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# THE TENSILE SHEAR STRENGTH OF OUTDOOR TYPE PLYWOOD PRODUCED FROM FIR, ALNUS, PINE AND POPLAR WOOD

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## ABSTRACT

In this study, it is aimed to determine both the tensile-shear strengths of plywood that produced by using phenol formaldehyde resin from Uludağ fir (*Abies nordmanniana* subsp. bornmülleriana Mattf.), alder (*Alnus glutinosa* L.), scots pine (*Pinus sylvestris* L.) and Samsun poplar (77/51 *Populus deltoides* Bartr.) trees rotary cut veneers combinations of poplar-pine, poplar-fir, poplar-alder and poplar wood along with the effect of wood types on adhesion quality of glue. According to standards TS 3969 EN 314-1, and TS EN 314-2 adhesion class 3, the test specimens were prepared and tested for the adhesion quality. The obtained data were analyzed statistically by using SPSS 22 statistical program. As a result, the tensile-shear strength values of poplar, pine-poplar, fir- poplar and alder-poplar plywood types were found to be as averages 1.34 $N·mm^{-2}$, 1.66 $N·mm^{-2}$, 2.18 $N·mm^{-2}$ and 2.46 $N·mm^{-2}$ respectively. Also, it was found that there was no significant difference between the alder poplar and fir-poplar plywood types about tensile-shear strength. Since these all plywood combinations are satisfied the required 1 $N·mm^{-2}$ strength value according to TS EN 314-2, all plywood types in this study are of suitable quality for outdoor uses.

KEYWORDS: Tensile-shear strength, adhesion quality, unprotected outdoor conditions plywood, fir, alnus, pine and poplar.

## INTRODUCTION

The plywood is one of the forest products among the other variety of the forest products. With the production of plywood, besides the more efficient use of wood materials, it is obtained large surface materials with high strength properties, low shrinkage and free from various defects (Özalp et al. 2009).

Many kinds of tree species can be used in the production of plywood. However, the density of wood, wood type, type of glue, coating thickness, number of layers, evaporation process and coating drying temperature have a direct effect on the physical and mechanical properties of plywood (Peker and Tan 2014).

Réh and Guoth (2016) have stated in their research that wood is an anisotropic material and it has different properties in longitudinal, radial and tangential main directions. Hence, in the producing plywood, veneer layers have to be odd number. Also, classification of plywood is based on wood species, veneer surface appearance, usage area, using conditions, glue type manufacturing conditions, etc.

Nowadays, plywood is produced for general purpose, decorative purpose or structural purpose according to wood type selection. In Turkey, mainly okoume (*Aucoumea klaineana*), beech (*Fagus orientalis*), hybrid poplar and birch (*Betula pendula*) species are used in the production of general purpose plywood. The plywood produced from birch wood is similar in color and appearance to beech plywood (Çakıroğlu and Aydın 2012).

Beech tree in general-purpose plywood production has an important position in our country and in Europe. However, the costs of plywood produced from beech are high. There are some limitations on the usage areas of poplar plywood. When alder veneers are examined, they have some advantages such as giving a similar color to the beech wood after being dried, easy to produce veneers and it is a fast growing species. In addition, the beech, alder and poplar woods have diffuse porous wood and they are listed in the most suitable group for rotary cut veneer technique (Demirkır et al. 2005, Çakıroğlu and Aydın 2012).

Over time, developments in the glue industry have given new dimensions to the production of plywood. Now, various types of glues are produced and by adding various additives to these glues, it has been tried to produce plywood which is more strength, better quality and suitable for special purposes. In this context, urea formaldehyde resins are used as an adhesive in the production of general purpose plywood and phenol formaldehyde resins are used in the production of building plywood (Özalp et al. 2009, Peker and Tan 2014).

Phenol formaldehyde (PF) resin is generally preferred as adhesives for plywood, which is resistant to water and used in the outdoor conditions. In addition, melamine-urea formaldehyde (MUF) adhesives with melamine content of 3-12% can produce boards to be used in such environments. However, under outdoor conditions it has been found that the plywood produced by the MUF resin is not as durable as the plywood produced by the PF resin (Demirkır et al. 2005).

In a comprehensive study of phenol-formaldehyde adhesive, Kariž et al. (2009) investigated that a yellow poplar (*Liriodendron tulipifera*) wood veneer and a phenol-formaldehyde adhesive were used to production of multi-layer boards with four different thicknesses. They also demonstrated that the rate of cure was the highest for the boards which produced from the thinnest veneer and the curing was getting decreased with the increasing thickness of the veneer.

Demirkır et al. (2005), some features of the middle layers of the okoume plywood were investigated in the case of using alder and beech veneers. Melamine-urea formaldehyde glue was used as adhesives in the produced plywood boards. The plywood produced with beech veneers in the middle layer was determined to have higher tensile-shear and bending strength than the plywood produced with alder and okoume veneers in the middle layer.

Moreover, Liu et al. (2012) determined the effect of phenol-formaldehyde (PF) resin on the leaching property of disodium octaborate tetrahydrate (DOT). In their study, low, moderate, and high molecular weights phenol formaldehyde (PF) resins were prepared and their combination with DOT were used to treat the sapwood of Chinese fir (*Cunninghamia lanceolata* Hook.). In a result of their study, it was determined higher concentration of PF bonded with boron better. Because of its capability of penetrating into the wood cell wall, low molecular weights PF were suitable for developing the leaching resistance of DOT. Additionally, as a results of FITR analysis low molecular weights PF would react with the wood components. They found that boron leaching was increased at high concentration of DOT. This situation is considered to be limited bonding capacity of PF to boron.

Kantarcı et al. (1999), they have indicated that the Kazdağı fir (*Abies equitrojani* Aschers, et Sinten.) is suitable for use in the production of plywood, especially as a middle layer material.

Biadała et al. (2015) investigated that the possibility of producing flexible plywood glued with UF resin with use of birch (Betula pendula Roth), beech (*Fagus sylvatica* L.), alder (*Alnus glutinosa* Gaertn.), pine (*Pinus sylvestris* L.), linden (*Tilia cordata* Mill.), poplar (*Populus alba* L.), willow (*Salix alba* L.) and spruce (*Picea abies* L.) wood veneer. They determined the optimal material for the core veneer of plywood is pine wood veneer. The best elastic properties were achieved from plywood with the outer surface made from poplar, birch and linden wood veneers respectively.

Demirkır et al. (2013) were determined characteristics of plywood and laminating veneer lumber (LVL) produced from plane (*Platanus orientalis*) tree veneers by using melamine urea formaldehyde (MUF) resin. As a result, the tensile-shear strength of plane plywood was found to be lower than both beech and alder plywood.

Réh and Guoth, (2016) were used two versions of thermoplastic adhesive for plywood productions. Then, under temperature 30°C and 40°C, the strength properties of the produced samples were determined. Test results show that test samples of both groups were not available for using thermoplastic adhesives.

Obviously, further research is needed about both tensile-shear strengths of plywood that produced using phenol formaldehyde resins for unprotected outdoor conditions and the effect of wood types on adhesion quality of glue.

Therefore, the aim of this study is to determine both the tensile-shear strengths of plywood that produced by using phenol formaldehyde resin from Uludağ fir (*Abies nordmanniana* subsp. bornmülleriana mattf.), alder (*Alnus glutinosa* L.), scotch pine (*Pinus sylvestris* L.) and Samsun poplar (77/51 *Populus deltoides* Bartr.) trees rotary cut veneers combinations of poplar-pine, poplar-fir, poplar-alder and poplar wood and the effect of wood types on adhesion quality of glue.

## MATERIALS AND METHODS

### Materials

The plywood samples were obtained from TKS Tosya Veneer and Particle Board Company (Kastamonu, Turkey). These plywood were unprotected exterior types and produced by using phenol formaldehyde resin from Uludağ fir (*Abies nordmanniana* subsp. bornmülleriana mattf.), alder (*Alnus glutinosa* L.), scots pine (*Pinus sylvestris* L.) and Samsun poplar (77/51 *Populus deltoides* Bartr.) trees rotary cut veneers combinations of poplar-pine, poplar-fir, poplar-alder and poplar wood. In the production of plywood, single surface of the veneer was glued by using amount of 220 $g\cdot m^{-2}$ one-component thermosetting phenol formaldehyde glue. The glue was provided by Polisan Kansai Dye Company. Glue specifications are given in Tab. 1. Also, pressing pressure was set to 0.7 $N\cdot mm^{-2}$, pressing temperature was set to 130°C and pressing time was set to 12 minutes.

*Tab. 1: Phenol Formaldehyde Glue Specifications.*

| Viscosity (at 20°C, cps) | Specific gravity (at 20°C, g·cm$^{-3}$) | Solid content (%) | Gel time (at 105°C, min) | Hardener | Appearance |
|---|---|---|---|---|---|
| 390 | 1.205 | 46.79 | 17 | None | Red |

## Methods

*Preparation of test samples*

The test specimens were prepared by using circular saws according to the dimensions specified in TS 3969 EN 314-1 (1998). Then, according to the instructions of TS EN 314-2 (1999) and adhesion class 3, the test specimens were firstly immersed in water at (20 ± 3)°C for at least 1 hour. Secondly they were immersed in boiling water for 4 hours. They were dried at 60 ± 3°C for 16-20 hours in an air-circulating dry oven. Thirdly, they were immersed in boiling water for 4 hours again. After this process, samples were immersed in water at (20 ± 3)°C for at least 1 hour. Finally, the samples were picked them up from water and the excess water on the sample surfaces was gently wiped off.

*Tensile-shear strengths*

The prepared test samples were tested for adhesion quality in a Shimadzu ™ AG IC 50 kN brand universal tester. The test speed was adjusted so that the plywood sample layers were separated in 1 min. Calculation of tensile-shear strength of the prepared specimens was made according to Eq. 1:

$$B = F / L \times b \qquad \text{(MPa)} \qquad (1)$$

where: B - tensile-shear strength (N·mm$^{-2}$),
F - maximum load (N),
L - shear plate length (mm),
b - shear plate width (mm).

## Analysis

SPSS 22 software (IBM, New York, USA) was used for statistical analysis of the data.

# RESULTS AND DISCUSSION

The data obtained from the tensile-shear strength test results and Duncan analysis results are given in Tabs. 2 and 3. According to Tab. 2, the lowest tensile-shear strength value is observed in samples obtained from poplar (1.34 N·mm$^{-2}$). The highest tensile-shear strength value is observed in samples obtained from the combination of alder-poplar wood (2.46 N·mm$^{-2}$). The Duncan analysis showed no significant difference between the tensile-shear strength of the alder-poplar and fir-poplar plywood specimens and it is collected in the same group. Finally, the tensile-shear strength of poplar-pine plywood is found to be lower quality than the third group as alder poplar and fir- poplar plywood.

*Tab. 2: Results of the tensile-shear strength and Duncan analysis.*

| Wood Species | $\bar{X}$ (N·mm$^{-2}$) | SD (±) | COV(%) | HG |
|---|---|---|---|---|
| Poplar | 1.34 | 0.15 | 11.19 | A |
| Pine-Poplar | 1.66 | 0.41 | 24.70 | B |
| Fir-Poplar | 2.18 | 0.62 | 28.44 | C |
| Alder-Poplar | 2.46 | 0.46 | 18.70 | C |

$\bar{X}$ - average value, HG - homogeneous group, SD - standard deviation, COV- coefficient of variation.

*Tab. 3: Results of the Duncan analysis at 95% confidence interval (N·mm$^{-2}$).*

| | 1. Group | 2. Group | 3. Group |
|---|---|---|---|
| Poplar | 1.3367 | | |
| Pine-Poplar | | 1.7288 | |
| Fir-Poplar | | | 2.3159 |
| Alder-Poplar | | | 2.4566 |
| Sig. | 1.000 | 1.000 | 0.448 |

The data obtained from the tensile-shear strength test results are given in Fig. 1.

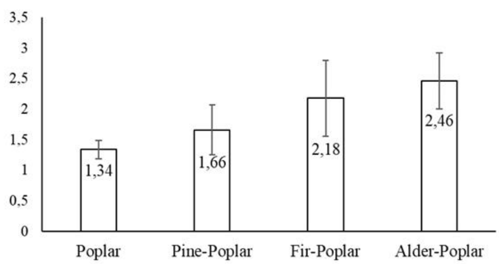


*Fig. 1: Tensile-shear strength test results (N·mm$^{-2}$).*

The dry strength value (TS EN 314-2 adhesion class 1) of the samples produced from using urea formaldehyde glue and necklace poplar (*Populus deltoides*), Scotch pine (*Pinus sylvestris* L.) and alder (*Alnus glutinosa* L.) woods were determined to be 1.30 MPa, 1.86 MPa and 2.21 MPa, respectively (Güdül et al. 2016, Demirkır et al. 2017, Cırrık et al. 2017). Thus, the obtained data of this study is similar to the given literature data even though the type of glue and adhesion class used in the experiments are different.

## CONCLUSIONS

The tensile-shear strength values of poplar, pine-poplar, fir-poplar and alder-poplar plywood types are found to be as averages 1.34 N·mm$^{-2}$, 1.66 N·mm$^{-2}$, 2.18 N·mm$^{-2}$ and 2.46 N·mm$^{-2}$ respectively. According to TS EN 314-2 it is indicated that the required lower limit 1 N·mm$^{-2}$ for unprotected exterior type plywood is provided. Thus, it can be concluded that all plywood types in this study are suitable quality for outdoor uses.

Poplar and pine-poplar plywood types have showed lower quality value as compare to fir-poplar and alder-poplar plywood types. These quality differences of plywood types may be explained with the anatomical, chemical, pH and density differences among the used tree materials as alder, fir, pine and poplar woods.

According to pine-poplar, fir-poplar, alder-poplar and poplar plywood combinations it was determined that alder-poplar and fir-poplar plywood combinations have the highest tensile-shear strength values. In addition, it was found that there is no significant difference between the alder poplar and fir-poplar plywood types about tensile-shear strength.

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