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Species Identification of Wooden Structural Members of the Beomeo Temple*1

Young Geun Eom*2†, Hwa Sung Kim*2, and Guang Zhu Xu*2

ABSTRACT

Tree species of wooden structural members of the Beomeo Temple were identified based on light and scanning electron microscopic characters in the present study. Of 10 structural members, 9 softwoods and 1 hardwood were identified. Among softwood members, 7 belonged to hard pine of the *Sylvestris* section, and the remaining 2 to hard pine of other than the *Sylvestris* section and hemlock of the genus *Tsuga*, respectively. A single hardwood member was identified as white oak of the *Prinus* section under the subgenus *Lepidobalanus*.

Keywords : species identification, wooden structural members, Beomeo Temple

1. INTRODUCTION

The Beomeo Temple, one of the famous buddhist temples with a long history in Korea, is located in Geumjeong-gu, Busan Metropolitan City. There are some different opinions about the date of construction of Beomeo Temple, but most believe that it was constructed by the monk Euisang-Daesa in the 18th year of King Munmu of the Shilla Dynasty (A.D. 678). After its foundation, Beomeo Temple led Korean Buddhism from the Koryo Dynasty to the middle of the Chosun Dynasty, but was completely destroyed by a fire during the Imjin Japanese invasion. The temple was rebuilt in the 35th year of King Sunjo of the Chosun Dynasty (A.D. 1602) but burnt down again by another fire. After this disaster, the Buddhist images, statues, and buildings of the temple were reconstructed in the 5th year of King Kwanghaegun of the Chosun Dynasty (A.D. 1613). Thereafter, there were several small and large scale repairs (Anonymous 2002).

Today, many wooden cultural properties are reported in severely damaged condition by the attack of termite and decay fungi, and need immediate repair work. The identification of wood species is very important for the restoration to the original state and thus must be included as an important and indispensable restoration stage.

For this purpose, the tree species of wooden structural members of the Beomeo Temple were

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*2 Department of Forest Products, College of Forest Science, Kookmin University, Seoul 136-702, Korea
† Corresponding author : Young Geun Eom (eom@kookmin.ac.kr)

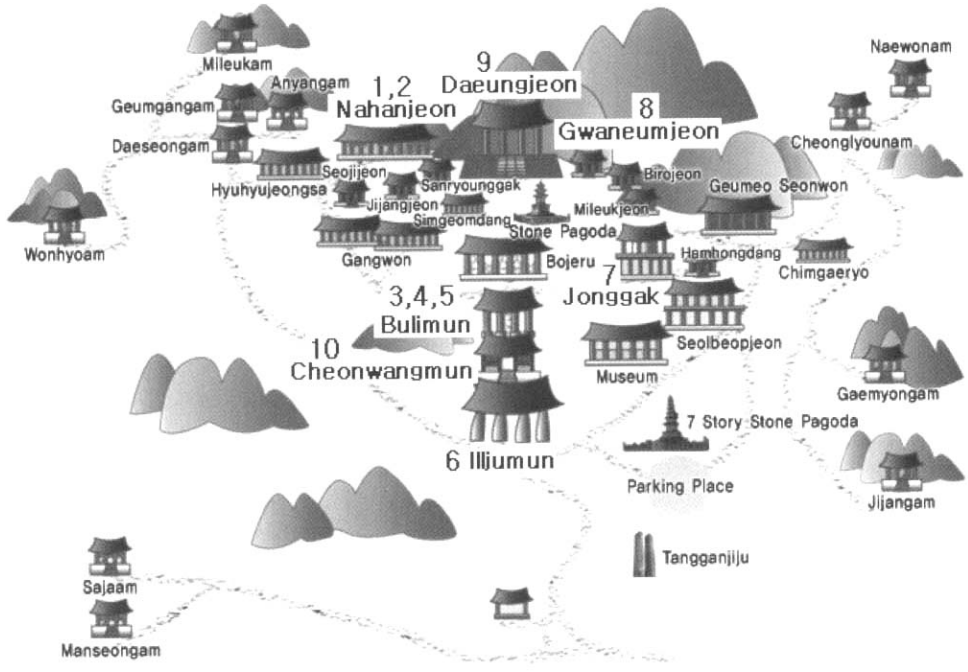

Fig. 1. Map of the Beomo Temple (Anonymous 2002) showing wooden structures from which samples for identification were taken. Arabic numerals indicate the wood sample number in Table 1.

identified based on light and scanning electron microscopic observations.

2. MATERIALS and METHODS

Wood samples in the form of chips were chopped with a chisel from 10 vertical structural members in wooden structures of the Beomeo Temple in February, 2003 (Fig. 1 and Table 1). Small cubes of about 10 mm per side were softened in water for 90 min. For light microscopy, transverse, radial, and tangential sections of 20 to 30 μm thick were cut with a sliding microtome, and permanent slides were prepared following standard laboratory techniques (Japan Wood Research Society 1985).

For scanning electron microscopy, wood blocks of about 5 mm^3 were prepared from the above softened blocks and the final cuts were made with single-edged, hard-backed razor blades. After removal of unwanted wood, the clean cut specimens were air-dried, glued to specimen stubs with double-sided carbon tabs, sputter-coated with gold to a thickness of 50 nm (Exley *et al.* 1974, 1977) using a JEOL JFC 1100E ion sputtering device and observed in a JEOL JSM 5410LV scanning electron microscope at 15 kV.

3. RESULTS and DISCUSSION

Out of 10 structural members, 9 softwoods and 1 hardwood were identified (Table 1). Among softwood members, 7 belonged to hard pine of the *Sylvestris* section, and the remaining 2 to hard pine of other than the *Sylvestris* section and hemlock of the genus *Tsuga*. A solitary hardwood member was identified as white oak of the *Prinus* section under the subgenus

Table 1. Wood samples and their identification results of structural post members

Structure Name	Sample No. in Fig. 1	Result of Identification
Nahanjeon (Fore Right Side, 1st)	1	Hard pine (*Sylvestris* section of the genus *Pinus*)
Nahanjeon (Rear Side, Shorter)	2	Hard pine (*Sylvestris* section of the genus *Pinus*)
Bulimun (Rear Left Side, 1st)	3	Hard pine (*Sylvestris* section of the genus *Pinus*)
Bulimun (Fore Right Side, 2nd)	4	Hard pine (*Sylvestris* section of the genus *Pinus*)
Bulimun (Fore Right Side, 1st)	5	Hemlock (Genus *Tsuga*)
Illjumun (Fore Right, Side, 1st)	6	Hard pine (*Sylvestris* section of the genus *Pinus*)
Jonggak (Downstairs Shop)	7	White oak (*Prinus* section of the subgenus *Lepidobalanus* under the genus *Quercus*)
Gwaneumjeon (Fore Left Side, 1st)	8	Hard pine (*Sylvestris* section of the genus *Pinus*)
Daeungjeon (Fore Right Side, 1st)	9	Hard pine (*Sylvestris* section of the genus *Pinus*)
Cheonwangmun (Rear Left Side, 1st)	10	Hard pine (Other than *Sylvestris* section of the genus *Pinus*)

Lepidobalanus.

Most structural members identified in present investigation were of hard pine of the *Sylvestris* section. Thus, the 3 structural wood members, hard pine of other than the *Sylvestris* section, hemlock of the genus *Tsuga*, and white oak of the *Prinus* section under the subgenus *Lepidobalanus* are thought to be replacements of relatively recent restoration.

The wood anatomical characteristics of each wood species identified were as follows:

3.1. Hard Pines (the genus *Pinus*) (Fig. 2~6)

Growth ring boundaries are distinct and latewoods are conspicuous with intermediate to abrupt transition from earlywood to latewood. Intertracheid bordered pits are mostly in one row and crassulae are commonly found in the radial walls of tracheids. Trabeculae traversing one or several lumen of tracheids are sometimes observed. Helical thickenings are not found in the tracheid walls and strand tracheids are observed in the vicinity of longitudinal resin canals. No longitudinal parenchyma cells excluding those associated with resin canals are found. Rays of 2 types, uniseriate and fusiform, present and generally composed of ray tracheids and ray parenchyma cells. Low rays consisting entirely of ray tracheids, however, are also more or less found. Ray tracheids typically have dentations. Normal transverse resin canals are found in the fusiform rays with normal longitudinal resin canals. Epithelial cells surrounding resin canals are thin-walled and tylosoids are observed frequently in the heartwood. Cross field pits are fenestriform with 1 or 2 pits per field or pinoid with 2 to 6 pits per field.

In softwoods, dentate ray tracheids and resin canals with thin-walled epithelial cells occur regularly only in hard pines (Panshin and de Zeeuw 1980). Among hard pines, fenestriform cross-field pits are found only in the *Sylvestris* section, whereas pinoid cross-field pits are present in the other sections including *Taeda* section (Yamabayashi 1938; Lee and Eom 1987; Eom 1999; Eom *et al.* 2003).

In Korea, the hard pines of the *Sylvestris* section were reported to be the major softwood

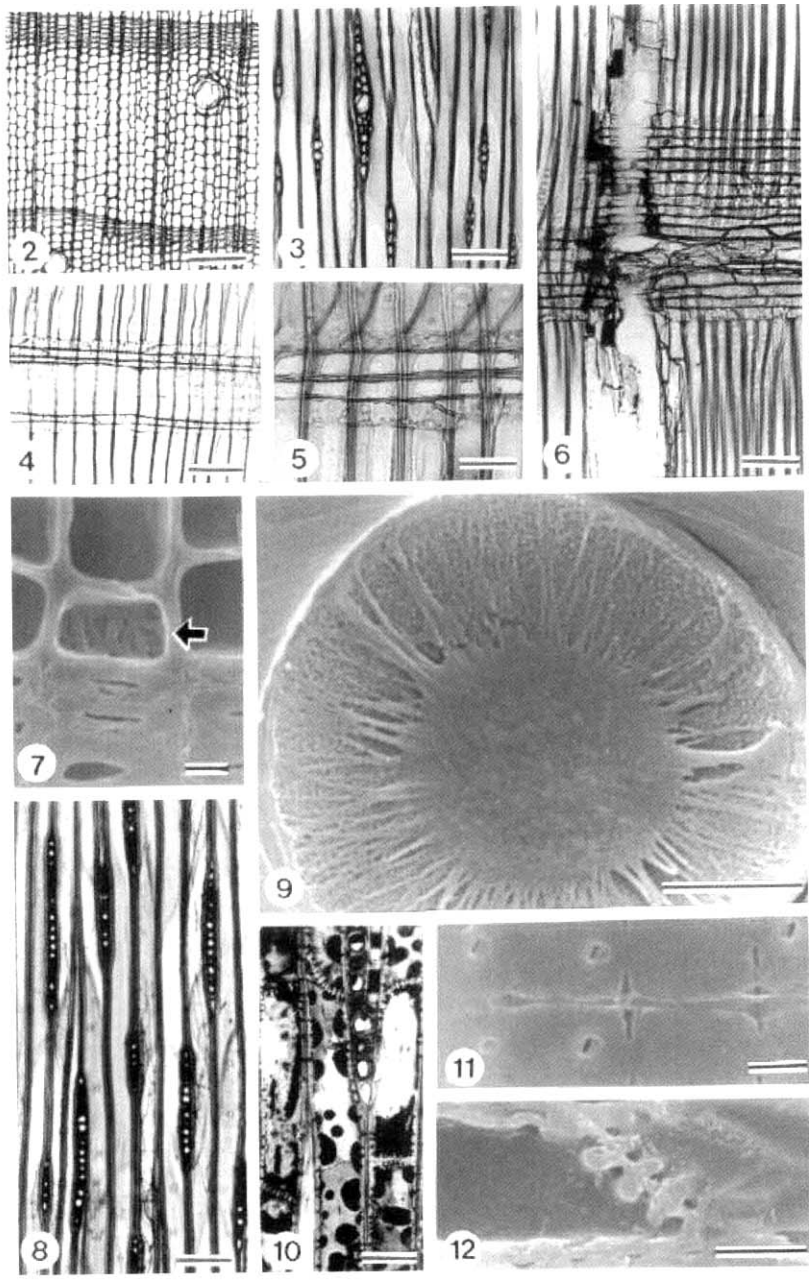

Fig. 2-6. Hard pines. - 2 & 3: Normal longitudinal and horizontal resin canals. - 4 & 5: Dentate ray tracheids, pinoid and fenestriform cross-field pits. - 6: Thin epithelial cells surrounding longitudinal and horizontal resin canals. - Fig. 7-12. Hemlock. - 7: Axial parenchyma cell (arrow). - 8: Uniseriate rays. - 9: Torus extension. - 10 & 12: Nodular end walls in axial and ray parenchyma cells. - 11: Taxodioid cross-field pits. -- Scale bar of Fig. 2 = 200 μm, of Fig. 3, 4, 6 & 8 = 100 μm, of Fig. 5 & 10 = 50 μm, of Fig. 7, 11, & 12 = 10 μm, of Fig. 9 = 5 μm.

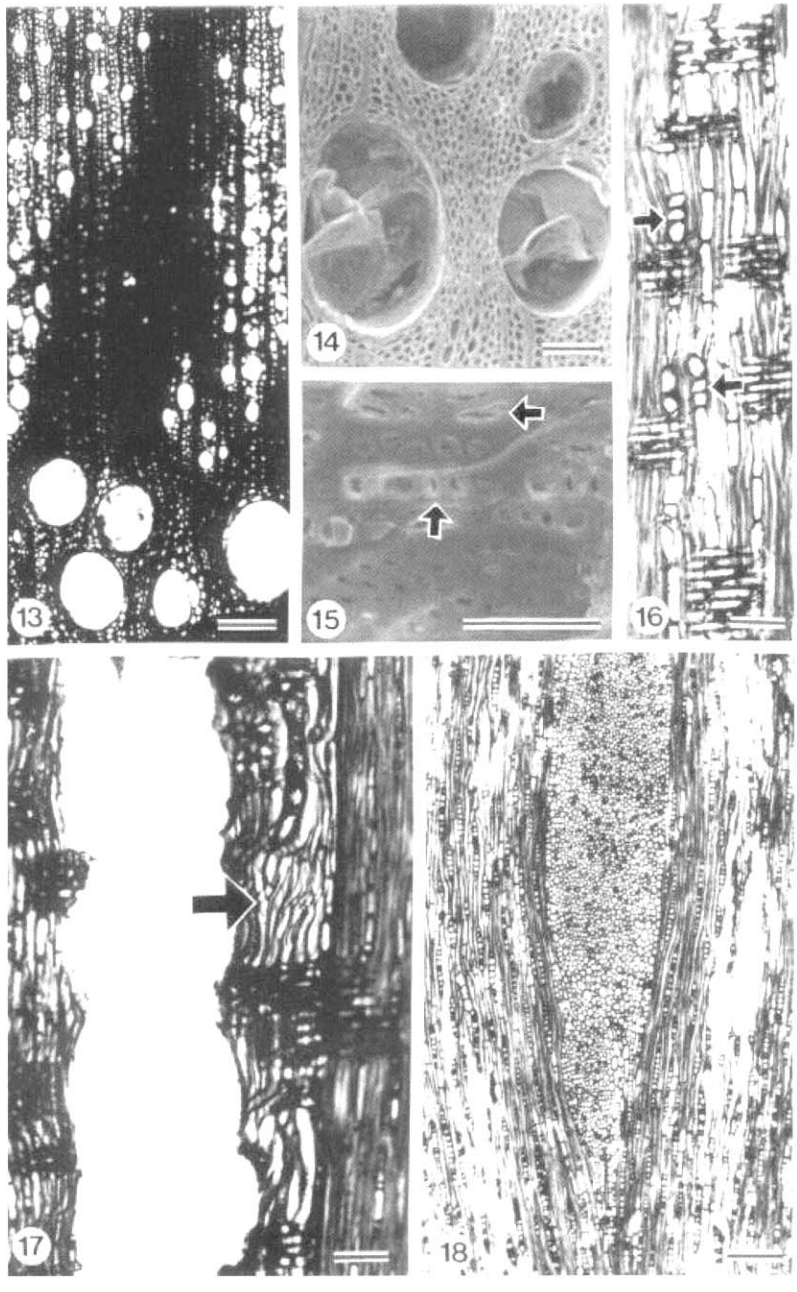

Fig. 13-18. White oak (*Prinus* Section of subgenus *Lepidobalanus*). - 13: Ring-porous wood and latewood vessels in diagonal to dendritic pattern. - 14: Tyloses in vessels. - 15: Vessel-ray pits with much reduced borders to apparently simple, horizontal to vertical. - 16: Prismatic crystals in parenchyma strands (arrow). - 17: Vasicentric tracheids adjacent earlywood vessel (arrow). - 18: Rays of two distinct sizes. - Scale bar of Fig. 13 & 18 = 200 μm, of Fig. 14, 16 & 17 = 100 μm, of Fig. 15 = 50 μm, of Fig. 7, 11, & 12 = 10 μm, of Fig. 9 = 5 μm.

species of structural members in ancient buildings (Eom *et al.* 2003; Kim *et al.* 2004; Park and Kim 2004).

3.2. Hemlock (the genus *Tsuga*) (Fig. 7~12)

Intertracheid bordered pits are mostly in one row and crassulae are commonly found in the radial walls of tracheids. Trabelcula or trabeculae traversing one or several lumen of tracheids are occasionally observed. Scalloped torus extensions are regularly found in the membranes of bordered pit pairs, and warts are present but helical thickenings are not present in the innermost layer of tracheid wall. Longitudinal parenchyma cells occur sparsely at growth ring boundary and have nodular end walls. Uniseriate rays consisting of ray tracheids and ray parenchyma cells are mostly found but low rays consisting entirely of ray tracheids are also occasionally observed. Ray tracheids have no dentations. Horizontal walls are well pitted and nodular end walls with indentures are also observed in the ray parenchyma cells. Normal transverse and longitudinal resin canals are absent. Cross field pits are cupressoid or taxodioid with 2 to 3 pits per field.

Among softwoods without normal resin canals, ray tracheids, sparse longitudinal parenchyma cells only at growth ring boundary, longitudinal and ray parenchyma cells with nodular end walls, and warts and torus extensions in tracheids are frequently found only in the genus *Tsuga* (Panshin and de Zeeuw 1980; Park *et al.* 1981; Saiki 1982; Wheeler *et al.* 1986; Lee 1994).

3.3. White Oak (Prinus section of the subgenus Lepidobalanus under the genus Quercus) (Fig. 13~18)

Wood is ring-porous with distinct growth ring boundaries. Earlywood pores are very large, circular to oval, exclusively solitary, and usually in 1 to 2 radial rows. Latewood pores are very small, thin-walled, angular, solitary or occasionally in multiples of 2 to 3, and form diagonal to radial pattern or seemingly dendritic pattern together with vasicentric tracheids and/or axial parenchyma. Vessels have simple perforation plates and intervessel pits are alternate. Vessel-ray pits with much reduced borders to apparently simple are round or angular to horizontal to vertical in shape and size. Tyloses are present but helical thickenings are absent in vessels. Apotracheal axial parenchymas are diffuse, diffuse-in-aggregate, and banded. And paratracheal axial parenchymas are scanty. Number of cells per axial parenchyma strand is 4 to 8. Rays are mostly homocellular composed only of procumbent cells but some heterocellular rays composed of procumbent cells with 1 row of upright or square marginal cells are also present. Rays of two distinct sizes occur. Narrow rays are uniseriate or occasionally biseriate and broader rays are commonly over 10-seriate. Vasicentric tracheids are found and thick-walled fiber tracheids with distinctly bordered pits compose the ground tissue. Prismatic crystals are occasionally present in nonchambered axial parenchyma cells.

In white oaks or subgenus *Lepidobalanus*, thin-walled, angular latewood pores are characteristic of section *Prinus* but thick-walled, rounded latewood pores are the features of section *Cerris* (Park *et al.* 1981; Hayashi 1991; Itoh 1995). The white oaks belonging to the *Prinus* section, however, are generally considered inseparable with certainty in the anatomical characters (Lee and Eom 1987; Hayashi 1991; Itoh 1995; Lee 1997).

Differently from this result, the white oaks belonging to the *Cerris* section were identified in some wooden structural members which excavated from the house site of Gaya Period (Park *et al.* 2004).

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