quite a prominent place on the building market, replacing load-bearing structural elements made from fired clay or concrete. Some types of wood are sufficiently resistant to climatic influences to be utilized in the external cladding of buildings, i.e. the wood is directly exposed to the external environment. In such applications, it is possible to encounter problems connected with sealing the structural joints between wooden facade elements or between timber and another material so that the gap does not allow the undesirable penetration of moisture into other structures. The use of some types of modern sealant is one of the options. There is a large amount of products on the market and the designers, builders or construction firms face the fundamental question of 'Which type of the material is the most suitable one?'.

Sealants are modern building materials which are primarily used as a means for sealing joints in building structures. According to European Standard EN ISO 6927: 2012 [1], a sealant is defined as a material applied in an unformed state which, once cured or dried, has the adhesive and cohesive properties to seal a joint. Sealing means placing the appropriate product in the joint in order to prevent the penetration of water, moisture and/or air between elements, components and assemblies made of the same or dissimilar materials. The fulfilment of stated requirements is dependent on ensuring the long-term reliability of the bonded joint without the occurrence of failure, i.e. without adhesive failure or cohesive failure.

2 LITERATURE REVIEW

Silicon sealants and adhesives as used in the construction industry were introduced approximately forty years ago. According to the findings which had been already published, many of the silicones applied in the early days are still performing today. Their commercial importance is mainly based on their unique combination of properties. Wolf [2] had in his paper stated that the material properties of sealants permit them to satisfy important needs in a broad variety of markets. He had also mentioned that the most important properties of silicone sealants for construction are durability and adhesion. Adhesives and sealants must form good adhesive bonds with adjacent surfaces to be effective [3]. The mode of preparation of silicones, their use and typical performances were studied and described by [4]. The attention was given to silicon use as sealants and structural adhesives in construction and building applications where adherence properties for assembling two substrates are important. The attendant processes as is the preparation of a substrate before bonding as well as the application of sealant, are described by [5] in detail.

There were published many other scientific papers about the material properties of silicone sealants as well as polyurethane. In 1999 was published a paper about 'Joint sealant for wall cladding'. The effect of weather changes on the degradation of the sealant joints was studied and discussed in more detail [6]. Later, papers about a series of on – site non – destructive tests of silicone sealants [7] as well as tests about the aging conditions of polyurethane sealants were published [8]. In 2001, 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 [9].

On the other side as stated in [10], the scientific research on joints composed by wood surfaces-silicone is still at infancy. Thus this area should be studied in more detail. It is apparent that the authors of this article tried to conduct a comprehensive literature review with the aim of comparing their own measurements with the results of other authors. However, no reasonable or more similar published works were found on the given topic. For these reasons, the research findings detailed below should be considered original.

3 METHODOLOGY

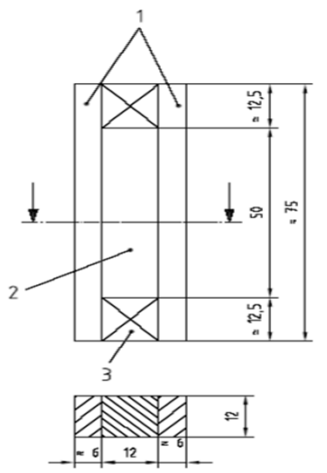
The authors of the article focus on the possibility of sealing wooden facade cladding. For the experimental part of the work, heat-treated Finnish pine wood was chosen as a substrate. It has been dried using a specific procedure at a temperature of 160 – 215 °C. Wood treated in this way should have a minimum lifespan of 30 years. The main aim of the research was to find a sealant which would make it possible to seal the above-mentioned substrate in such a way that the needed adhesion and cohesion is achieved. From the wide range of sealants currently available on the market, ten examples of commonly available products from three different manufacturers were selected, as displayed in Tab. 1. These are polyurethane, silicone and MS polymer sealants. Abbreviations used for the samples when recording and evaluating measurements are stated in parentheses.

Tab. 1: Overview of selected sealants

Type of Sealant	Manufacturer		
	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)

The test procedure is based on European Standard EN ISO 8340: 2005 [11]. The test involves the extension of the examined sealant to a predefined length and the maintenance of this extension under specified conditions. All adhesive and cohesive failures are recorded during the test.

The most important element is the test specimen, which is created by placing the tested sealant between test substrates made from mortar, aluminium or glass. According to [11], other material can be also used as a substrate, and therefore the authors used pieces of wooden facade cladding. The recommended test specimen geometry is shown in Fig. 1.

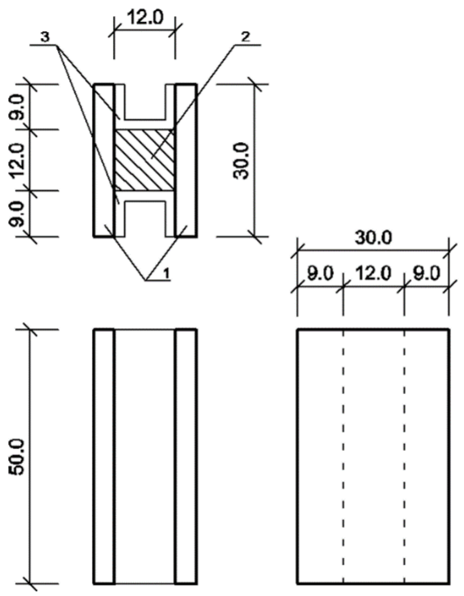


Legend:

1 Substrate bodies
2 Tested sealant
3 Spacers

Fig. 1: Test specimen according to [11]

European standard [11] also allows different types of test substrate, but the specified sealant dimensions, 12 x 12 x 50 mm applied between two base plates, must be followed. The test specimen shown in Fig. 2 was designed for the purposes of this research. This arrangement has the advantage of providing the test specimens with greater resistance against breakage during extension as the load is distributed along the whole length of the substrate plates and not only at their edges.



Legend:

1 Substrate bodies
2 Tested sealant
3 Spacers

Fig. 2: Test specimen designed for the experimental part of the project according to [11]

First, six test specimens had to be fabricated for each type of tested sealant from Tab. 1; there were 60 specimens in total for the 10 types of sealant. Fig. 3 shows several examples.

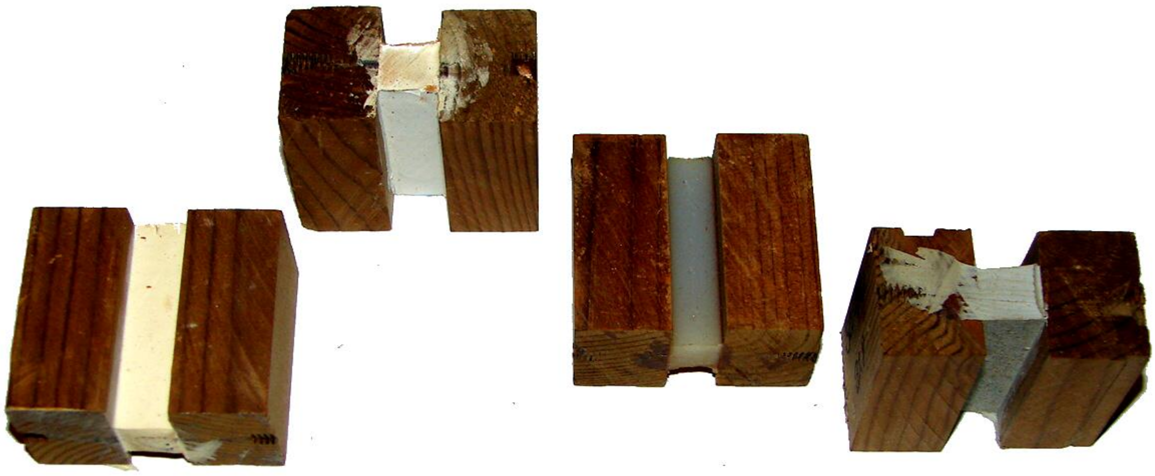


Fig. 3: Test specimen examples [personal source]

The test samples were stored at a temperature of 23 ± 2 °C and a relative humidity of 50 ± 5 % until the sealant had cured; afterwards 3 cycles followed:

- 3 days in a drying room at a temperature of 70 ± 2 °C
- 1 day in distilled water with a temperature of 23 ± 2 °C
- 2 days in a drying room at a temperature of 70 ± 2 °C
- 1 day in distilled water with a temperature of 23 ± 2 °C

Before testing, the test specimen had to be stored at a temperature of 23 ± 2 °C and a relative humidity of 50 ± 5 % for 24 hours. In order to test the specimens under freezing conditions, they were then also placed in an environment with a temperature of -20 ± 2 ºC for at least 4 hours.

The test itself takes place at temperatures of 23 ± 2 °C and -20 ± 2 ºC, and always with 3 specimens for each type of sealant. The test specimens are inserted into a testing device and extended by 60% of their original length at a speed of 5.5 ± 0.7 mm per minute. This extension is maintained at the given temperature for a period of 24 hours. After the specified time has elapsed, adhesive and cohesive failures are determined. These have to be measured with a suitable measuring device with a reading accuracy of 0.5 mm.

4 RESULTS

The results of the measurements are summarised in Tab. 2 and Tab. 3. Tab. 2 contains records of failures occurring during the extension of sealants carried out at a temperature of 23 ± 2 °C, while Tab. 3 contains failure records for -20 ± 2 ºC. The occurrence of failure is marked with the word YES for the relevant specimen; it is followed by the length of the relevant failure and the way in which the failure occurred.

Tab. 2: Test results for the temperature 23 ± 2 °C

Test sample	Failure occurrence	Length of failure	Characterization of failure
SO-U	-		
	YES	3 mm	Slight tear in the face of the sealant.
	YES	20 mm	Massive tearing from the substrate in many places.
SO-N	-		
	YES	22 mm	Deep crack in the middle of the sealant outside the substrate.
	-		
SO-PU	-		
	-		
	-		
SO-MS	-		
	-		
	-		
LU-U	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.
LU-N	-		
	-		
	-		
SL-U	YES	50 mm	Peeled off on one side during the test.
	YES	50 mm	Peeled off on one side during the test.
	-		
SL-N	-		
	-		
	-		
SL-PU	YES	50 mm	Peeled off on one side during the test.
	YES	3,5 mm	Slight tear in the face of the sealant.
	-		
SL-MS	YES	2 mm	Slight tear in the face of the sealant.
	-		
	-		

Tab. 3: Test results for the temperature -20 ± 2 °C

Test sample	Failure occurrence	Length of failure	Characterization of failure
SO-U	YES	14 mm	Deep detachment from the substrate.
	YES	3 mm	Slight tear in the face of the sealant.
	-		
SO-N	-		
	-		
	-		
SO-PU	-		
	-		
	-		
SO-MS	YES	50 mm	Peeled off on one side already during extension.
	-		
	-		
LU-U	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.

LU-N	YES	9 mm	Peeled off on one side already during extension.
	-		
	-		
SL-U	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.
	YES	4 mm	Peeled off slightly from the substrate on one side.
SL-N	-		
	-		
	-		
SL-PU	YES	50 mm	Peeled off on one side already during extension.
	YES	50 mm	Peeled off on one side already during extension.
	-		
SL-MS	YES	2 mm	Peeled off slightly from the substrate.
	-		
	-		

5 DISCUSSION

The research revealed interesting information. It is absolutely clear that not every sealant can be used to seal a given particular wooden substrate. Out of 10 different sealants, only two types passed this test: 25D polyurethane sealant manufactured by SOUDAL, and neutral silicone from SILCO, where no failure occurred in the case of perhaps one of the tested specimens. SILCO MS 60 sealant also came close to success as it exhibited only small defects, but despite that, SILCO MS 60 and all other tested sealants must be considered unsuitable for sealing the selected timber. The results also confirm the fact that the provision of the appropriate amount of adhesion is a decisive factor for reliability. Adhesive failures comprise approximately 95% of all failures, i.e. the sealant is separated from the substrate. In only 5% of cases, cohesive failure occurred, i.e. failure within the sealant material itself.

The measurements were carried out on the minimum possible quantity of samples, which is in accordance with the requirements [11]. An increase in the amount of tested specimens would lead to a rise in the probability of the occurrence of failures and thus also the risk that a given sealant would be rejected as being unsatisfactory. In this connection it needs to be realized that the testing of sealants according to [11] involves only a small proportion of the tests prescribed according to [12]. In the latter case, the performance of the necessary tests requires a significant increase in the number of experiments and a sealant can only be considered satisfactory in cases where no failure occurs. The 3 specimens tested at the temperature of 23 ± 2 °C and 3 others tested at the temperature of -20 ± 2 ºC are therefore adequate.

The authors of this article are working systematically on the testing of building sealants, creating a large file of statistical data for approx. 2200 samples; other research results will gradually be published.

6 CONCLUSION

The aim of this article was to find a suitable sealant for the sealing of joints which is able to pass a relatively demanding test for the determination of the tensile properties of sealants during maintained extension at temperatures of 23 ± 2 °C and -20 ± 2 ºC in cases where the base material is wooden façade cladding. Ten different commonly available industrially produced sealants were selected for the experimental part of the work. On the basis of the preceding chapters, the conclusion can be drawn that from all the evaluated sealants, only two were satisfactory: 25D polyurethane sealant manufactured by SOUDAL, and SILCO natural silicone.

Wood has proved to be a problematic substrate as far as sealing is concerned; expectations for it were significantly higher.

ACKNOWLEDGMENT

The article was produced thanks to the investigation of a research task for the Ministry of Industry and Trade of the Czech Republic: No. MPO FR-TI4/332 New Technologies of Bonded Facade Cladding with Anchor Elements with Increased Resistance to Corrosion.

REFERENCES

[1] European Standard EN ISO 6927: 2012. Buildings and civil engineering works – Sealants - Vocabulary.

[2] Wolf, A. T. *Durability of building sealants*. Published by RILEM Publications s.a.r.l. in 1999. ISBN: 2-912143-12-8. p. 137. Available at: https://www.dowcorning.com/content/publishedlit/Chapter8.pdf.

[3] Cochrane, H. *Industrial Minerals and Their Uses – Chapter seven - Adhesives and sealants – chapter seven*. Edited by: Peter A. Ciullo in 1996. ISBN: 978-0-8155-1408-4. p. 275-352. Available at: http://www.sciencedirect.com/science/article/pii/B9780815514084500089.

[4] Buyl, F. Silicone sealants and structural adhesives. *International Journal of Adhesion and Adhesives*, published by Elsevier Science Ltd. in 2001. **21**(5), doi:10.1016/S0143-7496(01)00018-5. p. 411-422. Available at: http://www.sciencedirect.com/science/article/pii/S0143749601000185.

[5] Congnard, P. *Handbook of Adhesives and Sealants*. Adhesives and Sealants — General Knowledge, *Application Techniques, New Curing Techniques*. **2**. Edited by Philippe Cognard in 2006. ISBN: 978-0-08-044708-7. Available at: http://www.sciencedirect.com/science/handbooks/18745695/2/supp/C.

[6] Chew, M. Y. L. Joint sealant for wall cladding. *Polymer testing scientific journal*. Published by Elsevier Science Ltd. in 2000. PII: S0142-9418(99)00038-0. pp. 653-665. Available at: https://www.dowcorning.com/content/publishedlit/Chapter8.pdf.

[7] Chew, M. Y. L. On-site non-destructive test for sealant. *Polymer testing*. **19**. Published by Elsevier Science Ltd. in 2000. PII: S0142-9418(99)00037-9. p. 643-651. Available at: http://ac.els-cdn.com/S0142941899000379/1-s2.0-S0142941899000379-main.pdf?_tid=144e248e-39c6-11e4-b680-00000aacb362&acdnat=1410448543_9234a7da0d85f51a5a4a6427046f3db7.

[8] Chew, M. Y. L., Zhou, X. Enhanced resistance of polyurethane sealants against cohesive failure under prolonged combination of water and heat. *Polymer testing.* **21**. Published by Elsevier Science Ltd. in 2001. PII: S0142-9418(01)00068-X. p. 188-193. Available at: http://ac.els-cdn.com/S014294180100068X/1-s2.0-S014294180100068X-main.pdf?_tid=fbae9d86-39c6-11e4-9a26-00000aacb361&acdnat=1410448931_9dd7d59cb742f7640c935208be5f044a.

[9] Chew, M. Y. L. The effects of some chemical components of polyurethane sealantson their resistance against hot water. *Building and environment.* **38**. Published by Elsevier Science Ltd. in 2003. doi: 10.1016/S0360-1323(03)00142-2. p. 1382-1384. Available at: http://ac.els-cdn.com/S0360132303001422/1-s2.0-S0360132303001422-main.pdf?_tid=07a88f8e-39c7-11e4-9d2c-00000aacb35d&acdnat=1410448951_ae87ddc7746b974993192d2e818af775.

[10] Pantaleo, A. Roma, D. Pellerano A. Influence of wood substrate on bonding joint with structural silicone sealants for wood frames applications. *International Journal of Adhesion and Adhesives*. **37**. Special Issue on Joint Design 3. Published by Elsevier Science Ltd. in 2012. doi:10.1016/j.ijadhadh.2012.01.017. p. 121-128. Available at: http://www.sciencedirect.com/science/article/pii/S0143749612000188.

[11] European Standard EN ISO 8340: 2005. Building construction – Sealants – Determination of tensile properties at maintained extension.

[12] European Standard EN ISO 15651-1 edition 2: 2013. Sealants for non – structural use in joints in buildings and pedestrian walkways – Part 1: Sealants for facade elements.