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Selected mechanical properties of one-year old twigs of *Salix acutifolia*

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Abstract: *Selected mechanical properties of one-year old twigs of Salix acutifolia.*
The article discusses selected mechanical properties of willow (Salix acutifolia) twigs. The performed investigations involved determination of the static bending strength as well as the assessment of the elasticity modulus and strain. The experimental, one-year old willow twigs derived from the Hell Peninsula, both from the side of the Baltic Sea and of the Puck Bay.

Keywords: willow, mechanical properties, static bending strength

INTRODUCTION

Within the willow family (*Saliceacae*), the following three genera are distinguished: poplar (*Populus*), chosenia (*Chosenia*) and willow (*Salix*) with willow represented by the greatest number of species ranging from 300 to 500 (Boratyński and Boratyńska, 1990; Bąkowski et al., 1995; Prądzyński et al., 1996; Waliszewska et al., 1999). They are heliophilous plants of low soil requirements. Most willow species grow on wet sites, sometimes even periodically flooded but there are a number of species that can be planted on dry soils, sometimes even on sands and dunes.

Salix acutifolia os one of the species that is exceptionally tolerant as regards soil and that is why it has found wide application in sand consolidation (Seneta, Dolatowski, 1997). *Salix daphnoides* var. *acutifolia* Willd. – violet, sharp-leaved willow, occurs in the form of bushes up to 6 m or trees – up to 10 m in height. *Salix acutifolia* is characterised by long, very elastic twigs, green with sour-cherry colouring on one side. Its main application is planting of shifting sands (Szczukowski et al., 2002). This species is particularly numerously represented along the seashore line as it withstands unfavourable site and climatic conditions (Prądzyński, Waliszewska, 1998). The Sea Office in Gdynia strongly supports wide introduction of plantations of this species as one of the biological methods of consolidation of the technical shoreline zone (Pestka 1996).

Willows are plants which provide a natural barrier between water and land, additionally, confining migration of mineral fertilisers to water. Furthermore, when placed appropriately in the riverbed, they can slow down its current thanks to strong anchorage to the bed by the well-developed root system (Waliszewska and Prądzyński, 2005).

Knowledge of strength indices constitutes the basis of economic application of wood in all kinds of constructions. Timber strength exerts a considerable impact on values of acceptable strains and the way of its utilisation. Willow wood is an anisotropic and hygroscopic material. Examination of its mechanical properties require taking into consideration many different factors of which anatomical direction and wood moisture content as well as the number and distribution of structural defects exert a strong influence on wood strength and possibilities of its application. According to Prądzyński and Żurakowski (1986), in processing practice, our knowledge of the wicker bending strength is most important. This opinion is confirmed by Korzeniowski (1968) who also maintains that, for practical reasons, the determination of mechanical properties of wickers is interesting both for industry and producers of industrial wicker.

A cycle of investigations was conducted at the Institute of Chemical Wood Technology of the Poznań University of Life Sciences concerning specificity of development, chemical composition, content of heavy metals and mechanical properties of willows from the Hel Peninsula. Initial experiments were carried out on twigs of varying age ranging from 2 – 5 years. On the basis of the obtained results, it was decided to examine wickers of *Salix acutifolia* willow of the same age from bushes growing in different places of the Hel Peninsula both from the side of the Baltic Sea and from the side of the Puck Bay. The first series of experiments was performed on one-year old willow twigs collected from the following places: Władysławowo, Kuźnica and Hel.

EXPERIMENTAL MATERIAL AND RESEARCH METHODOLOGY

The experimental material included one-year old willow (*Salix acutifolia*) twigs collected following one full vegetation cycle. The twig samples were collected from randomly selected 10 plants all growing on the Hel Peninsula in Władysławowo, Kuźnica and Hel situated either on the side of the Baltic Sea or the Puck Bay. For comparative purposes, investigations were also carried out on willow twigs obtained from *Salix daphnoides var. acutifolia* Willd. from Obory near Kwidzyn. Mechanical properties were determined on one-year old twigs with and without bark. Samples 160 mm long were cut out from middle sections of twigs. Experiments were conducted on 10 twigs with bark and 10 twigs without bark following their hydrothermal processing. The diameter of twigs was established with the assistance of electronic callipers. The moisture content of the examined twigs amounted to about 7% and differences in moisture content between individual twigs did not exceed 0.6%.

Investigations of the static bending strength were performed on ZWICK testing machine. Samples were bent with a concentrated force applied at the middle of support spacing which amounted to 10 cm.

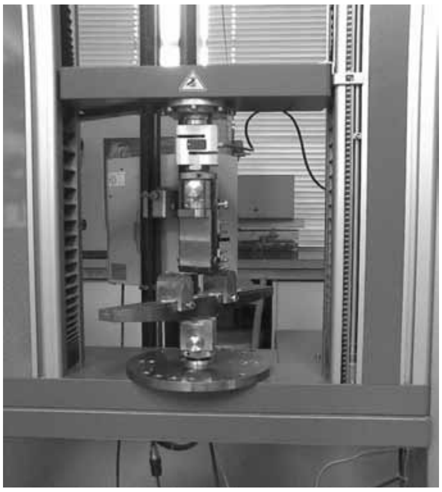

Figure 1. Testing machine with equipment used for experiments on static bending strength

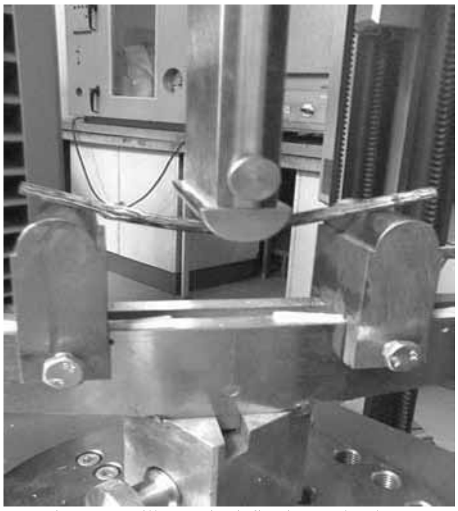

Figure 2. Willow twig deflection under the influence of applied force

Additionally, the static bending strength was also calculated according to the following formula (Korzeniowski 1968):

$$R_g = \frac{8l}{\pi D^3} \cdot P_n$$

where: R_g – twig bending strength (MPa),
l – bending span (support spacing) (cm),
P_n – destructive force (N),
D – twig diameter (mm).

RESEARCH RESULTS AND THEIR DISCUSSION

The highest static bending strength reaching 148.91 MPa was determined in debarked twigs collected from a small town, called Hel from bushes growing on the side of the Baltic Sea. Twigs collected from the same side of the Hel Peninsula from Kuźnica also showed high static bending strength of 131.33 MPa. The lowest strength amounting to 111.02 MPa was determined in twigs obtained from willow bushes growing in Hel but on the side of the Bay. Low bending strength of 115.34 MPa was also recorded in twigs from Kuźnica from bushes growing on the side of the Bay as well as in twigs from Władysławowo - 116.86 MPa obtained from bushes growing on the side of the sea. Control twigs from the plantation in Kwidzyn were characterised by high static bending strength amounting to 140.26 MPa. These values were exceeded only by twigs of *S. acutifolia* obtained from the town of Hel from plants growing on the side of the Baltic Sea.

Table 1. Static bending strength of debarked twigs of willow *Salix acutifolia*

Place	Side of the shoreline	Elasticity modulus E Mod [MPa]	Static bendig strength Rm [MPa]	Strain ε - Rm [mm]
Władysławowo	Sea	8805.43	116.83	10.51
	Bay	9348.07	126.39	10.96
Kuźnica	Sea	8375.85	131.33	12.34
	Bay	7335.98	115.34	11.11
Hel	Sea	9482.70	148.91	12.80
	Bay	7057.11	111.02	12.24
Kwidzyn plantation	-	8640.28	140.26	13.84

The determined modulus of elasticity of debarked willow twigs from the Hel Peninsula ranged from 7057. 11 MPa to 9482.70 MPa, whereas deflection – from 10.51 mm to 12.80 mm. The above parameters determined for twigs obtained from the plantation amounted to: 8640.28 MPa and 13.84 mm, respectively.

Table 2. Static bending strength of twigs with bark of willow *Salix acutifolia*

Place	Side of the shoreline	Elasticity modulus E Mod [MPa]	Static bendig strength Rm [MPa]	Strain ε - Rm [mm]
Władysławowo	Sea	7674.38	85.35	6.35
	Bay	6293.03	84.36	8.96
Kuźnica	Sea	5955.03	75.93	8.70
	Bay	5196.05	62.05	10.97
Hel	Sea	5293.24	63.10	10.39
	Bay	5861.68	72.10	8.77
Kwidzyn plantation	-	6800.68	89.61	8.67

Static bending strength of twigs with bark was by approximately 50% lower in comparison with debarked twigs and ranged from 62.05 MPa to 85.35 MPa (Tab.2).

When analysing the experimental twigs with bark obtained from the Hel Peninsula, it is clear that the highest strength was recorded in the twigs from Władysławowo, both from bushes growing on the side of the sea – 85.35 MPa, and the bay – 84.36 MPa, whereas willow twigs obtained from bushes growing from the side of the Puck Bay were characterised by the lowest static bending strength – 62.05 MPa.

On the basis of the obtained research results, it can be said that willow twigs from bushes growing in Władysławowo and Kuźnica on the side of the Baltic Sea were characterised by higher static bending strength than those growing on the side of the Puck Bay,

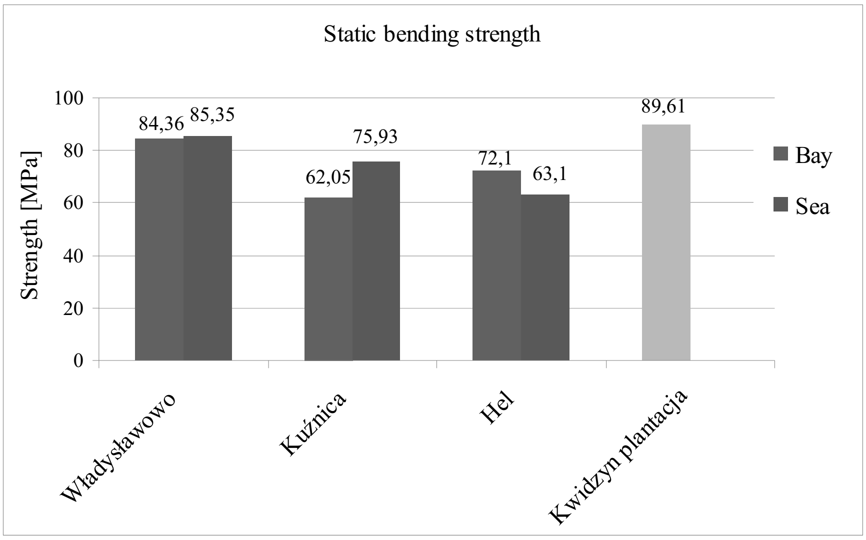

Figure 3. Bending strength of *Salix acutifolia* twigs on the side of the Puck Bay and the Baltic Sea

Analysing the research results of strength of willow twigs with bark derived from the Hel Peninsula, it can be concluded that, irrespective of the place of growing, they all showed lower static bending strength in comparison with the twigs collected at the plantation in Kwidzyn whose strength amounted to 89.61 MPa (Tab. 2; Ryc. 3).

The determined elasticity modulus of willow twigs with bark derived from the Hel Peninsula ranged from 5196.05 MPa to 7674.38 MPa, while their deflection - from 6.35 mm to 10.97 mm. The above parameters determined for the twigs from Kwidzyn plantation amounted to: 6800.68 MPa and 8.67mm, respectively.

RECAPITULATION

1. Debarked, one-year old willow twigs characterised by small diameters showed fairly high static bending strength ranging from 111.02 MPa to 148.91 MPa.
2. Twigs with bark collected both from the side of the Baltic Sea and the Puck Bay revealed static bending strength by about 50% lower than debarked twigs subjected to hydrothermal treatment.
3. The twigs with bark derived from Kwidzyn plantation were characterised by the highest static bending strength reaching 89.61 MPa, whereas twigs from the Hel Penisula, irrespective of the place of their development, showed strength ranging from 62.05 MPa to 85.35 MPa.

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Streszczenie: *Wybrane właściwości mechaniczne jednorocznych prętów Salix acutifolia.* W niniejszej pracy scharakteryzowano wybrane właściwości mechaniczne jednorocznych prętów wierzbowych *Salix acutifolia* rosnącej na Półwyspie Helskim z: Władysławowa, Kuźnicy i Helu, od strony Zatoki Puckiej i Morza Bałtyckiego. Badania obejmowały określenie wytrzymałości na zginanie statyczne, odkształceń badanych próbek i modułu sprężystości. Pręty z korą zarówno od strony morza jak i zatoki wykazywały mniejszą o ok. 50% wytrzymałość na zginanie statyczne niż pręty bez kory. Pręty od strony Morza Bałtyckiego z miejscowości Władysławowo i Kuźnica charakteryzowały się większą wytrzymałością na zginanie statyczne niż pręty od strony Zatoki Puckiej.

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