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The influence of artificial weathering on abrasion resistance of selected wood species from South America

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Abstract: *The influence of artificial weathering on abrasion resistance of selected wood species from South America* The artificial weathering method consisting of alternating soaking wood in water, drying at a temperature of 70 °C and UV radiation exposure was used to determine the influence of weathering on resistance to abrasion of garapa (*Apuleia leiocarpa* (Vog.) Macbride), cumaru (*Dipteryx odorata* (Aubl.) Wild.) and tatajuba (*Bagassa guianensis* Aubl.). Selected wood species were of similar structure, density and hardness. The results of artificial weathering are changes in the abrasion resistance. With the progressive artificial weathering abrasion resistance of wood changed gradually. In case of tatajuba and garapa wood resistance to abrasion was similarly. In case of garapa wood, the widest range of changes after weathering process was observed. It was found that not only wood density determines wood abrasive resistance, but an important factor is wood structure, mainly arrangement of wood fibers.

Keywords: artificial weathering, garapa (*Apuleia leiocarpa* (Vog.) Macbride), cumaru (*Dipteryx odorata* (Aubl.) Wild.) and tatajuba (*Bagassa guianensis* Aubl.), abrasion resistance.

INTRODUCTION

The important factors determining use of wood terrace boards and flooring surface are not only aesthetic attractiveness in terms of color, grain and figure, but in its good wearing properties such as abrasion resistance [Desch and Dinwoodie 1996]. Aesthetics is formed by the visual impression of the patterns of wooden elements layout, of structure of applied wood species, their color and surface finishing quality. During outside exposition wood surfaces is subjected to changes in texture and color. Factors responsible for these changes are alternating actions of humidity and temperature, photo-chemical and biological processes as well as mechanical erosion caused by wind and rainfall [Matejak 1983]. Variability of weather conditions and prolonged exposure to them causes the process called wood weathering also referred to as an ageing. Wood weathering is a process of irreversible changes in appearance and properties caused by long-term acting of the weather conditions: solar radiation, content of oxygen in air, changes in temperature and humidity, assuming no direct influence of biotic factors [Feist 1990; Colom et al. 2003, Williams 1999, 2005].

During exposure in natural environment, initially smooth wood surface becomes rough as wood fibers rise and wood cracks. This is accompanied by changes in chemical components [Williams 1999, Jankowska 2013]. All of these changes occur mainly in surface layer of wood. Research of chemical changes in wood represents explanation of degradation of the outer layers taking place in wood during exposure to natural conditions [Feist 1990, Donegan et al. 1999, Williams 1999]. Lignin constitutes 20-30 % of wood tissue and due to phenolic nature lignin absorbs most of the UV radiation, which consequently causes its degradation. Lignin deprived of cellulose chain adhesives and coatings is also degraded as a result of other weathering factors (variable ambient conditions).

Because of changes in wood surfaces during external exposition, we have undertaken to investigate the mechanical properties having a significant influence on the terrace boards usage, that is: hardness and abrasion (wear) resistance of the wood species from South America that are often found in Polish market. Furthermore, objective of this study was determination and comparison the influence of artificial weathering (assuming the absence of biotic interactions) abrasion resistance. The research includes selected wood species from South America: garapa, cumaru, tatajuba - wood often used in Europe for products dedicated to outside usage (such as terraces).

MATERIAL AND METHODS

Wood species selected for the research are deciduous hardwood species from South America (tab. 1). This wood is of diffuse-porous structure. All of species are wood with irregular fibres arrangement (striped or interlocked arrangement of fibers). Wood species selected for the research are a group of materials used for the production of elements used in external conditions (elevation, terrace boards, garden furniture, etc.).

Table 1. The research material

Latin names	Trade names and names according to EN 13556 (2005)	Origin
Apuleia leiocarpa (Vog.) Macbride	garapa*	South America
Bagassa guianensis Aubl.	tatajuba	
Dipteryx odorata (Aubl.) Wild.	cumaru	

* *Apuleia leiocarpa* (Vog.) Macbride are not included in EN 13556 (2005)

Samples of each wood genus were taken from one board to obtain "identical sample". That method let to keep wood structure so the appearing changes in the artificial weathering process were the main factor for the examined properties. 3 groups of 21 samples were taken from each species of wood. Tangential and radial wood surface was tested separately. Only longitudinal sections were tested because of the fact that in final product these sections dominate. Dimensions of samples were 100x100x20 mm. Each group was intended for the research of different stages of weathering. Surfaces of wood had been sanded before the experiment began.

The design of the artificial weathering cycle was based on literature [Matejak et al. 1983, Follrich 2011]. One artificial weathering cycle took 30 hours and was separated into three steps (Figure 2). The first step was soaking specimens in water at 20 °C (16 h). The conditions of second step (8 h) were 70 °C and 5-10 % relative humidity (RH) and the third step was performed at 30 °C and 20-25 % RH (6 h) with irradiation with UV rays. Four fluorescent lamps100R's Lightech of 100 W each, and the spectrum 300 - 400 nm (90 % of the radiation spectrum is a wavelength of 340 -360 nm) were used for irradiating.

The abrasive (wear) resistance was measured with the Taber method in accordance with the EN ISO 5470-1 (1999) standard. The test was based on the loss of thickness and loss of mass of the tested samples after 1 hundred revolutions of the wheel. The load amounted to 500 g, test temperature was closed to 20,0°C, and air humidity - 55 %. The abrasion test was made before artificial weathering process, after 20 and 40 cycles of artificial weathering. Prior to the determination of abrasive (wear) resistance, each group was conditioned in air at a temperature close to 20 °C and RH 65 ±5 %. To compare resistance to abrasion, percentage loss of mass was determinate.

We decided to determine wood density according to ISO 3131 (1975). Furthermore, wood hardness were determined according to EN 1534 (2000). These tests were carried out by the Brinell method, with a hardness tester of the company CV Instruments 3000LDB. The test consisted of indenting a 10 mm ball made of still into the wooden element being subject to the test, with the force of 1kN and during the time specified in the standard. For each indentation, the hardness was calculated in accordance to the formula:

$$HB = \frac{2F}{\pi D\left(D - \sqrt{D^2 - d^2}\right)},$$

where:
HB –Brinell hardness [MPa],
F – loading force [N],
D – diameter of steel ball [mm],
d – diameter of the indentation [mm].
The number of indentations for each wood species was 60 (30 on radial cross section and 30 on tangential cross section).

RESULTS

Carrying out 40 cycles of the process of artificial weathering resulted in changes of the appearance of wood samples. After the first cycles, wood samples surface became rough and cracks occurred. Soaking wood in water resulted in raising wood fibers during drying and partial chipping of material (gentle rubbing the surfaces with a finger resulted in chipping of wood substance showing degradation of ligno-cellulosic backbone of cell walls). The roughest surface was observed in case of cumaru wood. Probably, this phenomenon was accompanied by an irregular fibres arrangement. The artificial weathering process caused the cracking of the wood samples. Dealing with the issue of weathering, among others Matejak et al. [1983], Feist [1990], Williams [1999], the main reason that causes wood damage is sorption stress which occurs during rapid wetting and fast drying (running at high frequency of changes in humidity cause wood cracking).

Artificial weathering process caused a color changes. Initially, the surface of test wood samples became darker. The first cycles of artificial weathering caused no obvious change in color, but after each stage of the process differences were observed - samples became darker, which was probably the result of dissolved dye substances in deeper layers, and then depositing them on the surface of wood during drying. This phenomenon was confirmed by Donegan et al. [1999], Williams [1999] and Jankowska [2013].

Table 2. Results of determination density* of tested wood species (in bracket standard deviation was given)

Name of wood	Wood density
	$kg \cdot m^{-3}$
Cumaru	905 (25)
Garapa	895 (38)
Tatajuba	820 (24)

* moisture content after conditioning in air at a temperature close to 20 °C and rH 65 ±5 %

Table 3. Results of determination hardness* of tested wood species (in bracket standard deviation was given)

Name of wood	Radial cross section	Tangential cross section
	MPa	
Cumaru	70,8 (7,1)	75,8 (6,2)
Garapa	70,0 (8,2)	61,6 (12,2)
Tatajuba	48,9 (5,3)	58,8 (5,1)

* moisture content after conditioning in air at a temperature close to 20 °C and rH 65 ±5 %

Tested wood species show similar level of density (tab. 2). According to Krzysik [1978], all of tested wood species can be classed as very heavy wood. Effects of hardness tests showed that in case of cumaru and garapa there is no significant difference between radial and tangential cross section (tab. 3). Only in case of tatajuba wood difference between hardness on tangential and radial cross section was found and confirmed with t-Student test.

Comparison the effects of abrasive resistance test of untreated wood (percentage losses of mass were compared) – tab. 4, it can be said that garapa wood showed the highest resistance to abrasion (the smallest loss of mass). This phenomenon is a little surprising taking account that garapa is not the heaviest wood in group of tested wood species. As it is known from literature [Krzysik, 1978], abrasive resistance of wood is depending on density of a material. Furthermore, the heaviest tested wood species - cumaru showed the smallest resistance to abrasion. It lets to make conclusion that not only wood density determines wood abrasive resistance, but the very important factor is wood structure, mainly arrangement of wood fibers (cumaru and tatajuba have striped fibres but garapa rather interlocked fibres). In case of cumaru wood the roughest surface was observed, but after artificial weathering wood surface became smoother in touch. The loose wood fibers crumbled out during the first cycles of artificial weathering and after that losses of mass were smaller.

Table 4 Results of abrasive (wear) resistance tests* – percentage loss of mass (in bracket standard deviation was given)

Name of wood	**Before artifical weathering**		**After 20 cycles of artificial weathering**		**After 40 cycles of artificial weathering**	
	radial cross section	tangential cross section	radial cross section	tangential cross section	radial cross section	tangential cross section
Cumaru	0,021 (0,003)	0,022 (0,007)	0,024 (0,001)	0,039 (0,005)	0,027 (0,010)	0,030 (0,011)
Garapa	0,014 (0,003)	0,016 (0,004)	0,021 (0,005)	0,028 (0,005)	0,029 (0,008)	0,034 (0,010)
Tatajuba	0,016 (0,005)	0,015 (0,007)	0,022 (0,003)	0,022 (0,009)	0,028 (0,008)	0,029 (0,010)

* moisture content after conditioning in air at a temperature close to 20 °C and rH 65 ±5 %

In case of tatajuba and garapa wood resistance to abrasion was similarly. In case of garapa wood, the widest range of changes after weathering process was observed. It confirmed that artificial weathering caused gradually degradation of surfaces layer - degradation of ligno-cellulosic backbone of cell walls and in case of garapa degradation was the most dynamic.

After analysis of average value of percentage loss of mass it can be said that radial section is more resistant to wearing than tangential cross section. Only tatajuba wood did not confirm this relation.

Nevertheless of tested wood species, with the artificial weathering process abrasive resistance were worst. Moreover, it was observed that accelerated weathering has influence on variability of results (higher value of coefficient variation). It can be caused by variability of grade degradation of wood surface.

CONCLUSIONS

The artificial weathering method consisting of alternating soaking wood in water, drying at a temperature of 70 °C and UV radiation exposure was used to determine the influence of weathering on resistance to abrasion of garapa (*Apuleia leiocarpa* (Vog.) Macbride), cumaru (*Dipteryx odorata* (Aubl.) Wild.) and tatajuba (*Bagassa guianensis* Aubl.). Selected wood species were of similar structure, density and hardness.

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Streszczenie: *Wpływ przyspieszonego starzenia na ścieranie drewna wybranych gatunków z Ameryki Południowej* Praca dotyczy zmiany właściwości powierzchni drewna garapa (*Apuleia leiocarpa* (Vog.) Macbride), tonkowca wonnego (*Dipteryx odorata* (Aubl.) Wild.) i tatażuby (*Bagassa guianensis* Aubl.), spowodowanej działaniem sztucznego starzenia. wybrane do badań gatunki drewna charakteryzowały się zbliżoną strukturą, gęstości i twardością. Mająca symulować działanie naturalnych czynników atmosferycznych, zastosowana metoda starzeniowa polegała na przemiennym moczeniu drewna w wodzie, suszeniu w temperaturze 70 °C i naświetlaniu promieniami ultrafioletowymi. wraz z postępującym procesem sztucznego starzenia, odporność na ścieranie malała. Największy zakres zmian stwierdzono w przypadku drewna garapy. Stwierdzono, ze odporność drewna na ścieranie wynika nie tylko z gęstości materiału, ale także istotny wpływ ma struktura drewna, przede wszystkim układ włókien.

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