European Journal of Wood and Wood Products (2022) 80:731–740
https://doi.org/10.1007/s00107-022-01803-9

ORIGINAL ARTICLE

Evaluation of some mechanical and physical properties of 'Oriented Strand Board (OSB/3)' following cyclic accelerated aging tests

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Received: 9 April 2021 / Accepted: 17 February 2022 / Published online: 18 March 2022

Abstract

Despite the large-scale production of oriented strand board (OSB) which is produced in Europe according to EN 300: 2006 standard, and its application as roof and wall sheathing material, experimental data about its mechanical and physical properties following soaking–freezing–drying and cooling (which mimics accelerated aging) is relatively scarce. The properties of samples to be investigated according to EN standards, i.e. internal bond strength (IB), axial screw withdrawal resistance (SWR), the modulus of rupture for the major axis‖ and for the minor axis⊥ (MOR‖, MOR⊥), and the modulus of elasticity in bending for the major axis‖ and for the minor axis⊥ (MOE‖, MOE⊥), were determined by using three-point bending, together with deflection measurements by means of an optical gauge, thickness swelling (TS), and moisture content (MC). Analytical equations were used for attaining an approximation of the measured values for the aforementioned properties of OSB/3 depending upon the number of cycles involved. The values of IB and SWR (the latter in the cutting edge) dropped considerably after the first cycle, while MOR and MOE continued to decrease only a little or dropped somewhat further; TS and MC stabilised during the latter cycles. After the cyclic accelerated aging tests, the retention value of IB accounted for 61.3% of the values required in EVS-EN 300: 2006 standard: for MOR‖ the corresponding value was 62.8%, and for MOR⊥, 85.0%; for MOE‖ the corresponding value was 48.3%, for MOE⊥, 66.9%, and for TS, 168%. The surface and cross-section structures of the initially dry samples and the samples after the first and third soaking/oven-drying/cooling and soaking/freezing/oven-drying /cooling cycles (V313 test EVS-EN 321: 2002) were studied using X-ray technique.

1 Introduction

Climate change is a serious long-term problem which requires a multidisciplinary global approach when it comes to being able to resolve it. Carbon (carbon dioxide) sinks are needed in order to conserve carbon and expand its use in a socio-economically sustainable manner. One method of long-term carbon storage is the process of transforming biomass which is produced within a forest (from young, low trees) into wood products in order to obtain resources such as oriented strand board (OSB) (Swiss Krono 2022). In the EU, the production of OSB increased by between 4.8 and 7.0 million m^3 between 2010 and 2020 (European Panel Federation 2022; Eurostat 2021). Of that total, 77% was used in construction (mainly by the wood-based panel industry) (European Panel Federation 2022). OSB (EVS-EN 300: 2006) is mainly used as a structural material, such as for single layer flooring, wall and roof sheathing, and I-beam webs (Dataholz 2022). Five grades of OSB are defined in EVS-EN 300: (2006) in terms of their mechanical performance and relative resistance to moisture: OSB/3 is defined as load-bearing boards for use in humid conditions; OSB/4 is defined as heavy-duty load-bearing boards for use in humid conditions. OSB/3 and OSB/4 are also used in periodically changing (intermittent) rainfall or humid-dry conditions, followed by freezing–thawing conditions, which are commonly found in globally temperate regions (such as those of Central Europe, the Nordic and Baltic countries, and North-Western Russia). In the manufacturing of OSB, its biomass is formed of particles of various sizes, which are glued together with resin in a press under certain temperature and pressure conditions (Veigel et al. 2012; Ferrández-García et al. 2018). OSB is produced using large, flat strands of wood, with an approximate width of 15–20 mm, length of 50–75 mm

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and thickness of 0.3–0.7 mm, with the strands of the outer (facing) layers being aligned in the boards's longitudinal direction or towards the production line itself, and the core layer often being formed of smaller strands oriented at right angles to the outer layers (Irle et al. 2012; Plenzler et al. 2017; Sackey et al. 2008). It is already well established that the strength properties of OSB/3 and OSB/4 decrease markedly when the materials absorb water, but repeated soaking–freezing–thawing–drying cycles particularly accelerate their degradation (Derkowski et al. 2014). Derkowski et al. (2014) have determined that relative changes in the mechanical properties for both types of boards are very similar. It is possible to accelerate this aging process under artificial laboratory conditions for individual specimens, when they have been cut out of boards, which are used under outdoor conditions according to EVS-EN 321: 2002. A common application for an aging test is the modelling of one or more extreme environmental conditions in a short period of time (so-called accelerated aging), which can be used as evidence for the use of the product. An accelerated aging test, or a V313 test, is rarely used, as it is generally applied in indoor laboratory tests, and the results are usually not presented in the certificate of the properties of a given OSB.

The objective of this study was to use an analytical linear-fractional expression to approximate experimental data for internal bond strength (IB), axial screw withdrawal resistance (SWR), modulus of rupture (MOR) and modulus of elasticity (MOE), and to propose an exponential expression for thickness swelling (TS) and moisture content (MC) depending upon the number of cycles. Mathematical expressions can clarify the mechanical physical process and provide further information. The equations make it possible to calculate the final values of the studied mechanical (IB, SWR, MOR, MOE) and physical properties (TS) of OSB. In addition, the statistically significant ($p < 0.05$) relative measurement uncertainty (RMU) (usually described as the coefficient of variation) is estimated and calculated in percentages for average values according to EVS-EN 326-1: 2002.

OSB/3 boards are commonly used as a material layer of envelope structures exposed to outdoor conditions in building construction, where the aforementioned properties are essential. On the one hand, this study is a continuation of previous research (Telling 2019; Leppik 2020; Kask et al. 2020), while on the other a freezing cycle was added in order to mimic the requirements for an accelerated aging test. The effects were clarified in terms of soaking/oven-drying/cooling and soaking/freezing/oven-drying/cooling on the surface and in the cross-sectional structure of the test samples, with this phase taking place after the effects had been established in terms of soaking and soaking/freezing, as evaluated by means of the X-ray technique.

2 Materials and methods

Three commercial OSB/3 boards (with a thickness of 12 mm) originating from the different production batches were chosen for the study. The OSB/3 boards, which were produced by SWISS KRONO (Poland) were formed of three layers of Scots pine (*Pinus sylvestris*) strands which crossed at a right angle. The strands were glued within the resin's matrix (Plenzler et al. 2017): the surface layers were bonded using the four-component resin, melamine-urea-phenol-formaldehyde (MUPF) (with the density of 749 ± 22 kg/m^3), and the core layer was bonded with three-component methylene-diphenyle-diisocyanate (MDI) (with the density of 535 ± 12 kg/m^3). Test samples for the determination of IB (with dimensions of 50 mm × 50 mm), SWR (160 mm × 50 mm × 12 mm), MOR, and MOE (290 mm × 50 mm × 12 mm), according to EVS EN 326-1: 2002, were cut from the three OSB/3 boards (originating from different production batches) in the parallel direction (|| on the major axis), and in the perpendicular direction (⊥ on the minor axis) to the long edge of the board or to the production line. To obtain reliable mean values and a standard deviation, the number of samples for each stage of a series was at least six in total. The dimensions of the samples were measured using a digital calliper with an accuracy of 0.01 mm, along with a micrometer gauge with an accuracy of 0.001 mm and a diameter of the measuring head of 6.3 mm. The weight of the samples was measured by means of an electrical balance, a Kern PLB 1000-2 with an accuracy of 0.01 g.

The properties of the OSB/3 boards were investigated after one to three repeated cycles for IB and SWR, and six cycles for MOR, MOE, TS, and MC. Each of these accelerated aging cycles consisted of four stages (according to the EVS-EN 321: 2002): Stage 1 'Wet' property involved soaking in water at (22 ± 2) °C for 72 h; Stage 3 'Frozen' property involved freezing at (-20 ± 1) °C for 24 h in the refrigerator; while stages 2 and 4 'Dry' properties involved drying at (65 ± 2) °C for 48 h in a ventilated drying box and subsequent conditioning in a climatic chamber at 21 ± 2 °C and a relative humidity level of 65 ± 5%. A computer-controlled mechanically-actuated universal testing machine was used: Instron 3369. Deflection for the determination of the modulus of elasticity was measured by means of an optical gauge (Advanced Video Extensometer 2663-821). A load was applied at a constant rate such that failure occurred in 60 ± 30 s. The weight and dimensions of the test samples were measured immediately after the samples were taken out of the water tank or the climatic chamber in order to determine their TS and MC (using the weighing method), according to EVS EN 317: 2000, and EVS EN 322: 2002. The tests were carried out immediately following removal.

Samples for determining MOR and MOE were tested in their current state following the three-point bending test in accordance with EVS EN 310: 2002. For more details see a previous paper by Kallau et al. (2015).

The YXLON FF35 CT-computed tomography system was applied for an X-ray investigation of the structure of the OSB/3. Specimens for X-ray investigations were obtained from the samples of the bending test, according to the details shown in Fig. 1. It should be noted that the initial structure of the specimens which were cut from different parts of the samples varies somewhat (in terms of the dimensions and orientation of the strands, and in terms of the amount of resin involved).

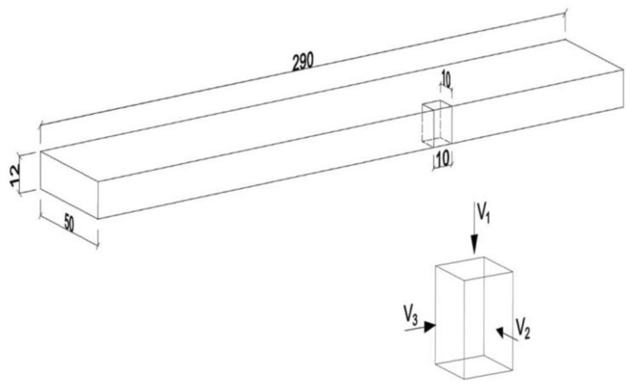

Fig. 1 Removal of a specimen from MOR and MOE samples for X-ray irradiation. X-rays are directed as follows: V_1 is the right angle to the face; V_2 is the right angle to the edge; and V_3 is parallel to the main axis of the samples

To evaluate IB and its edge-splitting tendency, the EVS EN 319: 2000 standard was applied. The plane surface of the test samples which were taken out of the water tank (Stage 1) and the refrigerator (Stage 3) was dried with a KX1682 heat gun and then covered with the hot-melt glue, Termik AD 0117, and melted with a Rapid PRO EG360 Pro-Industrial glue gun. The prepared sample was glued on the opposite side of plywood loading blocks (see Fig. 2b), and pressed by a G-cramp for thirty seconds to ensure a strong bond. As these procedures lasted only about two to four minutes, the fracturing core layer did not start melting. A similar technology was applied to the preparation of test samples to measure their tendency to split; for this, a screw was threaded into the edge at mid-thickness and at a right angle. For testing, the wood screw of type Hobau PROF TX20 (with a thickness of 4.2 mm and a length of 57 mm) was selected. A pilot blind hole, with a depth of 35 mm and a diameter of 2.5 mm, was drilled using a Bosch PBD 40 drill, and 30 mm of complete thread were embedded (Fig. 2a). The plywood blocks with the samples (Fig. 2b) were attached to the grips on the test machine and subjected to a tensile force which was perpendicular to the sample surface, until rupture occurred.

The EVS EN 320: 2011 standard was applied in order to determine SWR. For testing purposes, a wood screw of the same type (Hobau PROF TX20) was subjected to a tensile force (with a loading rate of 10 mm/min) according to the scheme presented in Fig. 3. The screw was threaded at a right angle to the face of the board. Although inserting screws into the OSB's edge (the core layer) is not usually recommended as it may give rise to splitting, it was nevertheless considered necessary.

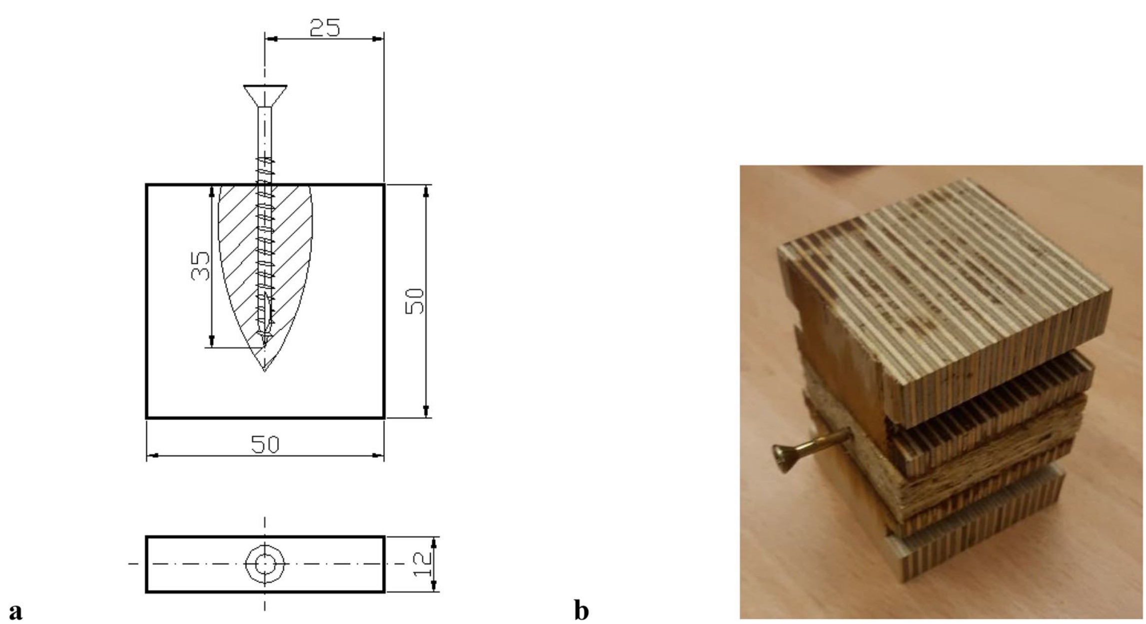

Fig. 2 IB test used to measure the tendency towards splitting for the samples: **a** inserting a screw into the core layer; **b** prepared sample for testing

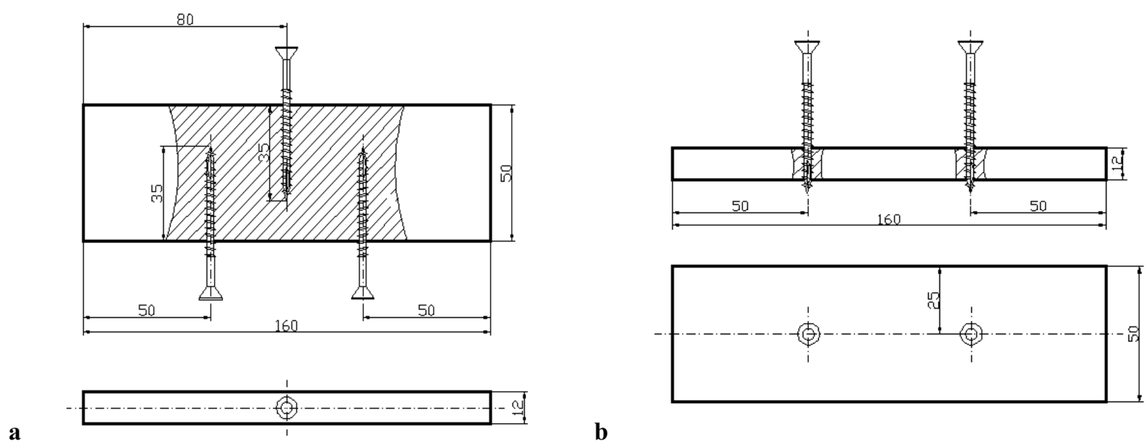

Fig. 3 Inserting screws: **a** into the edges of a sample and **b** into the face of a sample

Analytical equations were used for experimental data processing. The following linear-fractional (equilateral hyperbola) and exponential functions were used to approximate the experimental data for the investigated properties depending upon the number of cycles of soaking/oven-drying (Kallau et al. 2015):

$$Y(x) = \left(c\left(Y_i - Y_f\right)/(bx + c)\right) + Y_f, \tag{1}$$

$$Y(x) = Y_f((1 - e^{-ax}) \tag{2}$$

where Y_i, Y_f are the calculated initial ($x=0$) and final values ($x=\infty$) of the investigated properties, x is the number of cycles, and a, b, and c are constants.

The initial and final values of the properties and constants should be determined so that the experimental data that has been measured can be approximated in the best way by minimizing the square of any error (the 'least squares' form of regression). This issue was solved by using the Mathcad 15.0 program with its regression function, *genfit(vx,vy,vg,F)*.

Using Eq. (1), a curve or two intersecting lines are obtained to approximate the test data (the equilateral hyperbola asymptotically approaches the two intersecting lines). Equations (1) and (2) make it possible to calculate the final values of the studied properties when the samples are saturated with water. Equation (1) is used to calculate the limit state of IB, SWR, MOR and MOE. Equation (2) is used to calculate the values of MC and TS, respectively.

3 Results and discussion

The study focuses on the determination of changes in IB, depending upon the number of cycles involved. In a three-layer board, the IB characterizes the tensile strength of the core layer where it is oriented towards smaller strands which are parallel with the board's surface or the bond between the glue and strands. The experimental values which were obtained in relation to the samples, along with the approximation curves, are presented in Fig. 4 for three repeated cycles.

Following completion of the first cycle, the retention versus the initial values of the IB for Stages 1 and 2 were $(0.172/0.586)\times 100 = 29.4\%$ and $(0.226\ /0.586)\times 100 = 38.6\%$ respectively, and for Stages 3 and 4 $(0.157/0.586)\times 100 = 26.8\%$ and $(0.260/0.586)\times 100 = 44.4\%$, respectively. In this case, the accelerated aging effect was $(0.196/0.586)\times 100 = 33.4\%$. Such low retention values, making up to one third of the initial values, can evidently be explained by the fact that the commercial board had large initial IB levels in comparison to the values (0.32 N/mm^2) required by EVS-EN 319: 2000. Consequently, the IB retention value is $0.196/0.32 = 61.3\%$, which still accounts for almost two thirds of the recommended value. It should be noted that the IB values (and also the values for the properties below) when it comes to calculating the percentage value are taken from the approximation curves.

At the same time, it can be seen that freezing after soaking does not change the results in any practical way, and this trend continues during the consequent cycles (although the volume of ice is larger than that of water and has both compressive strength and some tensile strength). The IB values obtained with the dried samples are somewhat, but not significantly, higher than the IB values obtained from the soaked samples, but they do show larger levels of dispersion.

The IB values obtained from the samples containing an inserted screw—depending upon the number of cycles—show a similar trend. Table 1 presents the values and constants obtained by means of an approximation of the results of these tests. The edge splitting tendency to edge screwing for IB was only 69% compared with a defined IB, while the

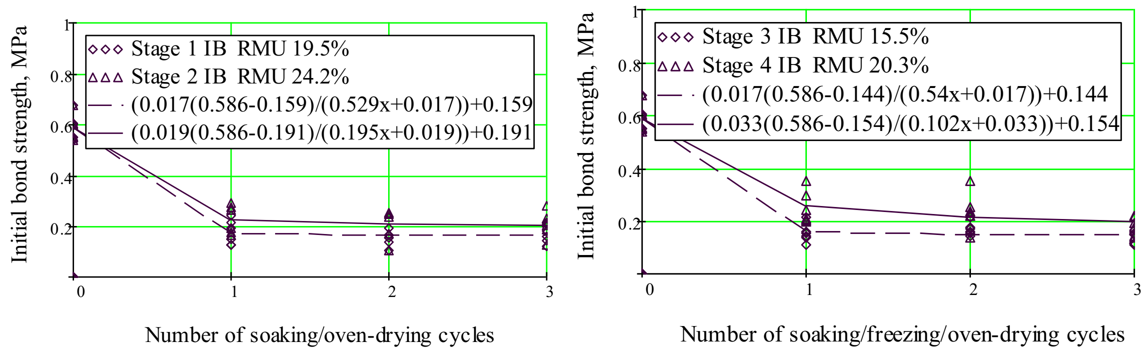

Fig. 4 Dependence of IB on the number of repeated cycles as follows: Stage 1 is 'Wet IB'; Stage 2 is 'Dry IB' (left plot); Stage 3 is 'Frozen IB'; Stage 4 is 'Dry IB' (right plot), and the curves of approximation according to Eq. (1)

Table 1 Calculated (formulae 1 and 2) average initial and final values and constants of the investigated properties for OSB/3 samples

Properties		IB, MPa	SWR, N/mm	MOR, MPa	MOE, GPa		MC, %
Stage	Constants	With screw	Into edge	⊥	‖	⊥	
1	Y_i	0.404 ± 0.101	47.8 ± 10.2	18.3 ± 2.6	4.50 ± 0.72	2.36 ± 0.37	
	Y_f	0.113 ± 0.028	12.2 ± 2.6	5.03 ± 0.71	0.69 ± 0.11	0.58 ± 0.09	111.1
	$Y(1)^*$	0.158	20.0	6.54	1.67	0.73	55.5
	a, b	0.21	0.15	1.478	0.101	0.295	0.693
	c	0.038	0.042	0.19	0.035	0.028	
	$Y(1)^*/ Y_i$, %	39.1	41.8	35.7	37.1	30.9	RMU = 7.6
2	Y_i	0.404 ± 0.116	47.8 ± 9.8	18.3 ± 3.2	4.50 ± 0.63	2.36 ± 0.37	
	Y_f	0.125 ± 0.036	17.3 ± 3.6	8.5 ± 1.45	1.46 ± 0.20	1.04 ± 0.16	10–12
	b	0.181	0.048	2.81	0.117	0.716	
	c	0.045	0.026	0.20	0.028	0.014	
3	Y_i	0.404 ± 0.108	47.8 ± 8.5	18.3 ± 3.6	4.50 ± 0.63	2.36 ± 0.45	
	Y_f	0.125 ± 0.034	19.5 ± 3.5	7.8 ± 1.6	1.09 ± 0.15	0.75 ± 0.14	100.7
	a, b	0.358	0.118	1.931	0.135	0.79	0.615
	c	0.02	-0.012	-0.136	0.025	0.002	RMU = 6.1
4	Y_i	0.404 ± 0.122	47.8 ± 11.2	18.3 ± 3.1	4.50 ± 0.65	2.36 ± 0.36	
	Y_f	0.160 ± 0.048	22.4 ± 5.3	7.2 ± 1.2	1.65 ± 0.24	0.89 ± 0.13	10–12
	$Y(3)^{**}$	0.136	22.2	8.50	1.69	0.937	84.8
	b	0.237	0.28	0.244	0.436	0.231	
	c	0.032	− 0.005	0.095	0.016	0.022	
	$Y(3)^{**}/ Y_i$, %	33.7	46.9	46.4	37.5	39.7	

diametrical section area of the screw's hole makes up about 6% of the fracture area of the sample (Fig. 2a).

As the values for edge-SWR change in relation to the number of cycles in a similar way to the IB values, with both characterising the core layer, graphs showing the first two stages are plotted together (Fig. 5). The other initial and final values and constants obtained are given in Table 1.

For the determination of face-SWR, the screws threaded through all three layers (face, core, and back), actually penetrate the two face layers, which are denser, have larger strands, and are less water repellent (Nishimura 2015). The values obtained for the three cycles are presented in Fig. 5.

After completion of the first cycle, the retention values versus initial values in terms of face-SWL for Stages 1 and 2 are 63.3% and 87.2% respectively, while Stages 3 and 4 are 67.5% and 81.3% respectively, and accelerated aging is (54.1/68.3) × 100 = 79.1%. According to a previous study, the retention value for face-SWR was 65.1% after 24 h of soaking, and 87.4% after 48 h of drying (Kask et al. 2020). Therefore, the result was practically unaffected at any point after the initial twenty-four hour soaking period. On the other hand, the effect of soaking here is significantly lower than it is for IB. The values for the initial withdrawal resistance for screws inserted perpendicularly into the face of the specimens and which had penetrated all three of its layers

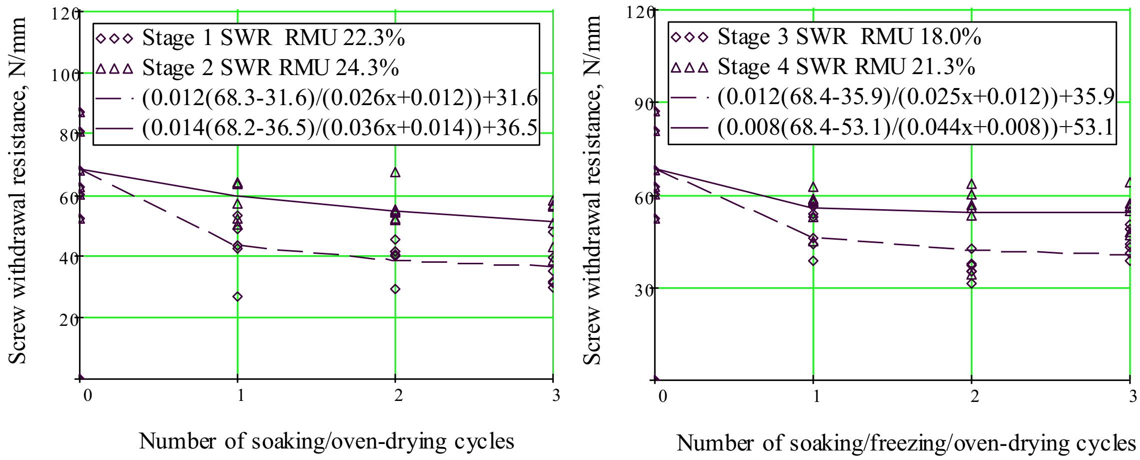

Fig. 5 Dependence of face-SWR on the number of repetitive cycles as follows: Stage 1 is 'Wet SWR'; Stage 2 is 'Dry SWR' (left plot); Stage 3 is 'Frozen SWR'; and Stage 4 is 'Dry SWR' (right plot), with curves of approximation according to Eq. (1)

(face, core, and back—where the working part of the thread is equal to an average sample thickness of 11.62 mm) are higher than in the case where the screws were inserted into the cutting edges of the sample's core layer (Fig. 3a, b). Note the fact that the core layer had a lower density when compared to that of the face layer. This indicates that the ratio of edge-to face-SWR is about 47.8/68.3 = 0.70. As edge-SWR is not defined for boards that are less than 15 mm thick in the standard used here (EVS-EN 320: 2011), the obtained results still reveal some evident trend and its magnitude for the investigated OSB/3.

The experimental MOR∥ values of samples affected by six repeated cycles (Derkowski et al. 2014), and the approximation curves are both presented in Fig. 6. After the first cycle, the retention versus initial values of MOR∥ for Stages 1 and 2 are 30.6% and 51.4%, respectively (79.6% after 24 h of soaking for Stage 2 (Kallau et al. 2015)), and for Stages 3 and 4 the respective values are 31.5% and 41.5%, and with accelerated aging (12.56/27.5) × 100 = 45.7%. If the approximation curves for MOR⊥, MOE∥, and MOE⊥ are similar to those for MOR∥ the initial and final values and the constants of curves are given in Table 1.

The most critical average calculated retention values for OSB/3 samples were found after the first soaking cycle in relation to those for the initial dry stage. The retention values were as follows: IB at 29.4%; MOR∥ at 30.6%; MOR⊥ at 35.3%; MOE∥ at 37.1%; and MOE⊥ at 30.9%. Therefore, all of these properties decreased about one third.

Both Figs. 4 and 6 show nearly identical trends. Consequently, it should be possible to predict one property from the results of the other. Since the bending test is much easier to perform than the IB test, considerable time and effort could be saved by predicting IB from MOR results (Fig. 7).

When calculating TS, the corresponding linear dimensions were measured from the bending test samples in order to obtain results for six repetitive cycles. All values from the experimental data of TS values were approximated according to Eq. (2) (Fig. 8).

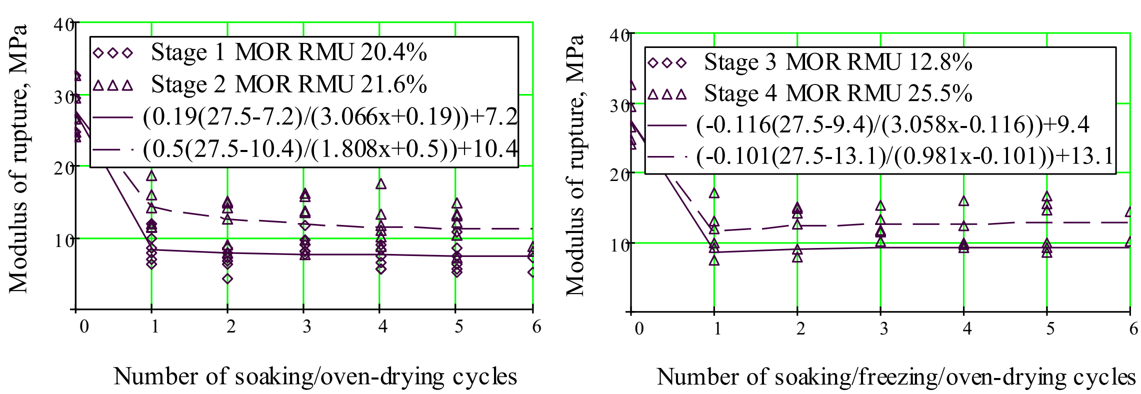

Fig. 6 Dependence of the average values for MOR∥ on the number of repetitive cycles as follows: Stage 1 is 'Wet MOR'; Stage 2 is 'Dry MOR' (left plot); Stage 3 is 'Frozen MOR'; Stage 4 is 'Dry MOR' (right plot) with the curves of approximation according to Eq. (1)

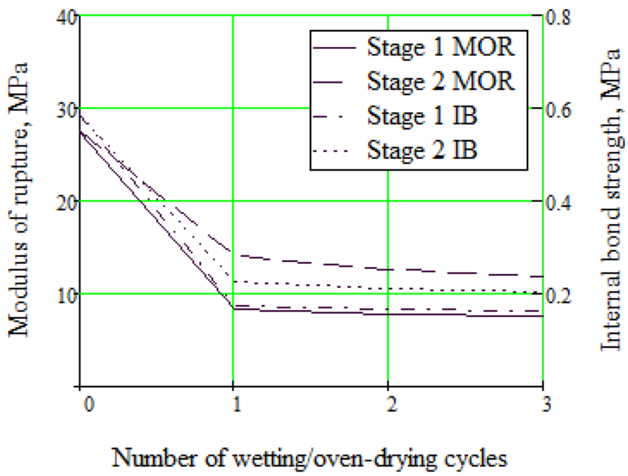

Fig. 7 Dependence of the average values for MOR|| on the number of repetitive cycles in comparison with IB

After completion of the first cycle, TS retention values for stages 1 and 2 were 21.4% and 19.0% respectively, and for stages 3 and 4 the values were 19.0% and 19.1% respectively, while accelerated aging (stage 4) was 25.2%. It is evident that the test results for Stages 1 and 2 practically coincide with those for Stages 3 and 4, meaning that, when compared to soaking, TS values are not markedly affected in these tests. This can be explained by the fact that, after soaking, the matrix from the resin is plastically deformed; however, frozen strands do not cause plastic deformations (only elastic deformations; see X-ray investigation), although the volume of ice is larger than that of water. The high TS value when compared to the recommended value (15%), according to EVS-EN 317:2000, may indicate the possibility that an insufficient amount of wax and water repellence was used during the manufacturing process for OSB board.

As the average MC shows a similar tendency to the results for TS—with the MC being determined according to EVS EN 322: 2002 and being dependent upon the number of cycles—only those terms which were calculated with formula (2) are presented in Table 1. Following completion of the first cycle of 72 h of soaking, the MC values were 55.5%, and it can be seen that the changes in the values for TS and MC depend, as expected, upon a ratio of 1/3, as TS is characterized by its linear dimension and MC is characterized by its cubic measurement.

The calculated retention values after cyclic accelerated aging tests ($Y(3)^{**}/Y_i$, according to EVS-EN 321: 2002 in percentages are: IB 33.4%; SWL in the face surface 79.1% and in the cutting edge 46.5%, respectively; MOR|| 45.7% and TS 25.2% (Figs. 4, 5, 6, 7, 8; for other cases see Table 1) compared to the corresponding properties in the initial dry state (with MC of 12%, and room-dry at 6.8%).

Figure 9 shows that the alignment of the strand on the surface layer is not perfectly parallel to the board length, which has probably impacted the MOR and MOE values. The ratio of MOR|| to MOR⊥ is 1.5, while the ratio for MOE is 1.91. The data from the experiments tend to fluctuate to a considerable extent; the coefficient of variation for the various properties is between 6.1 and 25.5%. Fluctuations in the results are smaller for MC and TS, and larger for IB. In the determination of IB, this is natural as the tensile load is applied with some eccentricity, and the two solid loading blocks are also not glued at a 90° offset to the test samples (Fig. 2b), which may be the reason for its low retention value, which in turn is considerably less than that recommended in EVS-EN 319:2000.

For accelerated aging after three soaking/freezing/oven-drying cycles, the average retention values in relation to the values required in EVS-EN 300: 2006 standard were: IB 61.3%; MOR|| 62.8%; MOR⊥ 85.0%; MOE|| 48.3%; MOE⊥ 66.9%; and TS 168%. Mirski et al. (2020) noted a significant drop in the bending strength of OSB/3 board: 68% for MOR|| and 71% for MOR⊥ after the first cycle of the aging test, and similar changes were also recorded for MOE. Derkowski

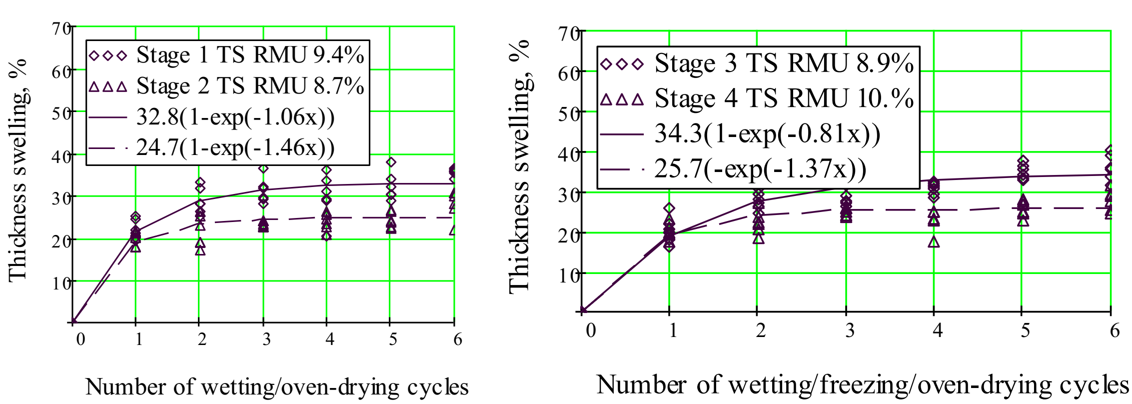

Fig. 8 Dependence of TS on the number of repetitive cycles as follows: Stage 1 is 'Wet TS'; Stage 2 is 'Dry TS'(left plot); Stage 3 is 'Frozen TS'; and Stage 4 is 'Dry TS' (right plot), with curves of approximation according to Eq. (2)

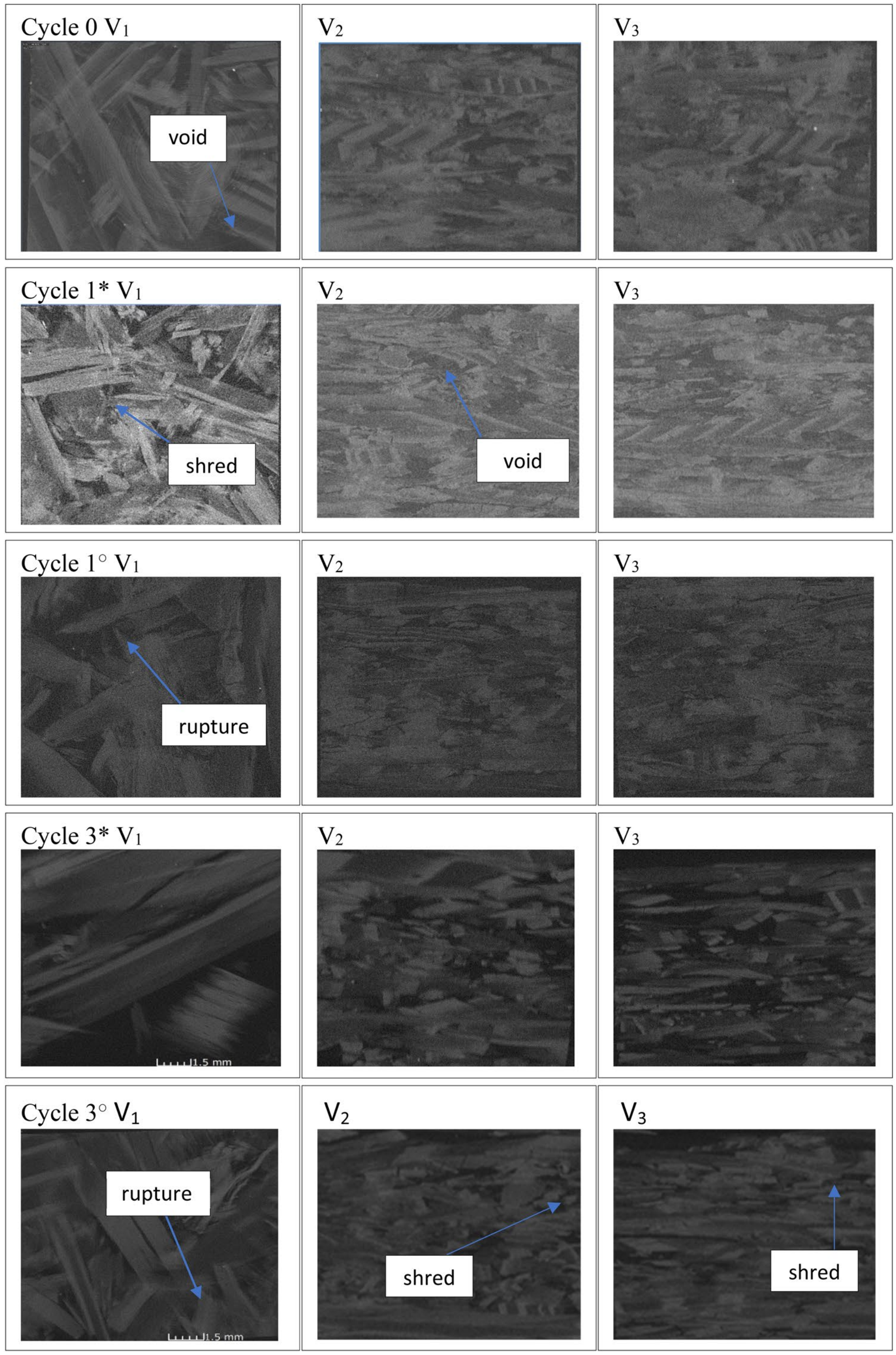

Fig. 9 X-ray image of the texture of three-layered OSB/3 in the following directions: V_1 to the face (outer) layer; V_2 and V_3 to the middle cross-section; initial dry (cycle 0), after the first and third *soaking/oven-drying and °soaking /freezing/oven-drying cycles

et al (2014) evaluated the impact of the number of cycles in the V313 test on the mechanical properties of 15 mm thick OSB/3. The results showed that the boards involved in the test were characterised by a 50% decrease in static bending strength and a 70% decrease in tensile strength perpendicular to the plane, i.e. IB.

The physical and mechanical properties of an OSB/3 board depend upon the structure of the material. To clarify the phenomenon causing a drastic decrease in the properties investigated after the first soaking, X-ray images of the test samples are presented (Figs. 1, 9). In cycle 0, the strands are plastically deformed at high pressure during hot pressing. Significant changes occur in the studied properties after the first soaking, when the strands that are embedded in the resin matrix tend to swell and jam, caused by a non-restored plastic deformation of the matrix. During the process of thawing and drying, the dimensions of the strands decrease, rupture partially (causing flaws in the face layer) and detach from the matrix of the deformed resin, which leads to an increase in the volume of voids within the material.

The voids are a source of discontinuities in a structure and in the bond lines between the strands and resin. The voids facilitate the delamination of the internal bonding of a particle, which results in a drastic decrease in IB (which in turn affects the weaker sections in the core layer, parallel to the plane with the fracture area evidently being similar during subsequent cycles), as well as also affecting edge-SWR values, which may still be an issue for manufacturers and users.

The current results are supported by findings reported by Li et al. (2019). Considerable strain along the thickness direction, induced during water sorption/desorption, can be transferred from the top surface to the bottom surface of the samples. Strain accumulation (identifiable as TS in the present study) is an important factor in terms of decreasing the load-bearing capacity of OSB.

During the subsequent soaking cycle, the intact and fractured strands swell again, but their initial location in the deformed matrix is not restored and the matrix is also plastically deformed. After completion of the drying cycles, the volume of voids will increase, more strands will be ripped, and their location is changed from their initial state. The volume of empty spaces increases, more strands of the OSB become smaller (shred), as indicated by the TS value of 25.2% (Fig. 9, and the X-ray image after the third cycle). However, their effect on the decrease in the values of the properties (except that of IB) will already be weaker (Table 1).

Therefore, the board is also less dense, which adversely affects its resistance properties, particularly its deflection abilities, and hence the MOE also decreases more than the MOR, depending upon the number of cycles, where the values for those properties are lower than the required values.

On the other hand, requirements concerning moisture resistance after the cyclic test as stated for IB are 0.15 MPa, while those for MOR|| are 8 MPa, which is calculated using the thickness measured following the cyclic test. In the present experiment, the obtained IB is 0.196 MPa, while the MOR|| value is 9.28 MPa, and both values are larger than the required ones. Therefore, the bending working structural elements still remain serviceable at cold, but stable climatic conditions (such as in winters without heavy snowfall or severe storms), even when soaking/freezing/drying cycles (the cyclic aging test) are accumulated across a longer period, as the MOR value does not decrease below the required values. Hence, the low durability of OSB/3 may not be immediately revealed during its use in wet outdoor conditions.

4 Conclusion

The major conclusions of this study are summarised below.

The most critical of the calculated average retention values for the OSB/3 samples were found after the first soaking cycle. These values have decreased by about one third (between 30 and 37%) in relation to the values obtained for the initial dry stage.

For accelerated aging, the average retention values in relation to the values required by standard accounted for 48–85%.

A comparison of the values for the properties investigated did not reveal any significant changes between standard soaking and soaking/freezing.

The proposed analytical functions represent an empirical regularity, which allows to predict to a certain extent the final values of the mechanical and physical properties of samples when their values are known after applying a small number of samples and cycles (two to three).

The X-ray investigations of the OSB/3 samples after accelerated aging revealed a considerable change in the investigated properties as a result of the non-restored plastic deformations in the resin matrix into which the embedded strands were jammed after soaking. For the same reason, the strands that were ripped off during oven-drying increased the volume of voids and decreased the volume of strands (shred).

However, this analysis here is limited to the data obtained from the above described experiments.

Acknowledgements The X-ray investigations for the current study were supported by the European Regional Fund, project No 2014-2020.401.16-0183, Smart Industry Centre (SmartIC).

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