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Expert's Report

Low cycle ductility classes for Würth screws

1 General

EN 14592:2022 Annex E provides a test method aimed at classifying the ductile behaviour of dowel-type fasteners by means of "low cycle ductility classes". To classify screws into a low cycle ductility class, three tests under cyclic load and three tests under monotonic load with single screws are necessary. In contrast to other test methods, only the screw itself and not a whole joint is tested. Two criteria must be met for the screw to be classified into a low cycle ductility class. For criterion 1, screws must reach a minimum bending angle of at least 45° for diameters up to 8.0 mm or 30° for screws with larger diameters, respectively. If the moment capacity under cyclic load after three fully reversed cycles (residual bending moment capacity) reaches at least 80 % of the moment capacity under monotonic load, the screw passes the test (criterion 2). Three different low cycle ductility classes are defined where for the higher classes providing more energy dissipation capacity, larger bending angles must be reached during the test. The bending angles α_c for the classification into the three low cycle ductility classes are defined for the low cycle ductility class S1 as $\alpha_c = \alpha$, for S2 as $\alpha_c = 1.5\alpha$ and for S3 as $\alpha_c = 2\alpha$. α is defined as $\alpha = 45°/d^{0.7}$ where d is the nominal screw diameter in mm.

Adolf Würth GmbH & Co. KG commissioned me to evaluate the low cycle ductility classes of ASSY 4 Würth screws from carbon steel and from stainless steel with diameters between 5.0 mm and 12.0 mm as part of an expert's opinion.

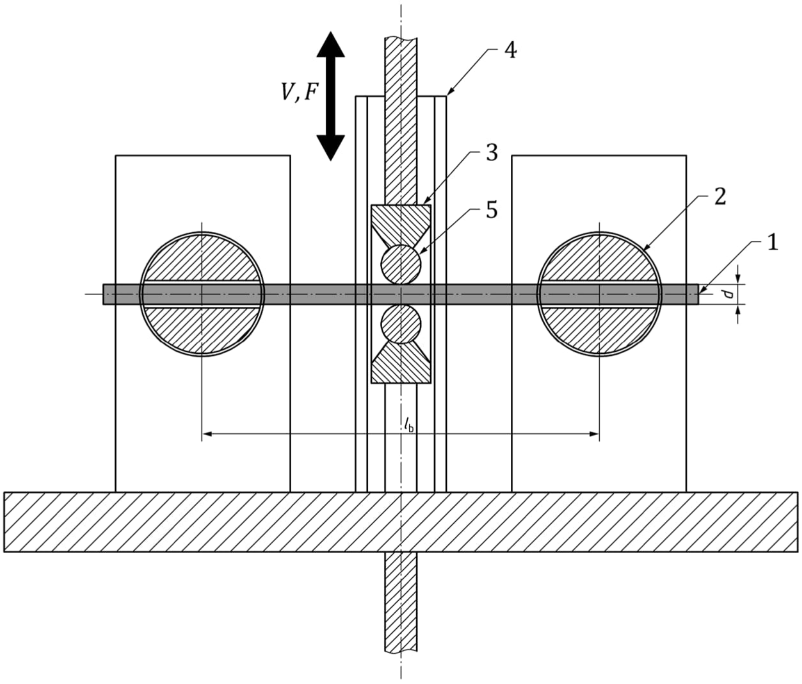
This expert's report is mainly based on the following documents:

- Test Report 246110: Classification of screws into low-cycle ductility classes in accordance with EN 14592:2022, Versuchsanstalt für Stahl, Holz und Steine, Karlsruhe Institute of Technology, 25.06.2024

- Casagrande, D., Bezzi, S., D'Arenzo, G., Schwendner, S., Polastri, A., Seim, W. and Piazza, M. „A methodology to determine the seismic low-cycle fatigue strength of timber connections", Construction and Building Materials 231 (2020) 117026, https://doi.org/10.1016/j.conbuildmat.2019.117026
- Cervio, M and Muciaccia, G. "Low-cycle behavior of wood screws under alternating bending", European Journal of Wood and Wood Products (2020) 78:41–52, https://doi.org/10.1007/s00107-019-01484-x
- Izzi, M. and Polastri, A. "Low cycle ductile performance of screws used in timber structures", Construction and Building Materials 217 (2019) 416–426, https://doi.org/10.1016/j.conbuildmat.2019.05.087
- Steilner, M., Kunkel, H. and Sandhaas, C. "Low cycle ductility of self-tapping screws", Paper 55-7-5, Proceedings, International Network on Timber Engineering Research, Bad Aibling, Germany, ISSN 2199-9740, 2022
- Eurocode 5 (EN 1995-1-1): Design of timber structures - Part 1-1: General - Common rules and rules for buildings
- EAD 130118-01-0603 "Screws and threaded rods for use in timber constructions"
- EN 14592:2022 "Timber structures – Dowel-type fasteners – Requirements; German version EN 14592:2022

2 Test method

Figure 1 shows the principal test setup from EN 14592.



1 Sample fastener
2 End support
3 Load device
4 Lateral restraint
5 Mandrel
V Displacement
F Load
d Nominal diameter
ℓ_b Distance between supports

Figure 1: Test setup given in Annex E of EN 14592:2022

The distance ℓ_b between supports shall be less 16 d. The diameter of the mandrel where the sample is bent over shall be 2 d ± 0,5 d. The end supports shall allow for axial displacements and free rotations of the sample. The sample shall be laterally restrained to prevent out of plane rotations. The test device must allow the applied displacement to be controlled and the appropriately applied load to be measured. Both the equipment used to measure displacement and the applied load must be able to achieve an accuracy of 1% of the reading. Figure shows an example of a moment angle diagram.

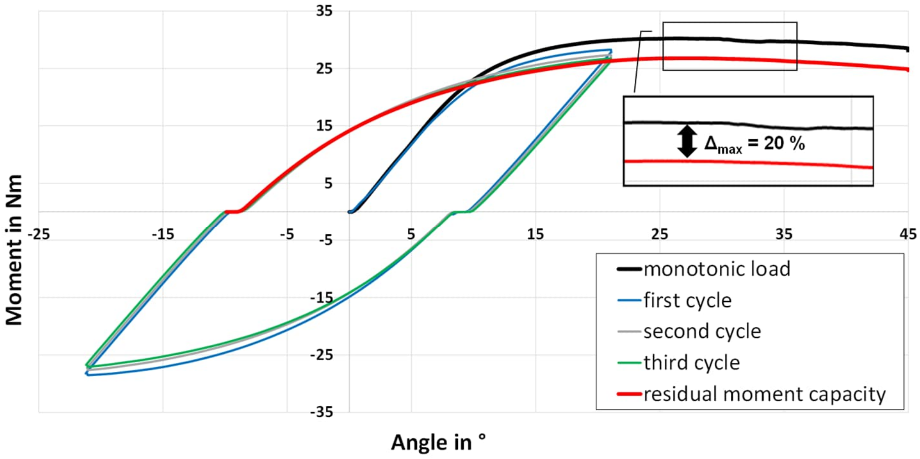


Figure 2: Moment-angle-diagram of monotonic and cyclic test in accordance with Annex E of EN 14592:2022 (from Steilner et al.).

Due to the change of load direction, a force-free slip in the zero crossing is created due to the backlash between mandrel and fastener. To compensate for this slip, all bending angles α_c are increased by 1.0°.

A study by Steilner et al. showed that a decreased testing time, a smaller mandrel diameter and a smaller distance between supports leads to more unfavourable results.

The classification into a low cycle ductility class is considered to have been reached if, after three cycles with full alternating loading up to the value α_c, the residual moment capacity of the screw is at least 80 % of the average yield moment, determined using monotonic tests (Section 5.3.1.9.2, EN 14592:2022), criterion 1. Additionally, the desired bending angle α_{max} must be achieved without prior failure of the fastener (Annex E, EN 14592:2022) - criterion 2.

In the tests, the criteria for low cycle ductility class S3 are first checked. If both criteria are met, the screw is classified as S3. If one or both criteria are not met, the tests are repeated with the less severe test parameters of low cycle ductility class S2. Again, if both criteria are met, the screw is classified as S2. If one or both criteria are not met, the tests are repeated with the even less severe test parameters of low cycle ductility class S1. Only if both criteria are met, the screw is classified as S1. Otherwise, no low cycle ductility classification is possible.

3 Test results

Table 1: Overview of tested ASSY 4 screws and test parameters

Diameter	Steel	Type	ℓ_b [mm]	D [mm]	α_c S1 [°]	α_c S2 [°]	α_c S3 [°]	α_{max} [°]
5 mm	Carbon	ASSY 4 WH 5x120/62	79	12	14.6	21.9	29.2	45
5 mm	A2	ASSY 4 A2 CS 5x100/52	79	12	14.6	21.9	29.2	45
6 mm	Carbon	ASSY 4 WH 6x200/70	95	12	12.8	19.3	25.7	45
6 mm	A2	ASSY 4 A2 CS 6x200/70	95	12	12.8	19.3	25.7	45
7 mm	Carbon	ASSY 4 CSMP 7x240/85	111	12	11.5	17.3	23.1	45
8 mm	Carbon	ASSY 4 WH 8x300/100	127	18	10.5	15.7	21.0	45
8 mm	A2	ASSY 4 A2 WH 8x300/100	127	18	10.5	15.7	21.0	45
10 mm	Carbon	ASSY 4 WH 10x360/120	159	18	9.0	13.5	18.0	30
12 mm	Carbon	ASSY 4 WH 12x440/145	191	18	7.9	11.9	15.8	30

The results of the low cycle ductility classification of the tested screws are summarised in Table 2.

Table 2: Low cycle ductility classification according to EN 14592 of ASSY 4 partially threaded screws

Diameter	Steel	Low cycle ductility class
5 mm	Carbon	S1
5 mm	Stainless A2	S2
6 mm	Carbon	S2
6 mm	Stainless A2	S3
7 mm	Carbon	S2
8 mm	Carbon	S3
8 mm	Stainless A2	S3
10 mm	Carbon	S2
12 mm	Carbon	S2

4 Summary

ASSY®4 partially threaded screws from Adolf Würth GmbH & Co. KG in Künzelsau were tested according to the test method in Annex E of EN 14592:2022 and the resulting low cycle ductility class was determined for the tested screws. The test results are documented in Test Report No. 246110 of Versuchsanstalt für Stahl, Holz und Steine, Karlsruhe Institute of Technology.

The test results show that screws made from carbon steel reach low cycle ductility classes S1 (∅ 5 mm), S2 (∅ 6mm, ∅ 7mm, ∅ 10 mm, and ∅ 12 mm) or S3 (∅ 8 mm) while screws made from stainless steel A2 reach low cycle ductility classes S2 (∅ 5 mm) or S3 (∅ 6mm and ∅ 8 mm).

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