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Performance Assessment of Existing Korean School Building (II) – Study on the Species Identification and Residual Strength Properties of the Rafter Members –

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In this study, a test was carried out on the rafters of a classroom in the Iri Agriculture and Forestry High School which was constructed in 1959 as the predecessor of Iksan National College. The rafter members were divided into two species groups according to their visual characteristics. Species identification and tests for residual performance of the rafters were carried out for the 50–year–old school building. The oven–dried specific gravities of pine and fir were 0.47 and 0.44, respectively. The moisture contents of pine and fir were 22.1% and 15.6%, respectively. In comparison to the data provided by the existing domestic report, the members showed significant strength properties in consideration of the building's old age of 50 years. It is concluded that the members can be used for more value added purposes rather than only for conventional uses such as landfill, wood panel productions and fuel wood. In cases where a particularly high safety standard is not required, many other uses for the rafter members could be possible such as reuse for structural members, material for antique furniture, outdoor landscape facilities, sidings for wooden frame structures, palettes, etc. Group 1 was classified as *Pinus densiflora*, while group 2 was classified as *Abies nephrolepis* by using microscopic picture inspection and a comparison of mechanical and physical properties.

Keywords: species identification, value added purpose, reuse, residual strength

INTRODUCTION

A masonry building which had been used as a classroom for 50 years was investigated in this study. While the structural and environmental aspects of the building were poor, it has been rebuilt with modern features.

In a previous study (Kim *et al*, 2009), the physical and mechanical properties of the roof rafters were evaluated. From a visual observation, the rafter members were initially identified as consisting of two major species. According to their visual characteristics, and to their physical and mechanical properties, *Pinus* spp. was estimated to be the main species for the rafter members. The identification of the two species of the used rafter members was conducted by examining the micro structure of the specimens, thus the residual strength properties were evaluated in reference to existing results of physical and mechanical properties of domestic species.

It is necessary to provide a precise evaluation of the residual capacity and a precise estimation of the residual service life in order to accelerate the recycling and reuse of wood process industry residues. In particular, in Korea 90% of wood demands have been imported from foreign countries (FRI, 2007). The importance of recycling or reusing wood residues must therefore be increased. Subsequent to this study, a further study will be carried out on the expected residual service life for sound material of the two species.

Recently, the supply of wood structures has been dramatically increasing in Korea. A significant amount of residue and wood product waste has been landfilled or discarded and only reused in wood based panel production; wood waste and residue is currently only being used for low added value products. The purpose of this study is to evaluate the exact residual strength and estimate the residual service life for the reuse and recycling of wood waste and residue. A prediction equation of the residual performance for a major domestic species will be developed by conducting an accelerated weathering test in future studies.

MATERIALS AND METHODS

In this study, a test was carried out on the rafters of a classroom at the Iri Agriculture and Forestry High School, which was constructed 1959 as the predecessor of Iksan National College. The members were divided into two groups according to their visual characteristics. There were a total of 196 members consisting of 99 members of group 1 and 97 members of group 2. The ranges of thickness, width and length of group 1 members were 89–140 mm, 88–124 mm and 165–376 cm, respectively. The ranges of thickness, width and length of group 2 were 104–133 mm, 114–144 mm and 101–367 cm, respectively. The physical and mechanical properties of these rafters were obtained from a previous paper (Kim *et al.*, 2009).

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RESULTS AND DISCUSSION

The rafters were classified into two different species as judged from an inspection of their visual characteristics. Precise species identification was assisted by the department of Forest Products, Korea Forestry Research Institute. Group 1 was identified as hard pine (*Pinus* spp.) and group 2 was identified as fir (*Abies* spp.). The evidence for the identification for the two species is as follows;

Microscopic feature of group 1 members

A microscopic picture of group 1 is shown in Fig. 1. The special features of group 1 are as follows: This species was softwood which consists of tracheids, a longitudinal–transverse resin canal, an epithelial cell, a ray parenchyma cell and a ray tracheid. Tracheids were distributed regularly with the longitudinal resin canal and the epithelial cells surrounded the resin canal were also seen in cross section (Fig. 1C). Ray tissues consist of ray tracheids and ray parenchyma cells (Fig. 1R). Ray tracheids were found in both the upside and downside of the ray parenchyma cells, and dentate thickening was found in the inner cell wall. The cross–field pitting was shaped window–like and there was single pitting on each cross–field. The ray cells in the tangential section (Fig. 1T) were uniseriate, 1–15 cell high, along with transverse resin canals. By integrating these results, this species was therefore considered to be hard pine (*Pinus* spp.). There are two species of hard pine in Korea – *Pinus densiflora* and *Pinus thunbergii*. *Pinus densiflora* is more widespread than *Pinus thunbergii*, while *Pinus thunbergii* is mainly found near coastal areas. In Korea, *Pinus densiflora* has been typically used for structural members. Thus, it is concluded that group 1 is identified as *Pinus densiflora*.

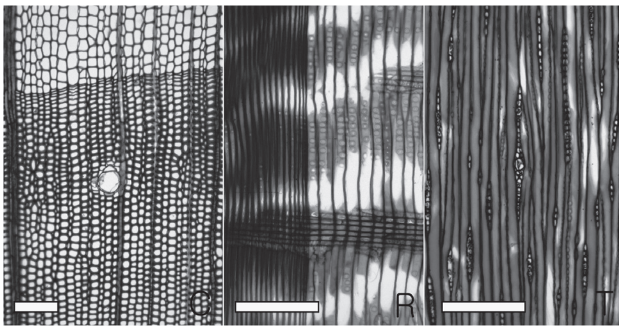

Fig. 1. Microscopic picture for group 1. Bars, 0.1 mm (C: cross section, R: radial section, T: tangential section).

Microscopic feature of group 2 members

A microscopic picture of group 2 is shown in Fig 2. The special features of group 2 are as follows: This species consists of only two types of elements – tracheids and ray parenchyma. Progression between earlywood and latewood is gentle and the width of late wood is narrow in cross section (Fig. 2C). Traumatic resin canals are often found in this species. Ray tissues were only comprised of ray parenchyma cells in a radial section (Fig. 2R). Irregular shaped parenchyma cells were found in the upside and downside of ray cells that were ray parenchyma cells. The ray parenchyma cells are slightly thickened and a nodular end wall was found. The type of cross–field pitting was taxodioid pitting, which was found to be 1 to 4 in each cross field, while crystals were rarely found. Most ray tissues in a tangential section (Fig. 2T) are uniseriate but biserial ray cells are also found. Some of the low ray cells were 1 to 2 cells high, and an over 30–cell–high ray was found. The ray cells were high in general. By integrating these results, this species was consequently identified as fir (*Abies* spp.). Because fir (*Abies* spp.) includes *Abies holophylla*, *Abies nephrolepis* and *Abies koreana*, it is difficult to identify among these species. These species have been typically grown in high mountainous areas. While most trees are known to have a small diameter, in Korea *Abies holophylla* is a large diameter tree. Thus, group 2 was considered to be *Abies holophylla*.

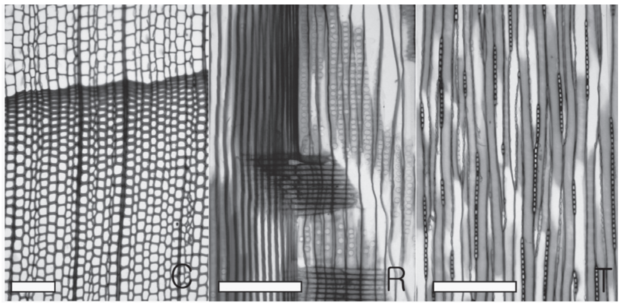

Fig. 2. Microscopic picture for group 2. Bars, 0.1 mm (C: cross section, R: radial section, T: tangential section).

Physical properties of rafter members

The oven–dried specific gravities of pine and fir were 0.47 and 0.44, respectively. The moisture contents of pine and fir were 22.1% and 15.6%, respectively. A previous study reported that the oven–dried specific gravity of pine is 0.47 and that of fir is 0.37 (LEE, 1997).

Table 1. Physical properties of rafter members

	Oven–dried specific gravity (g/cm^3)	moisture content
group 1	0.47 (0.04)*	22.1% (3.1)
group 2	0.44 (0.07)	15.6% (0.9)

According to Lee's (1997) report, the major uses of Korean pine wood are construction, civil engineering and tool production in that order of priority. Also, Lee reported that Korean fir is most commonly used for pulp as well as for posts, beams, boards, lumber, structural members, boxes, ship building, sculptures, and toys and furniture.

Mechanical properties of rafter members

From the previous study (Kim *et al.*, 2009), the compressive strength of pine was 360 kg/cm^2, with a tensile strength of 246 kg/cm^2, a bending strength of 740 kg/cm^2 and shear strength of 79 kg/cm^2. Because the unit of Lee's (1997) report for mechanical properties was kg/cm^2, the unit of previous study (Kim *et al*., 2009) result was changed to compare. As shown in Figure 3, results showed 83.7% of compressive strength, 27.8% of tensile strength, 99.1% of bending strength and 81.4% of shear strength in comparison to the results from the previous report (Lee, 1997). As mentioned in the previous paper (Kim *et al*., 2009), the results of the tensile strength test should be excluded because failure which occurred near the grip hindered the normal strength data. However, the members showed considerable residual strength properties of compression, bending and shear strength in consideration of the building's old age of 50 years.

Adequate uses for the members when recycled or reused might be able to be proved after an evaluation and prediction of the precise residual strength properties by an accelerated weathering test of a sound pine member. However, according to the results obtained so far, it is concluded that the members can be used for more value added purposes rather than merely for conventional uses such as landfill, wood panel productions and fuel wood. If a particularly high safety standard is not required, many uses are possible such as reuse for structural members, material for antique furniture, outdoor landscape facilities, sidings for wooden frame structures, palettes, etc.

From the previous study (Kim *et al*., 2009), the compressive strength of fir was 402 kg/cm^2, the tensile strength was 335 kg/cm^2, the bending strength was 855 kg/cm^2 and the shear strength was 76 kg/cm^2. *Abies holophylla* Max. and *Abies koreana* Wilson of abies spp. have been widely used as construction materials in Korea. In comparison to previous research (Lee, 1997) results for *Abies holophylla* showed 108.3% of compressive strength, 34.8% of tensile strength, 164.4% of bending strength and 67.3% of shear strength. *Abies koreana* showed 114.8% of compressive strength, 30.0% of tensile strength, 122.1% of bending strength and 108.3% of shear strength in comparison to previous research (Lee, 1997). Data for fir was also not considered because failure occurred close to the grip. The results from the compressive, bending and shear strength tests are shown in Figure 4.

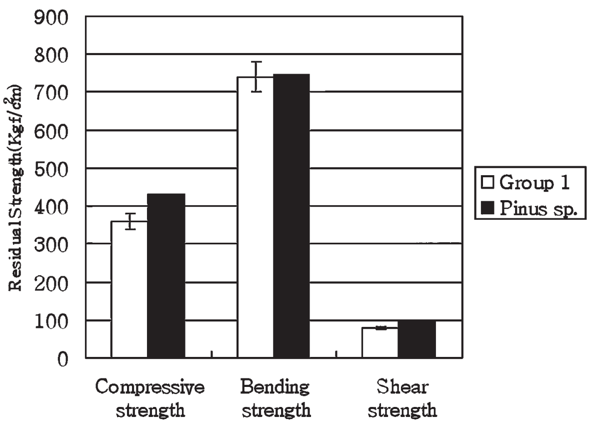

Fig. 3. Comparison of test results of group 1 with domestic report results.

While it cannot be endorsed that the tested data shows higher results than the previously reported values (Lee, 1997), when the members are evaluated by inspecting their visual appearance, the specimens of group 2 remained in better condition than those of group 1. When the specimens were collected at the remodeling site, the dried condition of group 2 was superior to that of group 1. Also, the specimens of group 2 rarely showed natural defects or artificial defects as a consequence of construction or preservation processes, and these specimens appeared to be in a well preserved condition. It was assumed that these factors affected the mechanical properties of the members. An additional mechanical property test was carried out to prove this hypothesis, but similar results were obtained to those of the first test. These comparisons are not convincing, because there are not sufficient existing reports to make accurate comparisons. Lee's (1997) report is the only comparable resource. Therefore, further research is needed to obtain more accurate results.

In this study, group 2 was identified as *Abies holophylla* rather than *Abies koreana*, because *Abies holophylla* is most suitable for obtaining large diameter trees in the current Korean situation. However, according to the comparison the specific gravity and the mechanical properties of group 2, shown in Table 2, may be considered to be *Abies koreana* rather than *Abies holophylla*. In addition, 50 years ago, when the building was constructed, it was possible to obtain large diameter trees of *Abies koreana*. Thus, group 2 used for this building is assumed to be *Abies koreana* rather than *Abies holophylla*.

Table 2. Comparison between test results and results from previous report (Lee 1997)

		Compressive strength (kgf/cm^2)	Bending strength (kgf/cm^2)	Tensile strength (kgf/cm^2)	Shear strength (kgf/cm^2)	S. G. (g/cm^3)
Test results	Group 1	360 (64)	740 (123)	246 (96)	79 (14)	0.47 (0.04)
	Group 2	402 (67)	855 (127)	335 (86)	76 (5)	0.44 (0.07)
Korea previous report (Lee, 1997)	*Pinus densiflora*	430	747	885	97	0.47
	Abies holophylla	371	520	963	113	0.37
	Abies koreana Wilson	350	700	1200	70	0.44

( ): Standard deviation

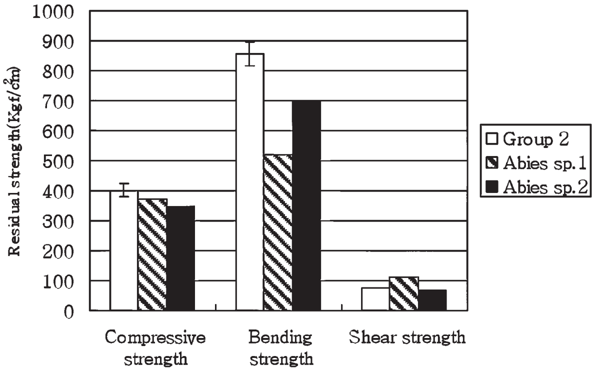

Fig. 4. Comparison of test results of group 2 with domestic report results.

Further research of sound wood for group 1 and group 2 (group 1 of *Pinus densiflora*, and group 2 of *Abies nephrolepis*) will be conducted to evaluate residual strength properties and to develop a prediction equation from an accelerated weathering test.

CONCLUSION

Species identification and tests were carried out of the residual performance of rafter members in a 50–year–old school building. Rafter members were categorized into two types of species according to their visual characteristics. Identification through microscopic picture inspection showed that group 1 was hard pine and group 2 was fir. The oven–dried specific gravities of pine and fir were 0.47, and 0.44, respectively. The moisture contents of pine and fir were 22.1% and 15.6%, respectively.

In comparison to an existing domestic report, the members showed a performance of 83.7% of compressive strength, 99.1% of bending strength and 81.4% of shear strength for pine. The members showed significant residual strength properties in consideration of the building's old age of 50 years. It is concluded that the members can be used for more value added purposes rather than merely for conventional uses such as landfill, wood panel productions and fuel wood. If a particularly high safety standard is not required, many uses can be possible such as reuse for structural members, material for antique furniture, outdoor landscape facilities, sidings for wooden frame structures, palettes, etc.

Group 1 was categorized as *Pinus densiflora*, and group 2 was categorized as *Abies nephrolepis* by microscopic picture inspection, and by a comparison of mechanical and physical properties.

Further research will be conducted to evaluate residual strength properties and to develop a prediction equation from an accelerated weathering test for domestic major construction species.

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