A contribution to the resistance of combined plywood materials to abrasion

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ABSTRACT: The aim of the paper was to propose the methodology of testing the abrasion resistance of combined water-proof plywood materials with the phenol-formaldehyde foil surface finish and to assess the surface resistance of a new combined plywood material of a given construction to abrasion. For sheathing, phenol-formaldehyde foils with the low content of resins were used, which are combined with unwoven and woven glass fibres highly resistant to mechanical wear. The paper for phenol-formaldehyde foils manufactured of sulphate pulp (basis weight 60 g/m^2) was impregnated by a low-molecular resin with the resin deposit 150% DM (dry matter) per paper DM. To evaluate the newly designed material our testing methodology was prepared in such a way that it will conform to related European standards. It is completed by the method of sampling and preparation of samples for tests including their acclimation. According to our proposal, measurements were carried out of selected constructions of water-resistant plied veneer materials with jackets of various basis weight combined with glass fibres. Data on the abrasion resistance were acquired which can be considered to be reliable. The values of abrasion resistance were assessed with respect to standards valid in the EU which determine fields of their use.

Keywords: abrasion resistance; foliated plywood; phenol foil; glass fibre; high-pressure laminate; abrasion; phenol-formaldehyde resin; Taber abraser

The surface of materials with glass fibre shows specific properties. Before the actual assessment of abrasion resistance, the methodology of testing the abrasion resistance of combined water-proof plywood materials with the phenol-formaldehyde foil surface finish without and with fibreglass was designed. Water-proof plywood is a large-area material glued by a phenol-formaldehyde adhesive. It is manufactured by the combination of beech, birch and spruce veneers. Water-proof plywoods are manufactured in two versions:

– plywoods with double-faced surface finish with a smooth foil;
– plywoods with the one side finished with a smooth foil and the other side with a foil subject to antislip treatment.

Lateral edges are treated with coating from effects of moisture. Plywoods treated with a phenol-formaldehyde foil are used where there is an increased risk of damage to the surface by abrasion, e.g. shelves, work platforms, sports floors, work tables, formwork, surface of lorry beds and railway wagons. Thanks to their resistance to water the plywoods can also be used in industries with higher moisture or at places where they will be subject to weather effects (Král, Hrázský 2003).

All these properties are affected by several factors: type and composition of resin, amount of resin deposit, quality and weight of bearing paper, special admixtures, shape of the pressing plate surface etc. (Soinné 1995).

In addition to static functions, combined plywood materials also show various special functions, for example thermal and insulation ones. By the combination of these two requirements a material originates which is more suitable as against the use of separate materials (Hrázský, Král 2007). These advantages consist particularly in price factors but also in the

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simplicity of production technology and productivity of work. Combined plywood materials are manufactured in smaller amounts than plywoods for construction purposes and the manufacture of formwork.

MATERIAL AND METHODS

Several standards deal with testing the abrasion resistance of wood-based materials. The particular methods differ because they examine various types of surfaces. Thus, there arise different requirements for abrasion resistance. The proposed methodology is based on the DIN 53 799 standard, being however completed by the procedure of sampling, preparation and air conditioning of samples in such a way that a well-arranged and integrated instruction for standard users will be created. This standard was used as a starting norm thanks to its high popularity in European manufacturers of plywoods with foil surface finish, particularly in Germany, which belongs to leading countries in the manufacture of plywoods.

Standards ČSN 91 0276 (Furniture. Methods of Determining the Surface Abrasion Resistance) and ČSN EN 13329 (Laminated Floor Coverings) were also taken into account. Members with surface finish on the basis of reaction-plastic amino resins. Specifications, requirements, methods of testing, ČSN EN 438-1 standard (High-pressure Decorative HPL Laminates. Boards based on reaction-plastics. Part 1. Introduction and general information) and ČSN EN 438-2 standard (High-pressure Decorative HPL Laminates. Boards based on reaction-plastics. Part 2. Determination of properties).

Products are sampled from the assessed batch using the method of random sampling. Tests can be carried out on control samples prepared in the process of manufacture as well as on samples prepared under laboratory conditions and showing the same surface as tested products.

To determine the surface properties at least 3 test specimens are necessary from each of the boards. The specimens are taken uniformly with respect to the product dimensions at places where no defect occurs relating to the surface finish.

The abrasion resistance was tested on combined seven-ply plywood boards 15 mm thick manufactured of beech and spruce veneers 1.8 and 3.0 mm thick, respectively. The surface of these boards was treated with single-layer phenol-formaldehyde foils of basis weight 167 g/m^2. The amount of the phenol-formaldehyde resin deposit ranged from 125 to 145 g/m^2.

Square test specimens of the edge length 100 mm are cut from the board. In the test specimen centre, a hole of 65 mm in diameter is bored for the purpose of fastening to a carrier. The specimen thickness must range between 0.5 and 5 mm. In larger thickness, the lower side has to be worked in parallel with the specimen level (Fig. 2). The specimen height has to correspond to requirements of a testing machine. If the testing machine does not allow to change the height of pivot points of holding arms, where abrasive disks are placed in such a way that the arms will be sufficiently parallel with the test specimen surface, it is necessary to carry out the working of the lower side of the test specimen.

The principle of tests

The ability of the board decorative surface layer to resist abrasion down to the board base is determined by a test. A rotating test specimen is abraded by the effect of loaded cylindrical abrasive disks with glued-on strips of sanding paper. The force of 5.5 ± 0.2 N acts on each of the abrasive disks. The sanding paper with a self-adhesive layer is glued on the whole girth of rubber disks. The ends of sanding paper are trimmed as necessary in such a way that the sending paper will cover the whole circumference of the rubber disk, however, not being glued crisscross. Abrasive disks are placed in such a way that their cylindrical surfaces will be at the same distance from the axis of rotation of the test specimen, not being however oriented to it tangentially.

By turning the test specimen abrasive disks rotate creating a groove of the annulus shape on the test specimen surface. As the rate of abrasion resistance, the number of revolutions (speed) of a test specimen is used to a certain degree of abrasion.

Preparation of test specimens

The test specimen surface is cleaned by rinsing using an anhydrous organic solvent, e.g. 1,1,1-trichloroethane, which disturbs the test specimen surface. Samples are visually checked before the beginning of the test. Defects found are recorded into a protocol. Before the actual test, samples are acclimatized for 72 hours at least in the environment with air temperature 23 ± 2°C and air relative humidity 50 ± 5%.

Test material and device

Self-adhesive sanding paper of basis weight 70–100 g/m^2 of dust Al_2O_3 (aluminium oxide) of grain dimensions which fall through the sieve mesh 100 μm, being however caught on the sieve mesh 63 μm. Grains have to be distributed on the paper

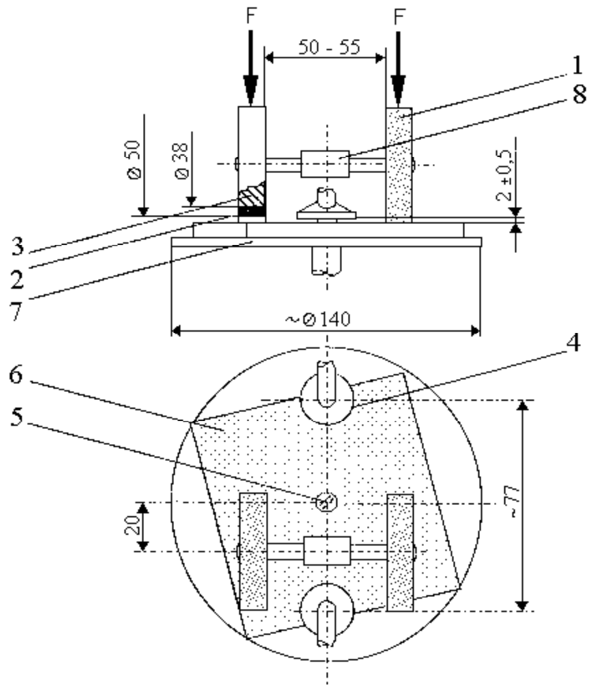

Fig. 1. Test device (dimensions in mm)
1 – sanding paper, 2 – rubber, 3 – abrasive disks, 4 – exhaust necks, 5 – clamping screw, 6 – test specimen, 7 – carrier (a disk carrying a sample), 8 – supporting and lifting device

uniformly. If the sanding paper is not self-adhesive, a double-sided sticky tape is necessary.

Test instrument. Tests are carried out with an instrument called Taber abraser (Fig. 1). The test principle consists in the determination of the resistance of surface layers of tested boards to resist abrasion to a base. A rotating test specimen fixed onto a carrier is worn by the effect of loaded cylindrical abrasive disks with stuck strips of sanding paper. The disks are placed in such a way their cylindrical areas will be at the same distance from the axis of rotation of the test specimen, not being however oriented tangentially to it.

By turning the test specimen abrasive disks rotate creating a groove of the annulus shape on the test specimen surface. The apparatus consists of a horizontally situated driving disk (7). A test specimen is fastened (6) onto the disk with a clamping screw (5). The carrier rotates at a speed of 55 ± 6 rpm. Speed is taken by a counter. Abrasive disks (3) consist of two cylindrical rubber wheels 12.7 ± 0.1 mm in width and 50 mm in diameter, which freely rotate around the common axis. The cylindrical surface of disks is covered to a depth of 6 mm with rubber (2) of 50 to 55 IRHD hardness according to ISO 48. Inner ends of disks are 50 to 55 mm from each other and their common axis must be at a distance of 20 mm from the vertical axis of the test specimen holder.

Strips of sanding paper (1) are fixed onto the rubber surface. Exhaust necks (4) are placed 1–2 mm above the abrasive zone of a test specimen in such a way that the one neck will be between abrasive disks and the other diametrically opposite. Centres of nozzles have to be 77 mm apart and 2 ± 0.5 mm from the test specimen surface. The exhaust device suction is 1.5 to 1.6 kPa and the device has to exhaust abraded material.

Check test of sanding paper

Two disks are prepared with conditioned unused sanding paper from the same batch that will be used for testing. A zinc plate is fixed onto the test specimen holder, the exhaust device is switched on, a revolution counter is set to zero, disks are started and the zinc plate is abraded at 500 rpm. The zinc plate is cleaned and weighed to the nearest 1 mg. The sanding paper is replaced by new strips of conditioned

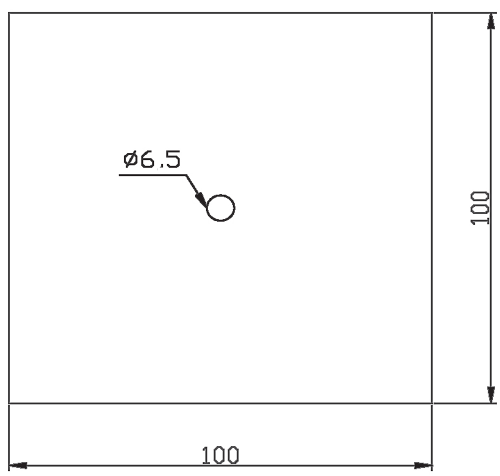

Fig. 2. Test specimen (dimensions in mm)

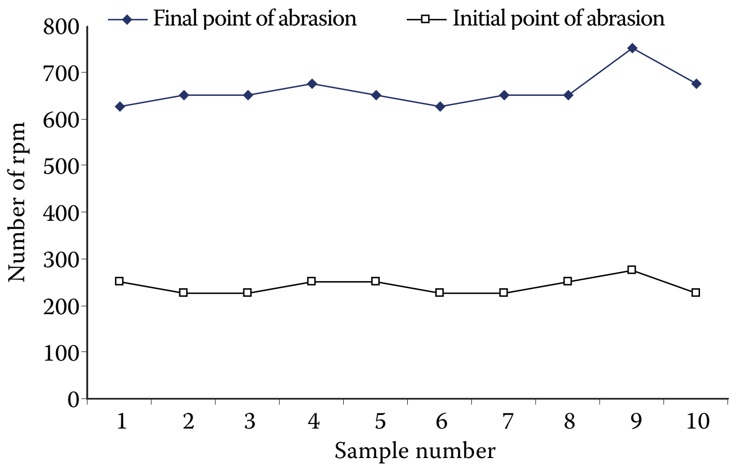

Fig. 3. Initial and final points of abrasion in samples without glass fibres

unused sanding paper from the same batch and the zinc plate is abraded at 500 rpm once more. The zinc plate is cleaned and reweighed to the nearest 1 mg. A decrease in its weight must be 130 ± 20 mg. The batch of sanding paper which causes the weight decrease out of this range must not be used for testing.

Preliminary test

The preliminary test shows if and how often the sanding paper has to be replaced during testing. The test specimen is fastened onto a plate being subject to orientation loading by abrasion at 500 rpm. The sanding paper and the abrasion image are assessed at every 25 revolutions (monitoring period). In particular, it is necessary to follow the uniform course of abrasion. If the sharpness of abrasion on sanding paper is smaller after one or several periods of monitoring, then the replacement of the sanding paper subject to the irregular course of abrasion has to be carried out at a half number of rpm.

Abrasion of the test specimen

The test is carried out immediately after calibration. Two disks are prepared with conditioned unused sanding paper from the same batch that was approved by the last calibration. The disks are placed into the apparatus and the revolution counter is set to zero. The first test specimen is fixed into the holder. It is necessary to ensure that the test specimen surface will be flat. The disks are actuated, the exhaust device is switched on and the test specimen is abraded. The test specimen is fixed to be flat, abrasive disks are put on the test specimen, exhaustion is switched on and turning starts. After every 25 revolutions, the abrasion of the test specimen and filling of the sanding paper with abraded material are checked. The frequency of the sanding paper replacement is

Table 1. The initial and final point of abrasion in samples without glass fibres

Sample	Initial point of abrasion (rpm)	Final point of abrasion (rpm)	Mean value (rpm)
1	250	625	437.5
2	225	650	437.5
3	225	650	437.5
4	250	675	462.5
5	250	650	450.0
6	225	625	425.0
7	225	650	437.5
8	250	650	450.0
9	275	750	512.5
10	225	675	450.0
Arithmetic mean (m)	240	660	450.0
Standard deviation (s)	17.48	35.746	24.296
Coefficient of variation V (%)	7.283	5.416	5.399

Table 2. The initial and final point of abrasion in samples with glass fibres

Sample	Initial point of abrasion (rpm)	Final point of abrasion (rpm)	Mean value (rpm)
1	275	3,075	1,675.0
2	250	3,125	1,687.5
3	225	3,100	1,662.5
4	250	3,050	1,650.0
5	275	3,500	1,887.5
6	275	3,150	1,712.5
7	275	3,150	1,712.5
8	250	3,025	1,637.5
9	225	4,700	2,462.5
10	225	3,400	1,812.5
Arithmetic mean (m)	252.5	3,327.5	1,790.0
Standard deviation (s)	21.89	506.273	248.803
Coefficient of variation *V* (%)	8.669	15.215	13.89

controlled according to observations from the preliminary test. The sanding paper has to be replaced in principle after 500 revolutions and after each test. Tests of this type are carried out until the initial point of abrasion is achieved when the number of revolutions is recorded and the test continues until the final point of abrasion is achieved. The number of revolutions is recorded again.

The initial point of abrasion occurs when:
- the first disturbance of the printed picture is visible in the printed decoration;
- in single-coloured decorations the basis (e.g. protective paper, particleboard etc.) is visible.

The final point of abrasion occurs when:
- in printed decorations some 95% of the printed picture is abraded;
- in single-coloured decorations 95% of the basis (e.g. protective paper, plywood etc.) shows through.

Abrasive resistance is calculated as follows:

$$Resistance = (P + K) : 2$$

where: P – initial value of abrasion,
K – final value of abrasion.

An arithmetic mean from the results of minimally 3 test specimens is taken as "resistance".

RESULTS

Table 1 shows the initial and final points of abrasion in samples without glass fibres inclusive the arithmetic mean, standard deviation and coefficient of variation.

Table 2 shows the initial and final points of abrasion in samples with glass fibres inclusive the arithmetic mean, standard deviation and coefficient of variation.

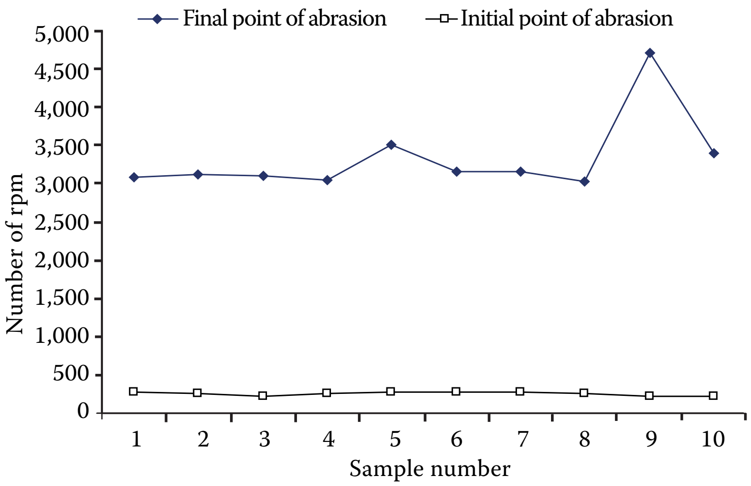

Fig. 4. Initial and final points of abrasion in samples with glass fibres

Table 3. Weights of samples without glass fibres before and after abrasion

Sample	Initial weight (g)	Final weight (g)	Difference in weight (g)
1	132.5857	131.8806	0.7051
2	133.0288	132.2633	0.7655
3	133.1010	132.4042	0.6968
4	133.5700	132.8663	0.7037
5	132.7647	132.0506	0.7141
6	130.9830	130.2733	0.7097
7	133.2222	132.4728	0.7494
8	131.2708	130.4759	0.7949
9	134.7634	133.8736	0.8898
10	134.5973	133.7465	0.8508
Arithmetic mean (m)	132.98869	132.23071	0.75798

Table 4. Weights of samples with glass fibres before and after abrasion

Sample	Initial weight (g)	Final weight (g)	Difference in weight (g)
1	132.3215	129.8397	2.4818
2	132.5481	129.8190	2.7291
3	132.8337	130.2251	2.6086
4	133.2488	130.7923	2.4565
5	132.6613	129.9653	2.6960
6	130.7662	127.9328	2.8334
7	132.9741	129.9868	2.9873
8	130.4613	127.8615	2.5998
9	134.0598	130.5533	3.5065
10	133.9012	130.8834	3.0178
Arithmetic mean (m)	132.5776	129.78592	2.79168

Table 5. Values of abrasion resistance –WISA plywoods

Firm name	Sheath weight (g/m^2)	Abrasion value (rpm)
Wisa-Form Spruce	120	300
Betofilm	120	320
Wisa-Form Birch	120	320
Wisa-Wire	145	380
Wisa-Wire	167	450
Wisa-Wire	220	570
Wisa-Form Birch	220	600
Wisa- Hexa Grip	240	630
Wisa-Wire	250	800
Wisa-SP	300	1,070
Wisa-Form Super	400	2,100
Wisa-Trans	500	3,500

Table 3 documents the weights of samples without glass fibres before and after abrasion inclusive the arithmetic mean.

Table 4 documents the weights of samples with glass fibres before and after abrasion inclusive the arithmetic mean.

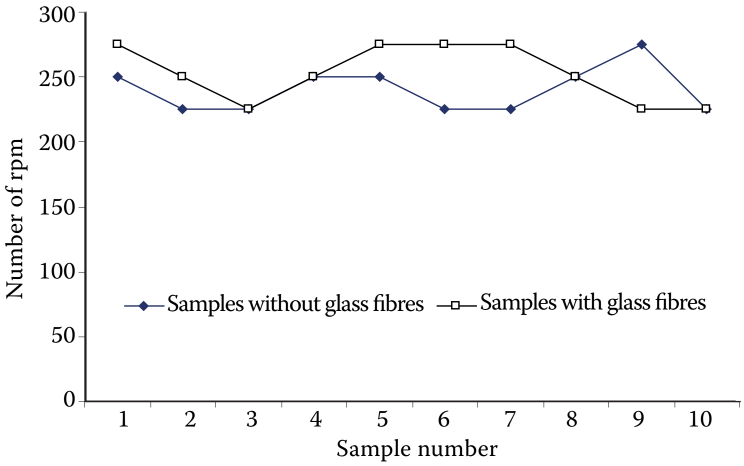

Fig. 5. Comparison of initial points of abrasion in samples with and without glass fibres

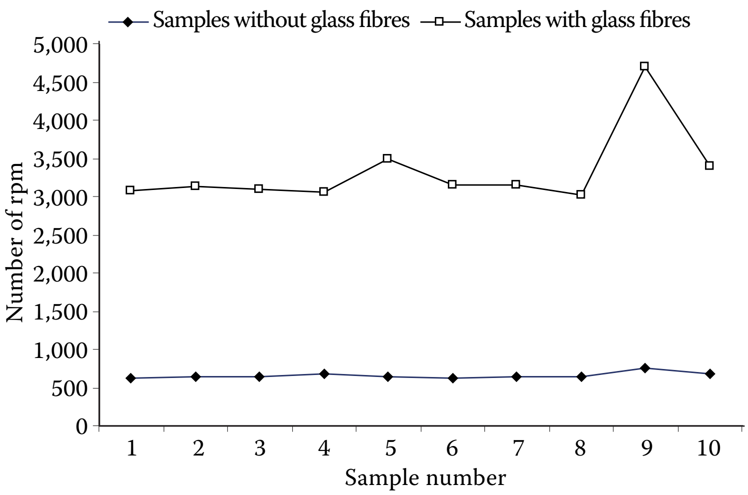

Fig. 6. Comparison of final points of abrasion in samples with and without glass fibres

Table 5 presents a comparison of the values of abrasion resistance in WISA plywoods.

Table 6 presents a comparison of the values of abrasion resistance in FINNFOREST plywoods.

Fig. 3 illustrates the initial and final points of abrasion in samples without glass fibres.

Fig. 4 illustrates the initial and final points of abrasion in samples with glass fibres.

Table 6. Values of abrasion resistance – FINNFOREST plywoods

Firm name	Sheath weight (g/m^2)	Abrasion value (rpm)
Metsä-Deck	120	350
Metsä-Form	120	350
Metsä-Form	170	600
Metsä-Deck	220	900
Metsä-Form	220	900
Metsä-White	250	500
Metsä-Sp	340	1,300
Metsä-Form	440	2,200
Metsä-Top	440	2,200
Metsä-Floor	500	3,200
Metsä-Diamond	580	3,100
Metsä-Form	660	3,200
Metsä-Top	660	4,100
Metsä-Floor	700	4,300

Fig. 5 compares the initial points of abrasion in samples with and without glass fibres.

Fig. 6 compares the final points of abrasion in samples with and without glass fibres.

DISCUSSION

Abrasion resistance was tested on boards of given thickness and construction. The surface of these boards was treated with single-layer phenol-formaldehyde foils in combination with glass fibres applied onto the sanded and unsanded underlay surface. Ten test specimens from each board were measured. On the basis of measurements, plywoods with glass fibres show higher abrasion resistance than plywoods treated with the foil only. It is caused by the presence of glass fibres. The glass fibre increases abrasion resistance because its strength is substantially higher than the strength of the foil alone. The fibre restrains forces induced by an abrader both in horizontal (rotation) and vertical direction (weight). After cutting through the upper foil to glass fibres there occurred a contact of the sanding strip with glass fibres which resulted in the destruction of the sanding strip margins. It is caused by a fact that sharp facets originate on slightly disturbed fibres which tear the strips.

The plywood which was not equipped with glass fibres showed quite different values of resistance. To cut through, a smaller number of rpm and sanding papers, which are not damaged by sharp edges of disturbed glass fibres, is sufficient. Variations in measurements can be caused by inaccuracies in measurements or by the board quality. The quality of the surface of the last ply of veneers is an important factor affecting abrasion. If the ply is not prepared well, the connection of a veneer with a foil is imperfect after gluing the foil. It results in a decrease of the initial point of abrasion when the places with rough surface are cut through earlier than the well foliated parts. The uniformity of glue spread below the foil ranks among other important factors affecting abrasion resistance. If the spreads differ markedly, faster cutting through occurs at the place of the thinner layer of the adhesive. On the other hand, the thicker layer of the adhesive is cut through for a longer time. Of course, it does not mean that higher layers of the glue are always suitable. The foil quality and kind are no less important aspects of abrasion resistance. The values of similar products obtained from foreign companies WISA (Finland) and FINNFOREST (Finland) serve for the purpose of comparison. Face veneers of these products are of birch except spruce boards Metsä-Form and Wisa-Form Spruce. All plywoods are reground before gluing the foil. Sheathing is carried out using a single-layer or multi-layer phenol-formaldehyde foils of a basis weight from 120 to 880 g/m^2. The comparison of values measured at our workplace and values provided by WISA and FINNFOREST manufacturers is rather problematic because only one tested kind of plywood is available. Plywoods differ in many factors.

CONCLUSION

The aim of the paper was to propose the methodology of testing the abrasion resistance of combined water-proof plywood materials with the surface finish of phenol-formaldehyde foils and to assess abrasion resistance of two different surface treatments applied onto these materials.

The methodology proposed is based on DIN 53 799 standard completed by the procedure of sampling, preparation and acclimatization of samples in such a way that a well-arranged and integrated instruction for common users will be created. This standard was used as an initial norm thanks to its high popularity in European manufacturers of plywoods with the foil treatment of surface particularly in Germany, which belongs to leading countries in the manufacture of plywoods.

According to the methodology proposed by our workplace we carried out measurements of selected samples of combined plywood boards with two types of surface foil. Data acquired from our research results concerning the abrasion resistance can be considered to be reliable in plywood without glass fibres, because the coefficient of variation does not exceed 6%. On the other hand, in the case of using glass fibres the coefficient of variation increased to 14%, which was caused particularly by one sample with the extremely high final point of abrasion. If this sample were excluded from measurements, the coefficient of variation would decrease and the measurement could be considered as reliable.

Boards including glass fibres are (thanks to their higher point of abrasion) suitable where the higher load of a construction occurs. On the other hand, boards without glass fibres are more suitable where constructions are less loaded, e.g. working boards of tables.

The comparison of boards in which our measurements were carried out with boards of other manufacturers is rather complicated because these products differ in many aspects, e.g. tree species of the underlying veneer, its treatment, surface design, and also the procedure of the abrasion resistance measurement.

Foliated materials are more suitable from economic aspects because the wood is utilized more efficiently. Thus, by the gradual improvement of properties of these materials also the field of their use in various industries is extended.

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Příspěvek k odolnosti kombinovaných překližovaných materiálů proti oděru

ABSTRAKT: Předmětem práce bylo posouzení odolnosti povrchu nového kombinovaného překližovaného materiálu stanovené konstrukce. K oplášťování byly použity fenolformaldehydové fólie s nízkým obsahem pryskyřice, které jsou kombinovány s netkanými a tkanými skleněnými vlákny vysoce odolnými vůči mechanickému opotřebení. Papír pro fenolformaldehydové fólie vyrobený ze sulfátové buničiny (o plošné hmotnosti 60 g/m^2) byl impregnován nízkomolekulární pryskyřicí s nánosem pryskyřice 150 % sušiny na sušinu papíru. Pro hodnocení nově navrženého materiálu byla naše zkušební metodika vypracována tak, aby odpovídala souvisejícím evropským standardům. Je doplněna o metodu odběru vzorků a přípravu vzorků ke zkouškám včetně jejich klimatizace. Podle našeho návrhu byla provedena měření vybraných konstrukcí vodovzdorných vrstvených dýhových materiálů s plášti o různých plošných hmotnostech, kombinovaných se skelným vláknem. Byly získány údaje o odolnosti vůči oděru, které můžeme považovat za spolehlivé. Hodnoty oděruvzdornosti byly posuzovány vzhledem ke standardům platným v Evropské unii, které stanovují jejich oblasti použití.

Klíčová slova: odolnost proti oděru; fóliované překližky; fenolická fólie; skelné vlákno; vysokotlaký laminát; obrušování; fenolformaldehydové pryskyřice; Taber abraser

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