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Compression strength along the grain in twin samples (wet and absolutely dry) coming from wood of wind- broken trees of Scots pine (*Pinus sylvestris* L.)

MARCIN JAKUBOWSKI, ARKADIUSZ TOMCZAK, TOMASZ JELONEK
Poznań University of Life Sciences, Faculty of Forestry, Department of Forest Utilisation

Abstract: *Compression strength along the grain in twin samples (wet and absolutely dry) coming from wood of wind- broken trees of Scots pine (Pinus sylvestris L.).* Analyses were conducted on two experimental stands damaged by strong wind I north part of Poland. This paper is a part of a cycle of research conducted in pine stands, which suffered from windfall disasters. The aim of the cycle of research was to describe the behaviour of the wood tissue under conditions caused by strong winds and to make an attempt at finding characteristics of wood and trees, which contribute to a reduction or increase in resistance to the action of strong wind. Experimental plots were located in the Świdwin and Kolbudy Forest Division. Wind damage in the analysed plots (broken stems) was found over at least 20% stand area. All trees taken into consideration were between 50 and 60 year old. Generally it may be stated that no significant differences in compression strength were found between wood of standing trees and that of broken trees. Potential slight differences were so small that they have no practical importance for the occurrence of windfall, while they may be useful in the development of methodology in further research on the subject.

Keywords: compression strength, wind-broken trees, stability of forest

INTRODUCTION

Compression strength is a major parameter describing mechanical properties of wood. In this study this parameter was used to describe the behaviour of wood under conditions of considerable stress found in case of hurricane wind. This paper is a part of a cycle of research conducted in pine stands, which suffered from windfall disasters. The aim of the cycle of research was to describe the behaviour of the wood tissue under conditions caused by strong winds and to make an attempt at finding characteristics of wood and trees, which contribute to a reduction or increase in resistance to the action of strong wind. Some studies on a similar subject were conducted by Cameron and Dunhan (1999). Numerous research studies on modelling of wind resistance take into consideration major stand factors, possibly biometric characteristics of trees (Peltola et al. 1999, Peltola et al. 2000, Talkkari et al. 2000, Jalkanen and Mattila 2000, Miller et al. 2000). Quality of wood is usually neglected in modelling. However, it is obviously not due to the negligible importance of wood, but rather due to the lack of reliable information on quality of wood and its behaviour in living trees. Technical testing of wood is usually performed under laboratory conditions at standardised moisture content levels, which is typical of testing conducted in industry. In case of critical compressive stresses attempts have been made to detect microdamage initiating them (Dill-Langer et al. 2002, Müller 2003, Brancheriau and Lanvin 2008). Under forest conditions wood behaves differently, it is found in the state of high moisture content and considerable elasticity. Thus within this study strength testing was performed under extreme conditions, i.e. at moisture content above fiber saturation point and at a moisture content close to 0%. Similar tests were the subject of earlier studies connected with the potential use of wood coming from windfall (Jakubowski and Pazdrowski 2006). Differences in strength between wet and dry wood tissue make it possible to detect differences in the reaction of wet and dry wood, which may be useful in the assessment of the effect of wind on the behaviour of wood.

METHODS

Experimental plots were located in the Świdwin and Kolbudy Forest Division. Wind damage in the analysed plots (broken stems) was found over at least 20% stand area. In each of the mean sample plots all broken trees and neighbouring standing trees were numbered and breast height diameters were measured on all marked trees. The height of broken trees (the standing part) and the height of standing trees (unbroken) were measured. Recorded data were used to identify mean sample trees. Mean sample trees were divided into three diameter classes (taking into consideration only breast height diameter) and four classes in terms of the height of breakage. In this way broken trees and standing control trees were selected. Model trees were felled, next biometric traits were measured and 0.5m blocks were collected for further laboratory analyses from stems from a height of 1.3 m - 1.8 m. Analyses of compression strength along the grain were conducted on standard samples of 20 mm x 20 mm x 30 mm cut from the heart plane, which was oriented in the direction in which the stem was broken. Tests were performed using a TIRA TEST 2300 testing machine. Twin samples were tested, of which one was tested at a moisture content above fiber saturation point, while the other was analysed at a moisture content close to 0%.

RESULTS

Tests were performed on 371 samples coming from 22 trees. In the plot located in Świdwin 12 trees (9 broken and 3 standing) were selected and from collected blocks a total of 182 samples were collected. A total of 10 trees (6 broken and 4 standing) came from the Kolbudy plot and from these trees 189 samples were collected. Wood coming from the Świdwin plot was characterised by a greater mean compression strength along the grain than wood coming from the Kolbudy plot. This difference was marked both in samples compressed at a moisture content above fiber saturation point (Świdwin - 18.75 MPa, Kolbudy - 12 MPa) as well as dry samples (Świdwin - 51.54 MPa, Kolbudy – 34.16 MPa). A similar difference was observed for the median: Świdwin (17.4 MPa wet samples, 49.61 MPa dry samples) vs. Kolbudy (11.61 MPa wet samples, 33.6 MPa dry samples). Observed differences were confirmed statistically using the Mann-Whitney test. It results from the presented list that differences were particularly marked in dry samples. Another comparison was related to compression strength of standing and broken trees. Differences were observed indicating a higher mean strength of standing trees (Tab. 1) in both populations (Kolbudy and Świdwin).

Table 1 Compression strength along the grain in wet and dry samples coming from broken and standing trees. Descriptive statistics.

			N	Mean	Median	Minimum	Maximum	Std dev.
Broken	**Świdwin**	**Wet**	68	17.59	15.88	4.18	32.15	6.32
		Dry	66	49.04	47.18	19.68	90.70	15.34
	Kolbudy	**Wet**	56	11.93	12.00	6.08	20.21	3.11
		Dry	63	32.68	32.66	11.22	52.50	9.47
Standing	**Świdwin**	**Wet**	24	19.91	18.92	11.94	33.56	5.17
		Dry	24	54.05	52.04	36.53	85.86	13.12
	Kolbudy	**Wet**	35	12.07	11.22	6.18	21.38	4.01
		Dry	35	35.71	34.51	8.61	65.44	13.32

However, these differences were slight and were statistically verified negatively. In the presented results a mean from samples coming from the entire cross stem section of the tested stem was considered. When samples were arranged in the radial direction, a marked variation may be observed resulting from the presence of juvenile and mature wood. Samples located at the pith turned out to be much weaker (Fig. 1, 2), although it was not in every case, since (relative) variation observed in samples tested at a moisture content above fiber saturation point was definitely greater than in case of dry samples.

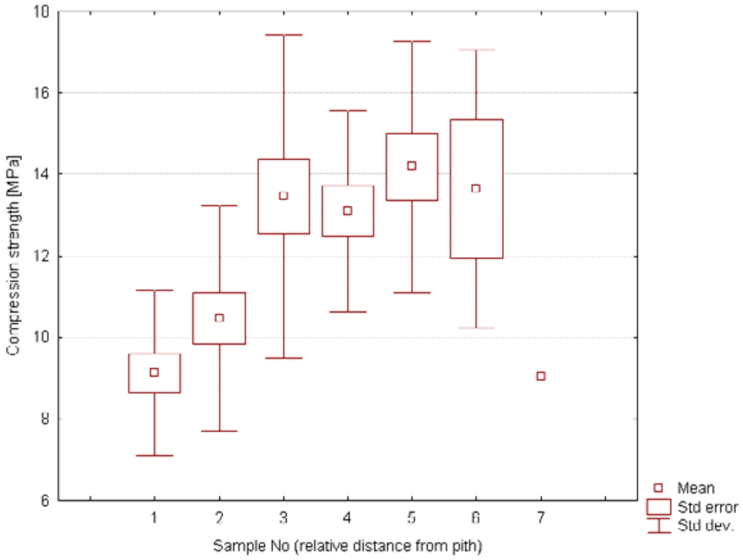

Fig. 1 Compression strength along radial direction in samples (wet) taken from Kolbudy plot .

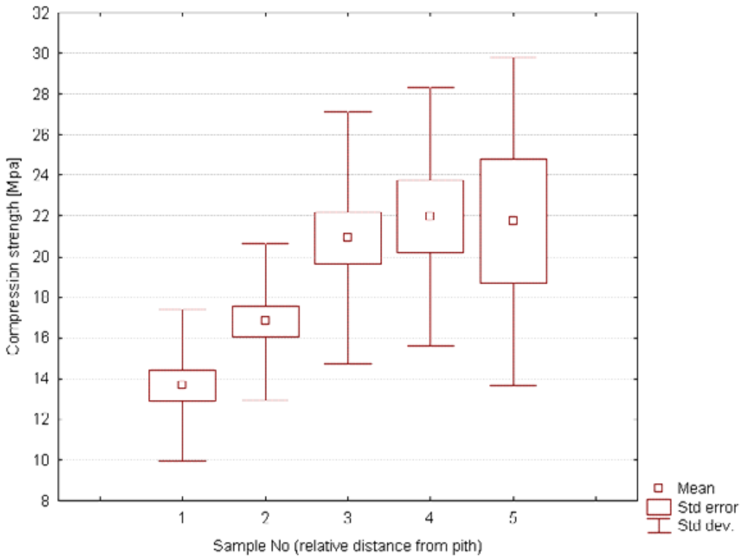

Fig. 2 Compression strength along radial direction in samples (wet) taken from Świdwin plot.

Wood located at the pith turned out to be exceptionally weak in wet samples, which more accurately reflect natural conditions. Thus it may be indirectly inferred that trees with a greater breast height diameter under natural conditions showed resistance to the action of compressive forces compensating with thickness the weak pith section. In studies on radial variation it was observed that only the first two samples from the pith exhibited relatively low strength. When observing mutual relationships between strength of individual trees we may see that they are different in wet and dry samples (Fig. 3, 4). At such a comparison a much greater standard deviation may be seen in dry tests and definitely greater differences were found in the mean strength.

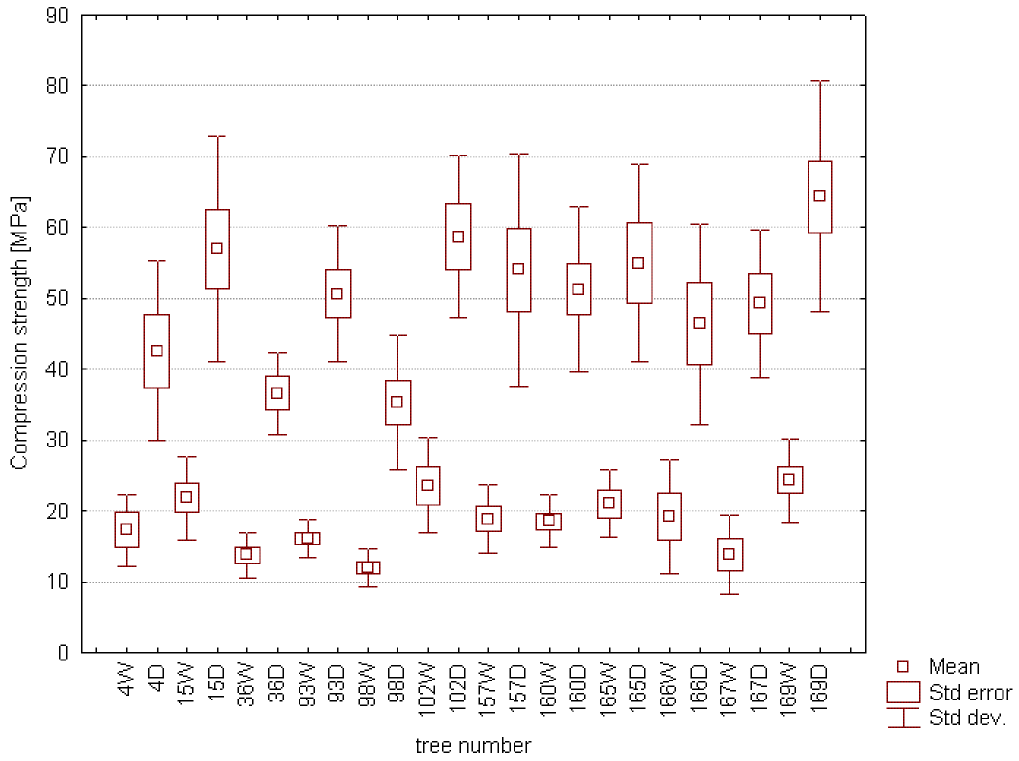

Fig. 3 A comparison of compression strength along the grain in samples tested at a moisture content over fiber saturation point (W) and in absolutely dry state (D), Świdwin.

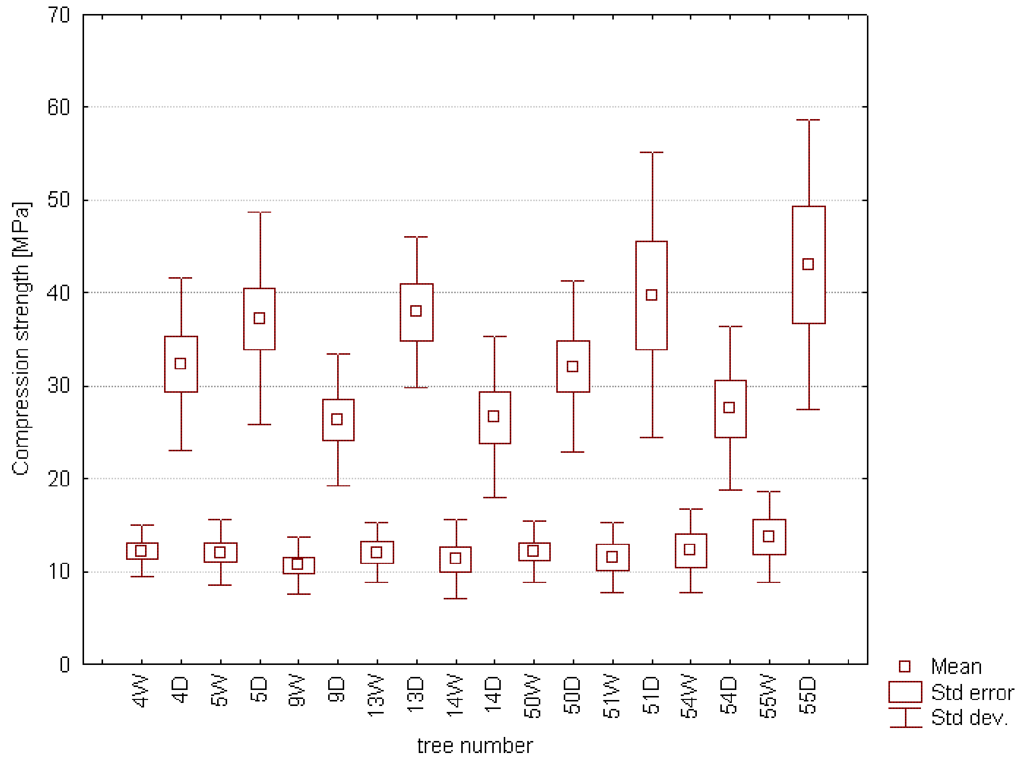

Fig. 4 A comparison of compression strength along the grain in samples tested at a moisture content over fiber saturation point (W) and in absolutely dry state (D), Kolbudy.

In case of trees coming from the Świdwin plot trees which proved to be stronger when wet were also strong when their wood was tested dry, while in trees coming from Kolbudy such a dependence was not observed. Trees were analysed in wet tests exhibited a similar strength, while when tested dry they differed considerably. It may also result from damage to secondary bonds in cell walls of wood, which may be caused by a strong load caused by wind. Generally it may be stated that no significant differences in compression strength were found between wood of standing trees and that of broken trees. Potential slight differences were so small that they have no practical importance for the occurrence of windfall, while they may be useful in the development of methodology in further research on the subject. It seems particularly advisable to neglect in further studies the pith zone, which has very low strength and from the point of view of stem mechanics is not subjected to such strong stresses as the circumference zone. Marked differences were recorded between tested stands coming from different geographical locations and growing under different site conditions.

CONCLUSIONS

1. Analysed populations in Świdwin and Kolbudy differed in compression strength measured along the grain. A greater strength both in wet and dry samples was found for the population in Świdwin.
2. No significant differences were found in compression strength between trees broken by wind and those which were not broken in either of the experimental plots. Probably biometric traits of trees were the cause of breakage.
3. Trees from the Kolbudy plot exhibited considerable variation in strength in dry tests in contrast to tests conducted at a moisture content above fiber saturation point. Mean strength for all model trees in the wet state was similar, while for dry tests the differences in means were considerable. This may indicate damage to secondary bonds in cell walls of certain samples. Such damage may result from considerable dynamic load caused by wind. This phenomenon was observed both in wind-broken trees and standing trees, thus it is advisable to continue studies in this respect.

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Streszczenie: *Wytrzymałość na ściskanie wzdłuż włókien prób bliźniaczych (mokrych i absolutnie suchych) pochodzących z drewna wiatrołomów sosny zwyczajnej (Pinus sylvestris L.)*. Praca stanowi część cyklu badawczego prowadzonego w drzewostanach sosnowych, które uległy klęsce wiatrołomów. Celem cyklu badań jest dokonanie opisu zachowania się tkanki drzewnej w warunkach silnych wiatrów i próba znalezienia cech drewna i drzewa , które przyczyniają się do spadku lub wzrostu odporności na działanie silnego wiatru. Powierzchnie badawcze zlokalizowano na terenie Nadleśnictwa Świdwin i Nadleśnictwa Kolbudy. Szkody od wiatru na badanych powierzchniach (złamania strzały) stanowiły co najmniej 20% powierzchni drzewostanu. Badaniom poddano łącznie 371 próbek pochodzących z 22 drzew. Z powierzchni zlokalizowanej w Świdwinie pochodziło 12 drzew (9 złamanych i 3 stojące) z pobranych wyrzynków przygotowano łącznie 182 próbki. Z powierzchni w Kolbudach pochodziło 10 drzew (6 złamanych i 4 stojące) z których przygotowano 189 próbek. Nie wykazano istotnych różnic w wytrzymałości na ściskanie między drewnem drzew stojących, a drewnem drzew złamanych. Ewentualne drobne różnice są na tyle małe, że nie mają praktycznego znaczenia w powstawaniu złomów, mogą być natomiast pomocne w konstruowaniu metodyki przy dalszym prowadzeniu badań w tym zakresie. Szczególnie wskazane wydaje się pomijanie w dalszych badaniach strefy przyrdzeniowej, która ma bardzo niską wytrzymałość i z punktu widzenia mechaniki pnia nie podlega tak silnym naprężeniom jak strefa obwodowa.

Corresponding author:

Poznań University of Life Science
Department of Forest Utilization
Ul. Wojska Polskiego 71A, 60-625 Poznań
Marcin Jakubowski PhD (marcin.jakubowski@up.poznan.pl)