Ss. CYRIL AND METHODIUS UNIVERSITY IN SKOPJE
FACULTY OF DESIGN AND TECHNOLOGIES
OF FURNITURE AND INTERIOR – SKOPJE
REPUBLIC OF MACEDONIA

WOOD TECHNOLOGY & PRODUCTS DESIGN
2nd INTERNATIONAL SCIENTIFIC CONFERENCE
30th August/2nd September 2015 - Ohrid - Macedonia

PROCEEDINGS

SECOND INTERNATIONAL SICIENTIFIC CONFERENCE

WOOD TECHNOLOGY & PRODUCT DESIGN

30th AUGUST – 2 nd SEPTEMBER, 2015
UNIVERSITY CONGRESS CENTRE – OHRID, MACEDONIA

SECOND INTERNATIONAL SCIENTIFIC CONFERENCE
WOOD TECHNOLOGY & PRODUCT DESIGN
Ohrid, 30th August – 2 nd September, 2015
PROCEEDINGS
Vol. II / Pg. 1- 352
Skopje, 2105
UDC 674-045.431(062)
684.4(062)
ISBN 978-608-4723-01-1

Published
Faculty of Design and Technologies
of Furniture and Interior – Skopje
Ss. Cyril and Methodius University - Skopje
Dean
Zoran Trposki, Ph.D.

PROGRAMME COMMITEE

ORGANIZING COMMITTE

Copies: 120
Printed by
KUKOM - Skopje
Publisher address:
Faculty of Design and Technologies of
Furniture and Interior
Ul. 16 Makedonska Brigada br. 3, PO box 8, 1130 Skopje
Republic of Macedonia

UDC (UDK): 674.031.632.2.028.9(497.11)

COMPARATIVE ANALYSIS OF BONDING STRENGTH OF BEECH PLYWOOD (*Fagus Silvatica L.*) ACCORDING SRPS AND EN STANDARD

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ABSTRACT

Both SRPS and end EN standards are actual in Republic of Serbia nowadays. In this paper the comparative analysis of accuracy and convenience of testing samples from the same eleven layers, 20 mm thickness plywood board according SRPS and EN norms has been performed. Both types of samples were treated under the same circumstances: water boiling proof test (WBP test). After treatment the glue line shear test has been performed on computer controlled testing machine. Results showed that the EN method was significantly more precise (F-test). This test treats pairs of glue lines simultaneously, includes assessment of wood failure and it is more accurate, more reliable, but in the same time more time consuming, compared to older SRPS testing procedure.

Key words: beech plywood, glue line testing, SRPS norms, EN norms, WBP test

1. INTRODUCTION

Standard is a document, established by consensus and approved by a recognized body, which determines, for common and repeated use, rules, guidelines or characteristics for activities or their results, in order to achieve an optimal level of regulation in a given context. Thus says ISO / IEC Guide 2: 2007. Our current national standards are labeled as **SRPS**, while the standard of the European Union are labeled as **EN**.

In Serbia there are still applicable SRPS standards for testing plywood, as well as the new EN standards, so that the tests are performed, after one or other standards. Although the benefits of EN standards are well known (Blomquist and Olson 1964, Cai Zhiyong 2009):, there are rare data from the practice, on which basis the numeric comparison of these two ways of testing for plywood should be performed (Zdravković 1992, Zdravković et al. 2015).

The aim of this paper is to compare the shear strength testing methodology in the layer of adhesive per SRPS and EN standards. By their comparison and seeing the difference between these two methods of testing, the conclusions shall be adopted about the advantages and disadvantages of both methods and about which method is more accurate and more comprehensive.

2. MATHERIALS AND METHODS

Testing was performed on 11- layer beech plywood panel thickness 20 mm. There were different thickness of longitudinal and transverse layers on board, i.e. transverse layers were thicker than longitudinal. The samples for testing shear strength of the adhesive layer were cutted by D.A8.067 and EN 314-1 standards from the same plywood panel, while the classification panel was according to SRPS D.C5.040 and EN 314-2 standards. To minimize the possible influence of the position of the sample in a plywood panel, the randomization of samples was performed, in such a way that all the samples are first cut and then selected at random order and clustered into groups according to the experimental design.

The main difference between the SRPS and EN standards is that, in the test according to SRPS standard all bond lines were tested simultaneously, while in the test according to EN standards, each pair bond line were tested separately.

Due to the simultaneous testing of all lines of adhesives per SRPS standard, arrangement of holes and notches should be such way that tensile force can only cover a specified glue lines (Figure 1). Arrangement and dimensions of the hole depend on the number of layers and the thickness of the veneer sheets in the structure of the plywood panel. No matter how accurately prepared probes, no matter how accurately drill the holes and notches were made, experience has shown that the fractures in such probes are generally uncontrollable. In contrast, glue bond shear strength test according EN is much more controlled. The shear strength of the adhesive layer was calculated according to the formula:

$$\sigma_s = \frac{2 \cdot F}{b \cdot l \cdot (n-1)} \quad (MPa)$$

Where:

σ_s – glue bond strength (MPa),
F – shear force (N)
b – shear width (mm)
l – shear length (mm)
n – number of plywood layers (no)

Figure 1. *The look of the testing probe according D.A8.067*

When testing according to EN 314-1 standard, each pair bond line was treated separately, which means that the number of groups for testing depends on the number of veneer sheets in the construction of the plywood (Figure 2). The shear strength of the adhesive layer was calculated for each bond line separately according to the formula:

$$\sigma_s = \frac{F}{b \cdot l} \quad (MPa)$$

Where:

σ_s – glue bond strength in treated layer (MPa),
F – shear force (N)
b – shear width (mm)
l – shear length (mm)

In this experiment the 6 groups of 10 specimens were prepared. The first group was made according to standard SRPS D.A8.067, while the other 5 were made according to EN 314 standard - each for a specified pair of bond lines.

In accordance with the adhesive used in the production of plywood, appropriate pre-treatment was chosen, for the plywoods which will be used in external conditions (WBP test). Pretreatment consisted of 6 h cooking probes at 100° C, and then from immersion in cold water for 2 h at 20° C. Pre-treatment was carried out for all established groups of testing at the same time.

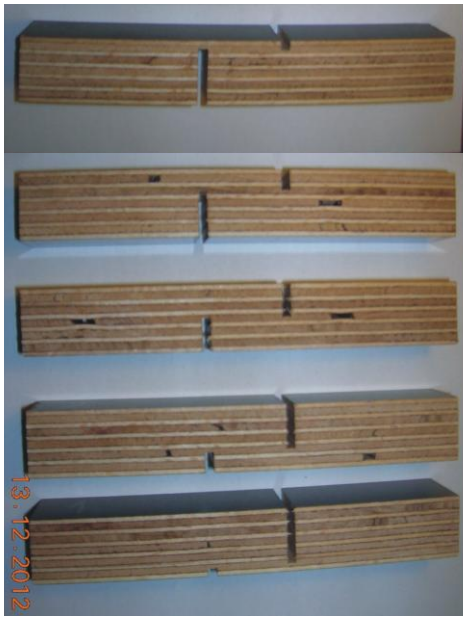

***Figure 2**. The look of the probes for testing according EN 314*

Upon completion of the pre-treatment, the probes were removed, drained and then tested on the computer controlled automatic laboratory testing machine Amsler WT 4 in accordance with the requirements of the standards.

3. RESULTS AND DISCUSSION

Table 1 shows the results obtained from testing with a basic statistical analysis. During the processing of results, some test probes were rejected, because the fractures were not occurred in the study area (one at the glue bond line one and three at the glue bond line 5).

***Table 1.** Testing results*

	Tessting according **SRPS D.A8.067**	Tessting according **EN 314-1**				
		Glueline 1	Glueline 2	Glueline 3	Glueline 4	Glueline 5
No. Samples	10	9	10	10	10	7
Mean value (MPa)	1.514	2.682	3.215	2.787	3.086	2.544
Standard deviation	0.260	0.622	0.598	0.785	0.766	0.991
Koef. Of variation (%)	17.188	23.192	18.591	28.179	24.818	38.973
Standard Error	0.087	0.207	0.199	0.262	0.255	0.330

Table 2. *Statistical analysis of the beech plywood panel test results according SRPS and EN*

STATISTICS	**METHOD SRPS**			**METHOD EN**		
Number of samples	N	10	samples	N	46	samples
Mean value	X	1.514	MPa	X	2.888	MPa
Standard deviation	σ	0.260	MPa	σ	0.757	MPa
Koeficient of variation	v	17.188	%	v	26.228	%
Standard error	St err	0.087	MPa	St err	0.252	MPa
Minimum	MIN	1.014	MPa	MIN	1.383	MPa
Maximum	MAX	1.981	MPa	MAX	4.384	MPa
Range	RANGE	0.967	MPa	RANGE	3.001	MPa
TESTING OF BOTH DISTRIBUTIONS NORMALITY	Testing performed in SPSS: **PASSED**					
VARINACE RATIO	**F**calculated**= 8.473** **F**tabulated= **2.816**					

Depending on the type of wood from which the plywood was produced, the requirements of SRPS D.C5.040 have to reach the minimum value of shear strength greater than 1 MPa for hardwoods, 0.8 MPa for softwoods, and for coniferous woods greater than 0.6 MPa. According to EN 314-2, if each test bond line achieved value greater than 1 MPa, it is considered that the plywood passed the test regardless of which type of wood is made.

Table 1, shows that the examined plywood met the criteria of both standards, but there were large differences in the calculated shear strength. Values obtained by D.C5.040 standard were far less than the values calculated for each glue lines according EN standard. The lowest shear strength according to EN was in glue line No. 5.

According to EN who requires that each test line meets prescribed criteria in relation to the percentage of fracture in the wood, so if the glue line 5 had a value of shear strength less than was required, it might be considered that plywood panel did not pass the examination, regardless of what other bond lines had values far greater than was required.

It can be said that the testing according to EN is more detail or to better indicate possible technological problems in the plywood production. From the results according to EN, it is clear that the glue line no. 5 was critical, so as due to significantly lower values of shear strength, but also because of the large spreading of results (coef. var.: 38.98%), as well as a large number of probes that had to be rejected from the sample due to the cracking out of the testing zone.

This can be a very important task for plywood producers, because if these results are replicated in other plywoods, it would mean that was a systematic error in the production process. In contrast, by testing according SRPS who give only an average value of shear strength for the test layers with a small possibility of insight where a potential problem was.

If calculated average shear strength value is lower than 1.0 MPa, than percent of breakage in the wood should be considered:

0.2-0.4 MPa - breakage in the wood must be greater or equal than 80%

0.4-0.6 MPa - breakage in the wood must be greater or equal than 60%

0.6-1.0 MPa - breakage in the wood must be greater or equal than 40%

Graphic display of this rule is shown in Figure 3. The disadvantage of this method is that the assessment of breakage in the wood is done visually with the aid of a magnifying glass, a reviewer compares the resulting fracture with pictures fracture presented in the standard. Such a decision may depend on the individual skills of examiners, and it is difficult that two different examiners make the same assessment. Also, its need a certain amount of experience and this kind of evaluation is quite slow.

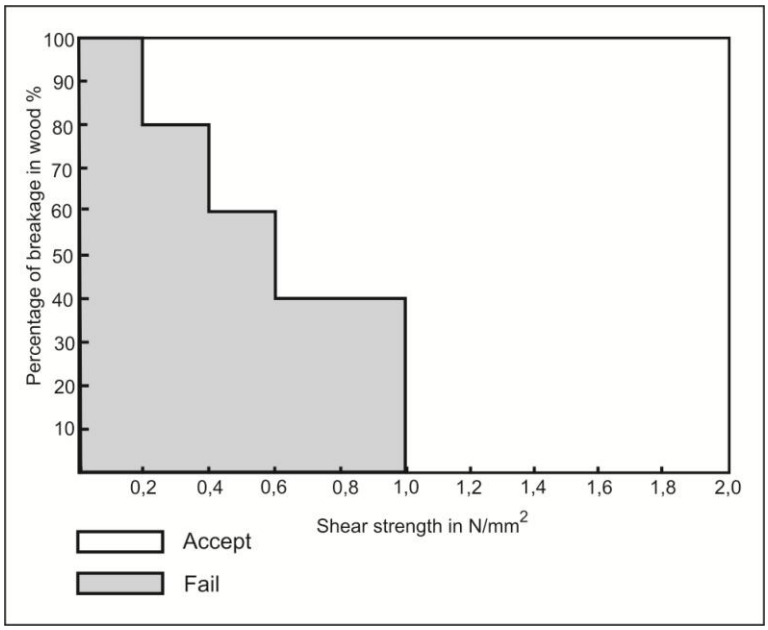

Figure 3. *Graphic illustration of the test requirements depending of percentage of breakage in wood*

Table 2 shows simultaneous statistical analysis of method SRPS and method EN. The basic idea is to statistically compare these two methods. Thus, the method SRPS has been treated as one group, and the average value for all 5 glue lines according EN as the second group. At the first time normality of distribution of both groups was tested in the software package SPSS. Since both groups passed test of normality of distribution, after that, one-tailed F test was proceeded, which showed that the EN method was more accurate (at the confidence level of p = 0.05). Also, regarding assessment of breakage in the wood, the EN method provide more information about glue bond quality, thus it is more accurate, more reliable, but in the same time more time consuming, compared to older SRPS testing procedure.

Although it can be considered that EN 314-2 standard is insufficiently precise - due to assessment of the percentage of breakage in wood, this data can provide us with valuable information. Table 3 shows the calculated values of the percentage of breakage in wood for the tested plywood.

Table 3. *Percent of breakage in wood (%) for different glue lines*

	Tessting according **EN 314-1**				
	Glueline 1	**Glueline 2**	**Glueline 3**	**Glueline 4**	**Glueline 5**
Percent of breakage in wood (%)	13.90	20.91	17.27	19.09	21.43

Results in Table 3 showed that the fracture was occurred mainly in the glue line (usually over 80%). This means that pre-treatment significantly reduced the strength glue joint, but the plywood still remained strong enough to achieve the shear strength greater than 1 MPa.

As a percentage of breakage in wood in the glue line no. 5 was the lowest than the other observed lines (together with the lowest shear sterngt value), the most likely reason for the occurrence of this was deviation in that layer quality compared to other tested layers. Or, for manual charging press, that veneer layer was long stood on the hot platen without pressure, so that a premature polymerization of the adhesive was occurred.

4. CONCLUSIONS

Upon completing an experiment and data processing, it was concluded that the test beech plywood fulfill the requirements both SRPS and EN standards, since they all calculated glue line shear strength mean were greater than 1 MPa.

Taking into account the whole experiment and theoretical study of standards, leads to the following conclusions:

1. SRPS order making probes that are more complicated, although their number is smaller. SRPS standard requires the preparation of specimens with holes, appropriate precision, which is very difficult to achieve. During the preparation of test specimens there was a problem just in this operation. During the preparation of probes according EN methodology, these problems were not existed, because their production was done without making a holes.
2. The results obtained by the EN method were refined and elaborated each layer separately. It has been concluded that the glue bond shear strength depended of the number of layers (and its position) in plywood panel, and that this value was variable in layers.
3. EN methodology introduces a new criterion: a percentage of breakage in wood, which provides detailed insight on the glue bond quality. The main disadvantage of this criterion it is i matter of individual assessment of examiners.
4. The different mean values of glue bond shear strength were obtained by examing the same plywood according the SRPS and EN methodology. The probes according SRPS gave lower values of shear strength 1.514 MPa, while the average value according EN was 2.888 MPa. The statistical tasting shoved that EN method was significantly more precise than older SRPS method.

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