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Status of stadardization of fire-resistant structures according to the Korean Building Act for glued laminated timber using Korean larch

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ABSTRACT: In wooden structures, it is widely known that the level of fire resistance is determined by a charring rate or charring depth, and their results are adopted for the design of fire resistance. In this study, specimens of Korea larch column with a lamination wooden type are prepared and the properties of fire resistance such as the charring depth, load ratio and the specific charring rate suggested by EN Code are investigated. In Korea, in order to apply to fire-resistant structures of buildings, fire resistance performance is certificated for each structure and can be used. The Koera standardization status for applying glued laminated timber as a fire-resistant structure according to the Korean Building Act is introduced and the current progress is introduced.

KEYWORDS: Korea larch, Korea Building Act, Fire resistance performance, Satandardization, Glued laminated timber

1 – INTRODUCTION

To prevent building collapse and loss of life during fires, the primary structural members of buildings must be designed to ensure fire-resistance performance. Accordingly, the Korean Building Act mandates that structural components of buildings exceeding a certain scale must be constructed as fire-resistant structures. A fire-resistant structure refers to a major structural component or system with fire-resistance capability, intended to provide sufficient evacuation time for occupants and to prevent structural collapse for a specified duration during a fire. In Korea, if a structure is not included among the fire-resistant assemblies specified in the Building Act, it must obtain separate fire-resistance certification through an official approval process. [1]

Industrial heavy timber structures must also be certified as fire-resistant to be used in buildings within the Korean construction market. For this reason, in 2005, structural glued laminated timber (glulam) was recognized under the Building Act as a fire-resistant structure, and it has since been applied to buildings as a certified fire-resistance assembly. Domestically, with the global push toward alternative energy sources and the Korean government's ongoing low-carbon green growth policy, there is increasing interest in the promotion of eco-friendly timber architecture, including traditional *Hanok* buildings. However, the institutional foundation for timber construction in Korea remains weak, and fire safety is frequently cited as a key barrier to the wider adoption of timber structures. Unlike traditional statutory fire-resistant assemblies, which have been verified through long-term testing and standardization, the fire-resistance certification system in Korea places emphasis on quality control during the manufacturing process. This system also enables applicants to continuously develop and commercialize new technologies or structural systems. As a result, fire-resistance certification in Korea is granted to specific technologies developed by individual manufacturers, which naturally highlights the uniqueness and proprietary nature of each company's fire-resistance technology. Excluding structures for which standardization is difficult, many timber structures—such as structural glued laminated timber—follow widely known and standardized production methods both domestically and internationally. In Korea, the Korean Industrial Standard KS F 3021 for structural glued laminated timber has already been established. Therefore, the development of standardized fire-resistance specifications for such timber structures aligns with the national policy to diversify the certification

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system and is expected to support the further growth of the timber construction market. [2]

Among industrial wood products, structural glued laminated timber is the most widespread and traditional. Korea's entry into fire-resistance certification for timber structures began in 2005 with a single certified manufacturer. Since then, the number of certified manufacturers has increased, technological advancements have been made, and production capabilities in the industry have improved. This indicates that the timber construction industry in Korea has progressed beyond the initial and growth phases and is now entering a phase of technological maturity. To support this next phase, the standardization of fire-resistant timber structures is now a critical and necessary task.

2 – BACKGROUND

Structural glued laminated timber (glulam) refers to a product among glued laminated timbers that is manufactured with the purpose of achieving a certain structural strength. It is made by laminating and bonding graded laminae or block layers in parallel to the fiber direction, and is produced to withstand specific stresses. Structural glulam is used as columns and beams, which are the main structural members of a building and must support large loads. Therefore, structural performance is critically important, and it is not possible to verify the performance of products that are not manufactured according to defined standards. For this reason, standardized structural glulam must be used. The Korean Industrial Standard "KS F 3021: Structural Glued Laminated Timber" was established to ensure safety, and it specifies manufacturing methods for structural glulam, including the arrangement and combination of laminae by grade, the allowable stress of the finished product, and the quality and performance testing methods of the product. The types of structural glulam are classified, according to the configuration and arrangement of the laminae, into same-grade glulam and symmetric or asymmetric different-grade glulam. [2]

According to the "Standards for Structural Design of Buildings" announced by the Ministry of Land, Infrastructure and Transport, glulam not specified in KS F 3021 may only be used as structural material when it is judged to be structurally acceptable based on proper testing and evaluation methods defined by KS or other standards. When timber structural members are exposed to fire, a char layer is formed through a pyrolysis process. During the required fire-resistance time, this char layer functions as a protective covering that preserves the residual cross-section of the member. The residual cross-section, which bears the structural load, is calculated through structural design. The final cross-section of the member is determined by considering the char depth according to the required fire-resistance time. In other words, fire-resistance design of timber structures involves calculating the char layer, and the char depth is calculated based on the charring rate and the duration of exposure to fire. In Korea, a fire-resistance certification system is in place to ensure the fire-resistance performance of structural members. Under this system, the char depth of timber members is applied based on verified performance through fire testing, and those members are certified as fire-resistant structures. However, the domestic system does not provide a separate regulation for calculating charring rate or char depth. In contrast, in other countries, the char depth of wood is calculated using charring rates and applied in fire-resistance design.

Buchanan and Abu suggested that when wood is exposed to fire and the temperature rises above a certain threshold, combustion occurs. When the width(b) × depth(d) of a timber cross-section is exposed to fire and reduces to the residual section ($b_f \times d_f$), the char depth of the exposed surface is presented as in Equation (1) below.[3]

$$c = \beta t \quad (1)$$

c = charring depth(㎜)

β = charring rate(㎜/min)

t = time(min)

As shown in Figure 2, after the formation of the char layer, the residual cross-section can be calculated using Equations (2) and (3) as follows.

$$b_f = b - 2c \quad (2)$$

$$d_f = b - 2c \text{ (4-side fire exposure)} \quad (3)$$

d_f = width of the residual cross-section

d_f = depth of the residual cross-section

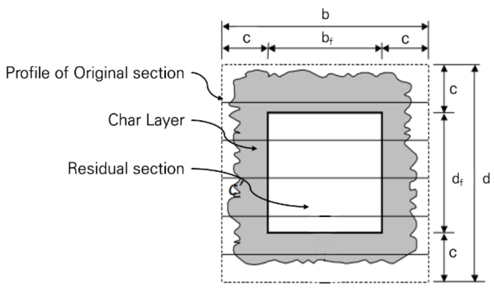

Figure 1. Fire rsistance design concepts for timber members

The char depth model for timber presented in the European timber design code (*Eurocode*) is the same as the above equation, and the charring rate β is obtained from the relationship between char depth and time. Since charring at the corners of a timber section is about 10% greater than on flat surfaces, the Eurocode timber design code also presents both the standard charring rate (β_0) and a notional charring rate (βn) that accounts for corner charring. Table 1 summarizes the design charring rates for timber presented in the Eurocode.[4]

Table 1. Design charring rates of timber(EN Code)

Material	Minimum density (kg/m^3)	Charring Rate.	
		β_0 (mm/min)	βn (mm/min)
Glue-laminated timber	290	0.65	0.70
	450	0.50	0.55

3 – PROJECT DESCRIPTION

In this study, fire-resistance tests were conducted on Korean larch, which is the primary species used in the production of structural glued laminated timber in Korea, to evaluate and analyze its charring characteristics. The objective is to propose a standard char depth suitable for Korean building act. By establishing this standard char depth, the study aims to provide a basis by which fire-resistance certification can be granted without separate fire tests, instead relying solely on the quality control capability of the manufacturing plant.

4 – FIRE TEST

Fire-resistance tests were conducted on Korean larch in accordance with KS F 2257-1.[5] These tests were performed as part of efforts to establish standardization criteria for structural glued laminated timber under the Korean Building Code. Detailed specifications of the test specimens and individual test results are not disclosed, as the analysis includes proprietary data from manufacturers that have previously received fire-resistance certification for their structural glulam products. Instead, a summarized overview of the overall test results is presented.

The results of the fire-resistance tests are shown in Table 2. Fire-resistance tests were conducted for durations of 1 hour, 2 hours, and 3 hours on structural glued laminated timber beams and columns made from Korean larch. Since the Korean Building Act requires a maximum fire-resistance rating of up to 3 hours, measurements of char depth and charring rate were limited to this duration. Additionally, the test results were compared with the corresponding char depths and charring rates specified in the European design code for the respective fire-resistance times.

Table 2 Fire Test Results of Structural Glued Laminated Timber (Beams and Columns) Made from Korean Larch

Test time(hour)		Beam	Column	EN Code	
				(β_0)	(βn)
Charring Depth (mm)	1	38.2	39.9	39.0	42.0
	2	73.4	74.8	78.0	84.0
	3	99.8	102.6	117.0	126.0
	1	0.64	0.67	0.65	0.70

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Charring Rate (mm/min)	2	0.61	0.62		
	3	0.55	0.57		

Figure 2. Before and after fire resistance test

Both loaded and unloaded fire-resistance tests were conducted, and the results for each condition were compared and analyzed. Figure 3, Figure 4 presents a comparison of the test results between the loaded and unloaded fire-resistance tests for beams and columns.

Additionally, Figure 5, Figure 6 shows a comparison of the measured char depths with those specified in the EN Code. The results indicate that, for both beams and columns, the structural glued laminated timber made from Korean larch exhibited lower char depths compared to the reference values in the EN Code.

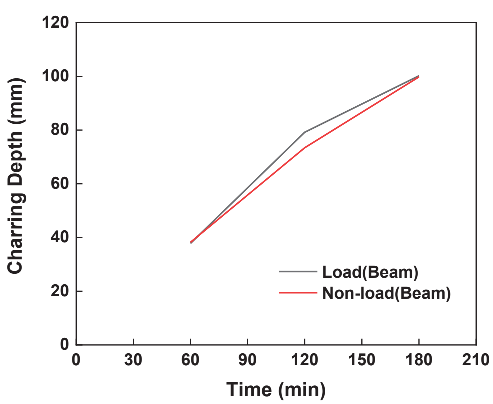

Figure 3. Time-Charring depth of Beam

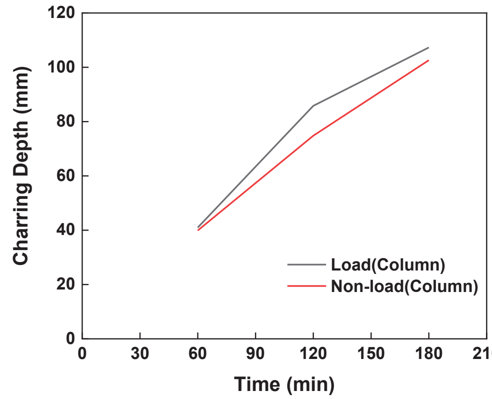

Figure 4. Time-Charring depth of Column

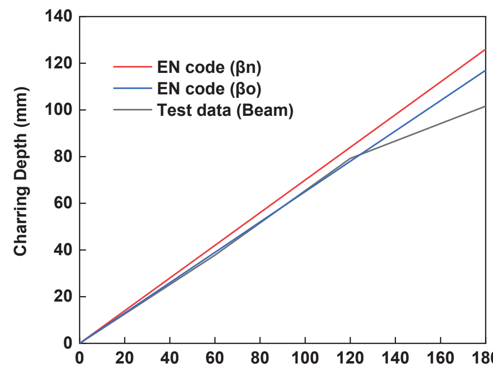

Figure 5. Comparison of Charring depth with EN Code(Bean)

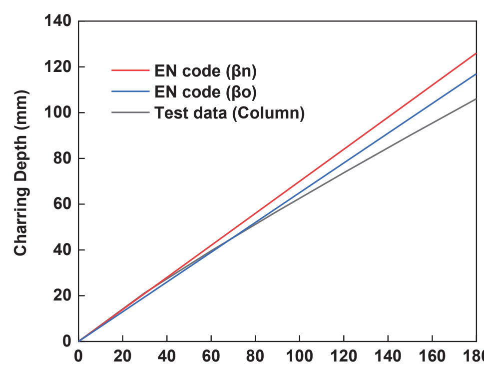

Figure 6. Comparison of Charring depth with EN Code(Column)

5 – RESULTS

According to the Korean Building Code, when certifying structural glued laminated timber as a fire-resistant structure based on measured char depth, a safety factor of up to 10% may be applied to account for construction tolerances, allowing for an increased char depth to be recognized.

However, when fire-resistance certification is granted based on a standard char depth—rather than on the results of individual fire-resistance tests—a more conservative safety factor exceeding 10% may be applied, in accordance with relevant regulations. Based on the Building Act and the results of the certification review committee, the standard char depths for structural glued laminated timber(GLT) beams and columns have been established.

The standard charring depths for beams and columns made from Korean larch are presented in the table below

Table 3. Standard Charring depth for GLT in Korea

Fire rating	Standard Charring depth(mm)	
	GLT(Beam)	GLT(Column)
1 hour	40.0	41.0
2 hour	82.0	86.0
3 hour	115.0	118.0

Figures 7 and 8 show a comparison between the standard char depths in Korea and those specified in the EN Code**.**

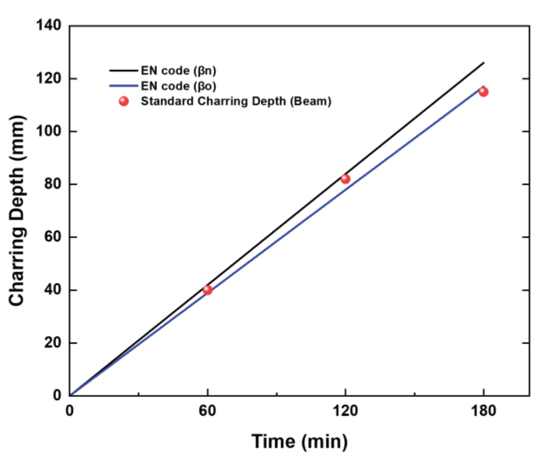

Figure 7. Comparison of Korea Standard Charring depth and the EN Code(Beam)

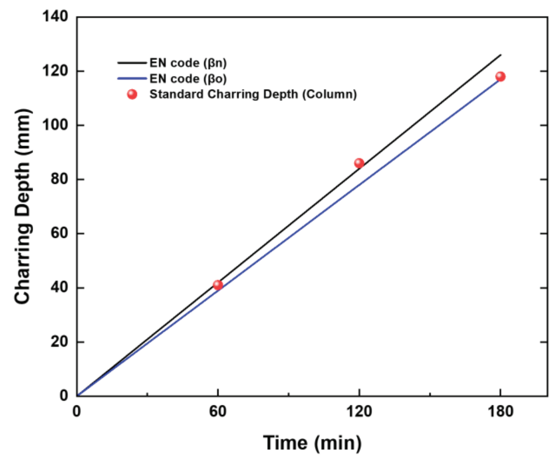

Figure 7. Comparison of Korea Standard Charring depth and the EN Code(Column)

6 – CONCLUSION

Korea's fire-resistance regulations do not specifically address the zero strength layer, which is the region immediately adjacent to the char layer where pyrolysis has occurred and the material no longer retains structural strength. Instead, Korea effectively utilizes a 10% safety factor to substitute for this layer, a practice that differs from those in other countries. In this context, the 10% safety factor can be interpreted as functionally equivalent to the zero strength layer.

Considering that the vast majority of structural glued laminated timber used in Korea is made from Korean larch, unlike other countries where a variety of wood species are used, the standard char depth has been proposed specifically for Korean larch. While structural fire design for timber typically involves char-depth-based calculations worldwide, Korea follows a unique approach in which fire-resistance performance is confirmed without requiring a separate structural fire design, and certification is granted accordingly. Given this distinct regulatory framework, the proposal and application of standard char depths can be seen as an appropriate form of fire-resistance design tailored to Korea's specific conditions.

7 – Acknowledgement

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