

## Anatomy of Wooden Core of Ottoman Composite Archery Bows (Anatomi Teras Kayu Komposit Busur Panah Uthmaniyyah)

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### ABSTRACT

*Composite archery bows have been well known and used by Asiatic societies for thousands of years. The Turkish composite bow, made of wood, horn, sinew and glue is one of the most famous and powerful bows in the world. Because of its high draw weight and mechanical efficiency, the Turkish composite bow became a powerful weapon in the Seljuk and the Ottoman empire. In addition to being a powerful weapon of war, at the same time the bow and arrow (archery) continued to be a sport of Ottoman (sultans, state officials, janissaries) until the late Ottoman period. In this study of the Ottoman composite archery bows in the collections of Izmir Ethnography Museum, a small wood sample was investigated on the basis of its wood anatomy. The results showed that it was made of maple wood (Acer sp.) and some of its qualitative and quantitative anatomical properties are presented here. One of the key properties for the identification of maple wood is the helical thickening throughout the body of the vessel element. Helical thickenings in vessel elements in cutting surfaces of maple-wooden core increase the bonding surface between the wood and sinew-horn. In most of the woods preferred traditionally for bow-making, helical thickenings in tracheids, vessel elements or ground tissue fibres should be taken into account at a hierarchy of cellular structures for elucidating the efficiency of Ottoman composite-wooden bow.*

*Keywords:* Acer; Ottoman; wood anatomy

### ABSTRAK

*Busur panah komposit telah dikenali dan digunakan dalam masyarakat Asia sejak beribu tahun yang lalu. Busur komposit Turki yang diperbuat daripada kayu, tanduk, urat dan gam adalah salah satu busur yang terkenal dan terkuat di dunia. Dengan berat tarik dan kecekapan mekanik yang tinggi, komposit busur Turki merupakan senjata yang penting dalam empayar Seljuk dan Uthmaniyyah. Selain daripada senjata perang yang kuat, pada masa yang sama busur dan anak panah (acara memamah) telah menjadi sejenis sukan dalam empayar Uthmaniyyah (sultan, pegawai atasan negeri dan janisari) sehingga ke akhir zaman Uthmaniyyah. Dalam kajian ini busur panah Uthmaniyyah dalam koleksi Muzium Ethnografi Izmir, iaitu satu sampel kayu yang kecil telah diselidiki daripada segi anatomi kayunya. Hasil kajian ini menunjukkan busur ini diperbuat daripada kayu Maple (Acer sp.) dan sebahagian daripada sifat anatomi kualitatif dan kuantitatif dibentangkan dalam kertas ini. Salah satu sifat penting untuk mengenal pasti kayu Maple ialah penebalan heliks keseluruhan komponen unsur sel salur. Penebalan heliks dalam unsur sel salur pada permukaan teras Maple yang dipotong meningkatkan ikatan permukaan antara kayu dan urat. Dalam kebanyakan kayu yang digunakan secara tradisi untuk membuat busur panah, penebalan heliks dalam trakeid, unsur sel salur atau gentian tisu perlu dipertimbangkan pada hierarki struktur sel untuk mendapatkan kecekapan busur panah komposit kayu Uthmaniyyah.*

*Kata kunci:* Acer; anatomi kayu; Uthmaniyyah

### INTRODUCTION

The history of bow and arrow goes back to prehistoric times (Clark & Piggott 1965). However, the oldest known bows, which were made of elm (Clark & Piggott 1965; Grayson et al. 2007) and of yew (Fadala 1999), belongs to around 6000 BC and 3300 BC, respectively. It is known that there are two main type of archery bows based on material and method of bow-making: self-bow and composite-bow (Grayson et al. 2007). It is certain that the Holmegaard elm bow and Otzi's yew bow were made of a single wooden stick (*self-bow*). However, composite archery bows have been well known and used by Asiatic societies for thousands of years. The Turkish composite bow, made of wood, horn, sinew and glue is one of the most famous and

powerful bows in the world (Yücel 1999). To construct this type of bow, sinew was glued to the back (tension side) and horn to the belly (compression side) of preferred wooden core (Grayson et al. 2007; Yücel 1999).

Regarding the contribution of archery to the Turkish conquest of Anatolia, Kaegi (1964) pointed out that the skillful use of the bow and arrow gave the Turks the decisive advantage and that the Seljuk preferred the bow to other weapons in Byzantine-Seljuk warfare. Because of its high draw weight and mechanical efficiency (Karpowicz 2007), Turkish composite bow became a powerful weapon in the Ottoman Empire. The great combination of the powerful composite bows and high velocity light arrows contributed greatly to the Ottoman achievement in conquering many

lands in Asia, Europe and the Middle East (Karpowicz 2007). In addition to being a powerful weapon of war, at the same time the bow and arrow (archery) continued to be a sport of Ottoman Sultans, state officials, Janissaries and various professional people as well as civilians until the late Ottoman period (Yücel 1997). Among many shot records of about 800 m in different years, the longest recorded distance for traditional Turkish composite bow is 846 m, carried out by Tozkoporan Iskender in the era of II. Bayezid (Yücel 1999).

Karpowicz (2007) examined 46 Ottoman bows, the draw weights of which vary between 40 and 240 lb with a mean of 120 lb. After eliminating six low weight (<70 lb) and ten high weight bows (>150 lb) he determined for the majority of Ottoman bows that the realistic range of draw weights is from around 90 lb to 140 lb (a mean of 111 lb  $\pm$  17 lb) for the shortest bows. According to today's standards it appears very high to draw (Karpowicz 2007). However, De Busbecq (2005) stated that the Ottoman cavalymen were professionals and accustomed to constant practice since childhood to use forceful composite bows.

On the basis of wood anatomy the present study aimed to identify and measure the small wood sample of

an Ottoman archery bow and to put forward a 'scientific explanation' regarding a significant anatomical feature (helical thickening) occurring in the woods preferred traditionally for composite bow-making in the Ottoman Empire.

#### MATERIALS AND METHODS

A small sample (2 mm  $\times$  7 mm  $\times$  1 mm) from a wooden Ottoman composite archery bow in the collections of Izmir Ethnography Museum was investigated on the basis of wood anatomy. The broken bow (*inventory number 2564*), which is 114 cm in length and 230 gram in weight, is dated to early 1800s (Figures 1 and 2). Routine procedures were carried out for the preparation of transverse, radial longitudinal and tangential longitudinal sections of small wood sample (Merev 2003; Yaltrık 1971). Microphotographs were taken using light photomicroscope, Zeiss Axiostar-plus. Identification was made using manuals of wood anatomy (Akkemik & Yaman 2012; Fahn et al. 1986; InsideWood 2004-onwards; Merev 1998; Schoch et al. 2004) and comparative thin sections of fresh wood from Turkey.



FIGURE 1. The broken arrow with inventory number 2564 in the collection of Izmir Ethnography Museum

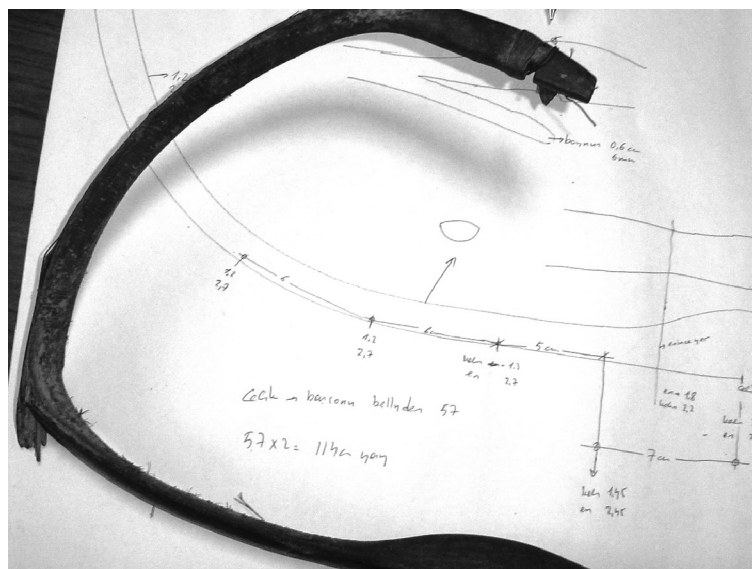


FIGURE 2. The broken arrow with inventory number 2564 in the collection of Izmir Ethnography Museum

## RESULTS AND DISCUSSION

The anatomical investigation showed that the bow was made out of maple wood (*Acer* sp.). It is most likely Field Maple (*Acer campestre* L.). The qualitative and quantitative anatomical properties of the small wood sample taken from the bow are shown Table 1 and its micrographs are presented in Figure 3.

Whether self- or composite-bow, it is very important to select the appropriate wood for making the perfect bow. Throughout history a variety of woods were used to construct traditional archery bows. One of the oldest bows (around 6000 BC in Holmegaard-Denmark) was made of elm wood (*Ulmus* sp.) (Clark & Piggott 1965; Grayson et al. 2007). Another old bow (5300 years-old), Otzi's long bow was made from yew wood (*Taxus baccata*) (Fadala 1999). Yew in Europe and Osage orange (*Maclura pomifera*) in Native Indian America has been the main woods for centuries to construct the bows that armies fought with (Slater 2009). In addition, desert willow (*Chilopsis linearis*) was also used by local Indians for making bow (Armstrong 2010). Yamauchi (1981) reports that ancient wooden bows found all over Japan were usually made from branches of Inugaya (*Cephalotaxus harringtonia*). Ottoman Turks selected maple wood (*Acer* sp.) to make the most efficient bows in the world (Yücel 1999). Cartwright and Taylor (2008) identified that most of 15 Egyptian ancient wooden bows were made of Acacia (*Acacia* sp.) and sidder (*Ziziphus spina-christi*) wood. One of Prophet Mohammed's wooden bows, El Baydaa, was made of Shawhat wood. The Bedouins still use the name Shawhat. It is a woody plant (*Cotoneaster orbicularis*), which has strong and flexible branches (Abdel-Aziz A. Fayed, pers. comm.). In addition to these there were many woods traditionally used for bows around the world,

including hazel (*Corylus avellana*), cornel (*Cornus* sp.), laburnum (*Laburnum anagyroides*), elder (*Sambucus nigra*), ash (*Fraxinus excelsior* and *F. ornus*) (Cartwright & Taylor 2008), hickory (*Carya* sp.), black locust (*Robinia pseudoacacia*) (Grayson et al. 2007), mountain mahogany (*Cercocarpus ledifolius*), Juniper (*Juniperus* sp.), mesquite (*Prosopis* sp.) (Wilke 1988), chokecherry (*Prunus virginiana*), serviceberry (*Amelanchier* sp.) and mulberry (*Morus* sp.) woods (Weitzel 2001).

The availability of species usually influenced which wood was used in a given region (Wilke 1988). In the tropics, a small number of species with helical thickenings have been used for traditional bow-making (Africa, New Guinea, Malaysia and Amazon), because the incidence of the species having this feature in the tropical woody flora is very low (Wheeler et al. 2007). Most of woody plants cited above come from Europe, America, North Africa, Asia and Turkey. Practically any wood type can be used for a bow stick, but the efficiency and power of a bow vary depending on wood species selected for bow-making. People historically tried to select the most appropriate wood species for bows: it seems that most of the woods preferred traditionally for bow-making have a common significant feature: 'helical thickening' on tracheid, vessel and/or fibre walls (61% -bold ones- of above-mentioned woody plants). Moreover, the most highly prized ones for bow-making for centuries have been yew, Osage orange (Slater 2009) and maple (Yücel 1999). One of the common properties in wood of these three species is helical thickening on the inner face of cell wall (in throughout body of vessel element for maple (Figure 3(e)) and Osage orange wood and in tracheids for yew wood).

It has been known that, in terms of physiology, cell wall structures such as helical thickenings have positive

TABLE 1. Visible anatomical properties of small wood sample belonging to the Ottoman bow

Taxon	<i>Acer</i> sp. ( <i>Acer</i> cf. <i>campestre</i> )	
Common Name	Maple ( cf. Field Maple)	
Growth Ring Boundaries	Distinct	
Vessels	Porosity	Diffuse-porous
	Groupings	Mostly Solitary and some radial groupings of 2 to 4 (5)
	Perforation Plate	Simple
	Intervessel Pits	Alternate, shape of alternate pits polygonal, small – 4 – 7 µm
	Helical Thickenings	Helical thickenings throughout body of vessel element
	Tangential Diameter (µm)	46.25 ± 5.03 (35 – 55)
	Radial Diameter (µm)	57.25 ± 6.67 (42.50 – 67.50)
Fibres	Frequency (number per square mm)	76.20 ± 4.44 (71 – 81)
	Width	17.69 ± 2.30 (13.75 – 22.50)
	Lumina	11.17 ± 1.73 (7.5 – 15)
Rays	Wall Thickness	3.26 ± 0.63 (thin- to thick-walled)
	Width	1 to 4 - seriate
	Cellular Composition	All ray cells procumbent
	Number per mm	9.21 ± 1.84 (6 – 12)
	Mean Maximal Height Of Uniseriate Rays As Cell Number	8.83 ± 1.94 (6 – 12)
Mean Maximal Height Of Biseriate Rays As Cell Number	19.80 ± 4.15 (15 – 25)	
Mean Maximal Height Of Multiseriate Rays As Cell Number	39.37 ± 8.21 (28 – 49)	

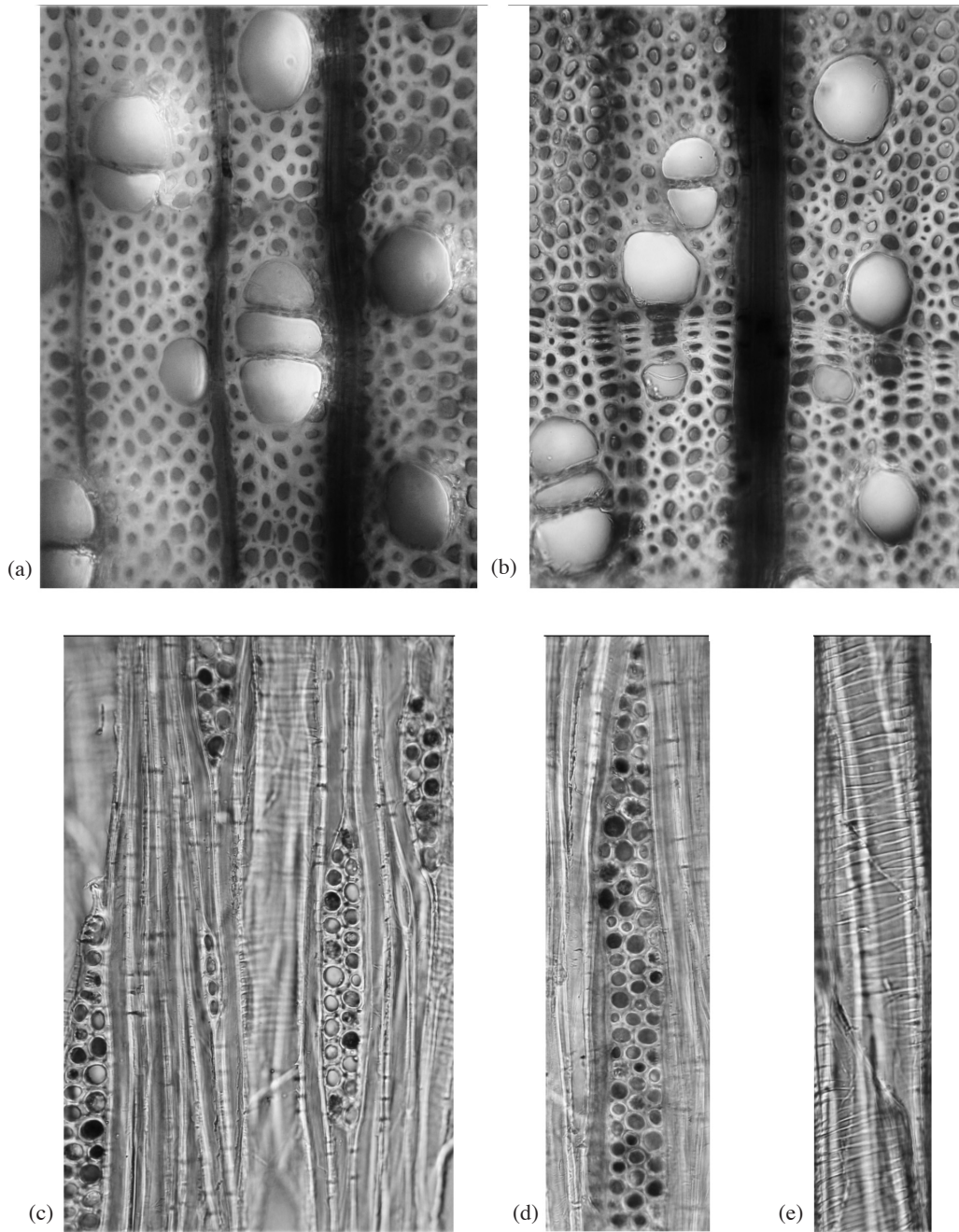


FIGURE 3. (a) Solitary and grouped vessels and fibres in transverse section (TS), (b) solitary and grouped vessels, fibres and a distinct growth-ring border in TS, (c) 1-2-seriate rays in tangential longitudinal section (TLS), (d) 3-seriate ray (TLS) and (e) helical thickening on vessel wall (TLS)

effects on conductive safety (Carlquist 1988). Moreover, regarding this structure another theoretical explanation is increase in vessel wall strength (Carlquist 1975; Zimmermann 1983). Keunecke et al. (2009) report yew wood has an exceptional elasto-mechanical behavior and they indicate that it is highly elastic in the longitudinal direction (MOE is low and the stretch to break high) in spite of a relatively high density. Keunecke et al. (2009) also state that both the mechanical effects of helical thickenings in cell wall are largely unknown and that their influence on the mechanical properties of yew wood is negligible.

In yew wood, in spite of a relatively high density, low Young's modulus was ascribed to the relatively large MFA of tracheids by Keunecke et al. (2009). In a given wood there are also other matters on elasto-mechanical response; the constant strength design principle of vessels (Karam 2005) and interaction among different cell types. Moreover, there is a question: What is the effect of helical thickenings in cell wall on elasto-mechanical behavior of wood? Micro-mechanical experiments at the cellular level are needed on vessel elements / tracheids with and without helical thickening. In addition, multi-scale models of wood

microstructure are essential to comprehend the mechanical nature of wood (Mishnaevski & Qing 2008).

#### CONCLUSION

A variety of woods were used to construct traditional archery bows throughout history. However, for centuries, the most highly prized ones for bow-making have been yew, Osage orange and maple. In these three wood types and most of the others preferred traditionally for bow-making, helical thickening in tracheids, vessel elements or ground tissue fibres is one of the anatomical features that should be taken into account for elucidating the efficiency of a self- or composite-wooden bow. It has been known that helical thickening increases the surface-to-volume ratio of a cell and it has an influence on cell micromechanics. In Ottoman wooden composite bow, sinew was glued to the back (tension side) and horn to the belly (compression side) of maple-wooden core by a collagen-based adhesive produced from sturgeon bladder. We suggest that helical thickenings in vessel elements in cutting surfaces of maple-wooden core increase the bonding surface between wood and sinew-horn. Moreover, considering collagen structure in nanoscale or microscale, the coherence between the surface anatomy of maple-wooden core and collagen-based adhesive, which is a strong mechanical bond with wood surfaces having helically thickened-cell walls, is noticeable. Thus, on the basis of multi-scale models of wood microstructure, the micro-mechanical properties of vessel elements (or tracheids) with helical thickening should be investigated at a hierarchy of cellular structures in wooden core of Ottoman composite archery bows.

#### ACKNOWLEDGEMENTS

The authors are grateful to the Izmir Ethnography Museum, General Directorate of Cultural Heritage and Museums and the Ministry of Culture and Tourism of Turkey for providing of small wood sample of the bow. We would like to thank Dr. Nesrin Hadidi for her valuable comments on Prophet Mohammed's wooden bows.

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Received: 10 February 2011  
Accepted: 14 November 2012