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11TH HARDWOOD CONFERENCE PROCEEDINGS

Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Content

Session II - Hardwood resources, product approaches, and timber trade

Session III - Surface coating and bonding characteristics of hardwoods

Session IV - Hardwood structure and properties

Session V - Hardwoods in composites and engineered materials

Session VI - Modification & functionalization

Withdrawal capacity of Green ash (*Fraxinus pennsylvanica* Marsh.) and Box elder (*Acer negundo* L.)

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ABSTRACT

Efforts to curb the spread of invasive species are made worldwide, but the wood mass available of these species is already significant in certain areas. The properties of these wood species are little or not at all known, such as those of green ash (*Fraxinus pennsylvanica* Marsh.) and box elder (*Acer negundo* L.). The withdrawal capacity of wood screws of the two wood species examined showed significant differences, perpendicular to the grain. The tests conducted using chipboard screws showed withdrawal capacity of green ash to be 1.5 times greater than that of box elder. For the screw and driving depth applied, the average withdrawal load of green ash and box elder were 3845 N and 2550 N respectively.

INTRODUCTION

The use of metal screws as fasteners dates back to the 15th century in Europe. The first patent was registered in the 18th century for the industrial manufacturing of wood screws. The majority of the releasable joints used in furniture production and the majority of functional fittings such as hinges, slide door hardware systems, drawer slides and mechanisms serving to store various products are connected to the structural components with the help of screws (Jivkov et al. 2017).

The resistance of the wood screw driven into timber to withdrawal characteristically shows strong correlation with the strength, density and shear modulus of the wood. Withdrawal capacity tests may be performed on various structural components, such as:

- timber structures of log cabins and off-site construction houses
- structures of viewing towers and timber bridges
- timber of roofing structures
- timber of floor structures (ÉMI 2020).

Nail and screw withdrawal capacity tests are conducted in laboratory environment on universal testing machines (UTM), but special instruments have also been developed for the on-site testing of various structures (Divós and Őry 2022).

In case of structural elements, failure is often initiated at the joints, normally at the weakest points of timber structures. It is therefore essential to examine how connections and fasteners behave under various loads. When subjected to tensile force, fasteners may be pulled out of the timber components or may snap (Abdoli et al. 2022).

Fastener pullout resistance is influenced among others by diameter, thread geometry, penetration depth of a fastener, and load-to-grain angle. In case of timber, it is usually defined parallel or perpendicular to the grain. Perpendicular to the grain may be further distinguished into radial and tangential directions. Its definition in the various anatomical directions is necessitated by the anisotropic nature of wood.

Teng et al. (2018) have come to the conclusion that the insertion angle significantly influences withdrawal capacity, while no significant difference can be observed between the cases of radial and tangential directions. A positive correlation has been found to exist between density and withdrawal strength.

According to Eckelman (1990) denser materials largely show greater withdrawal strengths, but the strength decreased with the increase of moisture content.

The spread of invasive plant species and their habitat transforming effect represent a significant environmental problem worldwide. A sizeable share of these species are woody species (Ónodi 2016). The term ‘invasive species’ is used by literature ambiguously. According to the most common definition,

biological invasion revers to the spread of a non-indigenous (alien) species. On the other hand IUCN defines only those alien species as 'invasive' that endanger the biodiversity of the natural areas (Csiszár 2012). There are attempts to restrict the spread of invasive species globally, and fundamental information on the use of the wood of such are less available to the related processing industry. The volume of available literature in invasiveness has seen sharp growth over the recent decades, but these do not focus on the material properties of the timber of invasive species.

Green ash, an invasive woody species, has spread very quickly in Central Europe over the past 25 years (Drescher and Prots 2016), due to certain physiological and morphological traits allowing it to survive in washlands and flooded areas as an early-to late-succession species of riparian forests, mostly observed along larger watercourses in mixed forests of *Fraxinus excelsior*, *Quercus robur* and *Ulmus spp*. (Branquart et al. 2010).

Its strong, durable, and shock-resistant timber is a valuable raw material for niche uses such as making tool handles and baseball bats. Green ash is also a popular ornamental tree and it is widely planted in urban and suburban areas throughout the US and abroad due to its suitable shape and the shade its canopy provides (Kovacs et al. 2010). The timber is of a lower grade than common ash, and is rarely a species to be found in plantations as such, but it does yield better timber than that of common ash when planted in drier areas where it can grow slower. In northwestern Turkey, where narrow-leaved ash is preferred species of fast-growing plantations in swampy lowlands, the timber of Green ash has properties similar to poplar species, making it a suitable raw material for pulp and plywood, LVL, glulam and other bonded wood products. Its leaves are suitable livestock fodder, and the tree has been traditionally cultivated in Southern Europe as such. Green ash is also a popular urban and street tree (Caudullo and Houston 2016).

Initially introduced to Europe in the 17th century as a decorative tree, box elder has by now become widespread and is considered an invasive species (Ednich et al. 2015).

Box elder has a low-grade, low-strength timber, suitable for making entry-level furniture, fences, wooden crates, etc, occasionally used as firewood, and also for park and landscape architecture. It has also been used to control wind erosion, initially in the USA and later globally, and also yields a sap used to make 'mountain molasses', similarly to other maple species. (Barstow et al. 2017)

From the perspective of industrial suitability of wood, one of the most important properties is density. The air dry density of green ash and box elder is 647 kg/m^3 and 501 kg/m^3 respectively. Green ash has been found to have greater compressive strength, modulus of rupture, modulus of elasticity and impact bending strength than box elder (Komán and Varga 2021).

The present research has examined the screw withdrawal capacity of two invasive wood species to promote the more widespread use of their timbers, not insignificantly from the perspective of fundamental research as well, as very little is known about the basic properties of the wood of these species.

MATERIALS AND METHODS

The screw withdrawal capacity test was conducted according to the provisions of the EN 1382:2016 standard. The tests were carried out on specimens stored under normal climate conditions (T=20°C; φ=65%) until equilibrium moisture was reached. During the test, chipboard screws were driven 20 mm deep into the wood, perpendicular to the grain (Figure 1).

The screw withdrawal capacity was calculated using the following formula:

$$f_{ax} = \frac{F_{max}}{d \times l_d} \quad (1)$$

where

f_{ax} – withdrawal parameter, in newtons per square millimetres

F_{max} – maximum withdrawal load, in newtons

d – is the outer thread diameter for screws

l_p – the effective depth of penetration of the fastener, in millimetres

Figure 1: Withdrawal capacity measurement

RESULTS AND DISCUSSION

The test results may be correlated to density, as the density of green ash is 30% greater than that of box elder. The difference of screw withdrawal capacity perpendicular to the grain is even greater for the two species than the difference of their densities. The screw withdrawal capacity of green ash tis 50% greater than that of box elder (Figure 2). The significant difference between the two species is also interesting from the aspect that green ash is a ring-porous species and box elder is diffuse-porous. The values obtained for the two deciduous wood species are multiples of those obtained by Gašparík et al. (2021) for larch and spruce. To pull out screws driven 20 mm deep, average forces of 3845 N and 2550 N were required for green ash and box elder respectively.

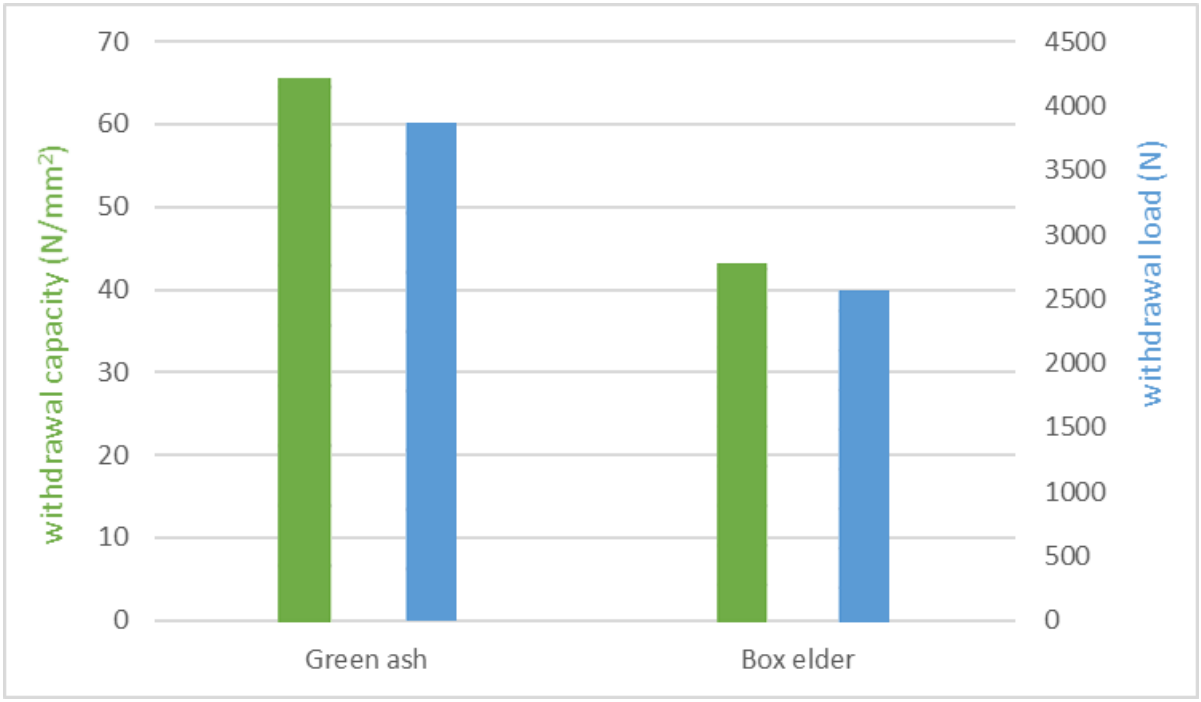

Figure 2: Withdrawal capacity and withdrawal load

CONCLUSIONS

Little information is available on the possibilities of using timbers of various invasive species, the primary objective being the restriction of their populations. From the perspective of their industrial use, besides knowing their characteristic densities – which fundamentally determines their physical and mechanical properties – knowledge of their technological parameters is no less important. Screw withdrawal capacity is also greatly influenced by anatomical structure, not only affected by the anatomical directions, but also by the ring-porous or diffuse-porous nature of hardwoods. Although the density of ring-porous green ash is 30% greater than that of box elder, and even greater difference of screw withdrawal capacity can be observed between the two species. These values, however, exceed those of softwood species by a significant margin, therefore the industrial use of both species is recommended, as far as screw withdrawal capacity is concerned.

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