TOWARD THE FUTURE NECESSITY OF TIMBER CONSTRUCTION AND ITS LONGEVITY IN JAPANESE WOODEN ARCHITECTURE

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(Received: May 05, 2025; Revised: June 12, 2025; Accepted: June 18, 2025)

DOI: 10.31130/ud-jst.2025.23(10C).675E

Abstract - This research examines a rational maintenance management for wood by verifying the effectiveness of surface protection coatings, aiming for the long-term durability and versatility use of wooden materials. In recent years, the use of wooden materials has been legally promoted toward achieving a decarbonized society; however, the wooden materials performance challenge of being vulnerable to global warming are keeping. In this study, the effects of protective coatings, such as penetrating paints and acrylic silicon-based coatings, were compared on wooden materials used in various applications, such as residential and public facilities, and the color changes and durability of the wooden materials were evaluated. Additionally, the selection of coatings according to the place of use and purpose for example, using natural coatings in areas where children may touch was considered, demonstrating the importance of enhancing weather resistance while maintaining the wood's texture.

Key words - Lumber; wooden building materials; surface protection; finishing Aesthetics; cracking

1. Introduction

In recent years, Japan has been actively promoting the realization of a low-carbon society. Among various construction materials, timber play a significant role in this effort due to its ability to store carbon and reduce CO_2 emissions [1] - [3]. A series of legislative measures have been enacted to encourage timber utilization, the Act on Promotion of Use of Wood in Public Buildings (2010), the Act on Promotion of Timber Structures (2014), and the Act on Promotion of Use of Wood in Buildings Contributing to the Realization of a Decarbonized Society (2021). These laws have collectively facilitated the active adoption of timber in architecture [4] - [6]. However, timber and wooden materials has inherent weaknesses, particularly its vulnerability to climatic degradation and aging over time [7]. To mitigate these drawbacks, the application of surface protective coatings has become a common practice. Previous studies have shown that acrylic-silicone-based transparent coatings exhibit excellent durability while preserving the natural appearance of wooden materials through their high level of transparency [8] - [10]. From the perspective of surface protection, this study aims to explore rational maintenance and preservation strategies that enhance the long-term durability and multifunctional application of timber and wooden materials in architecture.

2. Experimental Overview

2.1. Enhancing the Durability of Acrylic-Silicone-Based Transparent Protective Coatings (AS)

Table 1 presents an overview of the study. Since 2018, experiments have been conducted to evaluate the effectiveness of acrylic-silicone-based transparent coatings (AS) in preventing discoloration and degradation caused by ultraviolet radiation. Figure 1 shows a cross-sectional diagram of the test specimens and the setup of the exposure test apparatus. The timber used for the tests was selected based on its common use in architectural applications and its high frequency of actual usage. To simulate real-world environmental conditions, the specimens were exposed at inclination angles of 0°, 45°, and 90°. Each specimen had a three-layer coating, designed to improve durability and reduce the characteristic glossiness of film-forming coatings.

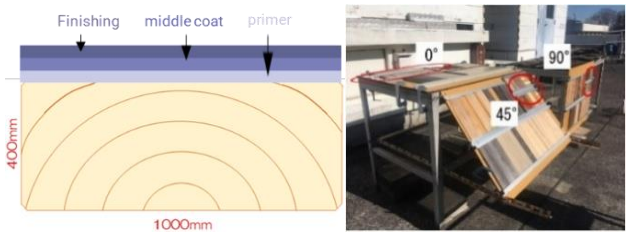


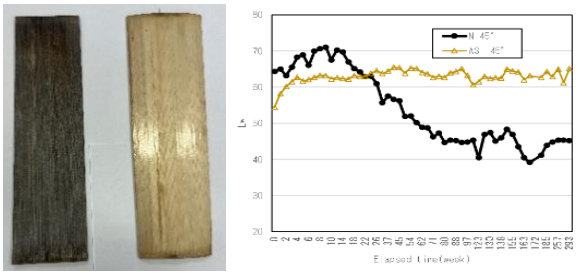
Figure 1. *AS type Surface Coating Diagram and Test specimens exposed outdoors in Tokyo*

Table 1. *Materials Used and Exposure Conditions in Tokyo*

Types of coating	Conditions		Exposure start time	Exposure angle
【Traditional Wooden Panel】 Katsura wood	Uncoated		May 2018	45 degrees
	Acrylic silicone-based transparent protective paint (AS)	UV absorbent 1%		
【Finishing Wooden Panel】 Cedar	Uncoated		May 2018	90 degrees
	Acrylic silicone-based transparent protective paint (AS)	UV absorbent 1%		
【Structural Wooden Panel】 Cedar	Uncoated		May 2018	90 degrees
	Acrylic silicone-based transparent protective paint (AS)	Thermowood treatment		

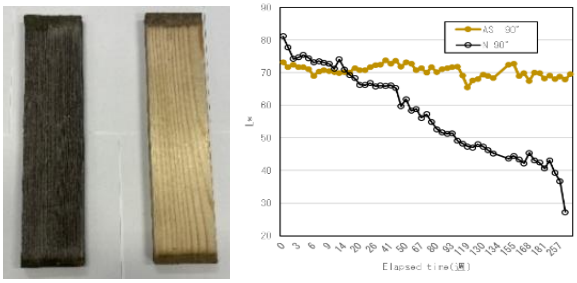
2.2. Results and Discussion

Figure 2 shows the condition of the exposed specimens as of May 2025, along with changes in their L* values. The specimens coated with acrylic-silicone-based transparent protective coating exhibited significantly less discoloration compared to the uncoated specimens. In particular, the uncoated structural panel specimens showed signs that the thermos wood treatment had lost its effectiveness. Across all samples, those with coatings demonstrated better resistance to color change than their uncoated counterparts. These results indicate that the protective coating maintains its effectiveness for over seven years, suggesting that its application at the time of construction can reduce the maintenance cycle and associated burdens.



Unpainted paintedAS *Changes L* values*

a) Traditional panel



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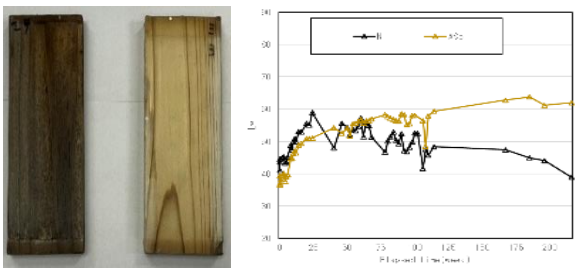
b) Finishing panel



Unpainted paintedAS *Changes L* values*

c) Structural panel

Figure 2. *Various Wooden Panel Outside Exposure Protective Effects (2018~) and Changes in L* values*

3. Investigation of Timber and wooden materials Applications and Building Functions in Recent Architectural Works

3.1. Research Content and Methods

Table 2 outlines the survey factors and their corresponding levels. This study examined award-winning projects selected in the *Architectural Institute of Japan's Selected Architectural Designs* between 2013 and 2024. The buildings were categorized into three residential, seven non-residential, and one classified as "other" (i.e., buildings that cannot be clearly categorized as either residential or non-residential, or serve dual functions), for a total of eleven projects. A survey was conducted to analyze the distribution of building functions and the locations where timber was used in these structures. Among the surveyed projects, three buildings that made extensive use of timber throughout the entire structure were selected and are listed in Table 3. For these three buildings, hearing surveys were conducted. The content of the questionnaire used in these surveys is also presented in Table 4, organized into three categories: (1) Origin and harvesting (2) Processing and manufacturing (3) Use and evaluation. On-site investigations were carried out at each location.

Table 2. *Survey Factors and Levels in Wooden Architecture*

Item	contents
Years	From 2013 to 2024 within 10 years of construction
Target	All 310 buildings awarded in the Japan Architectural Institute's collection using wood building
Uses	Single-family homes, row houses, multi-family housing, offices, hospitals, department stores, hotels, assembly halls, factories, schools, and others
Parts	(Exterior) Exterior walls, Eaves, Columns, Beams, Frameworks, Floors, Fences (Interior) Interior walls, Ceilings, Columns, Beams, Frameworks, Floors

Table 3. *Target Buildings for Investigation*

Building Name	Survey Date	Location	Award Year	Applied parts
Nagano Prefecture K City Hall	December 2024	Nagano Prefecture	2024	(Exterior) Exterior walls, Eaves, Columns, Beams, Frameworks, Floors, Fences (Interior) Interior walls, Ceilings, Columns, Beams, Frameworks, Floors
Chiba Prefecture O Elementary School	November 2024	Chiba Prefecture	2023	
Fukushima Prefecture Minamiaizu K	November 2024,	Fukushima Prefecture	2024	

3.2. Results and Discussion

Figure 3 illustrates changes in the proportion of timber usage across different parts of the selected buildings. Due to timber's vulnerability to weathering, a high percentage of timber was used for interior applications. Overall, timber usage rates were higher in 2013. This may be attributed to the tendency before the legal revisions to use timber extensively throughout entire buildings. After the revision, timber usage likely became more diversified and distributed across different functions and parts of buildings, reflecting an expansion in its application scope. Figure 4 presents the proportion of each building function category among the selected works. In 2013, prior to the legal revision, residential buildings accounted for more than half of the total. By 2024, however, the use of timber had become especially common in schools and residential buildings. This trend is thought to reflect the

suitability of timber for spaces where people gather and live, due to its warm and natural aesthetic qualities. For instance, at O Elementary School in Chiba Prefecture, timber was chosen specifically to allow children to experience the warmth of wood in their daily environment. It is expected that the use of timber will continue to expand into a wider variety of building types and functions in the future.

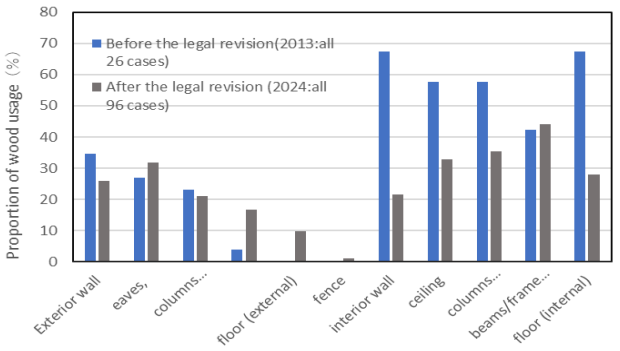


Figure 3. *Change in the Ratio of Wood Usage by Parts of the AIJ Award selected group of buildings*

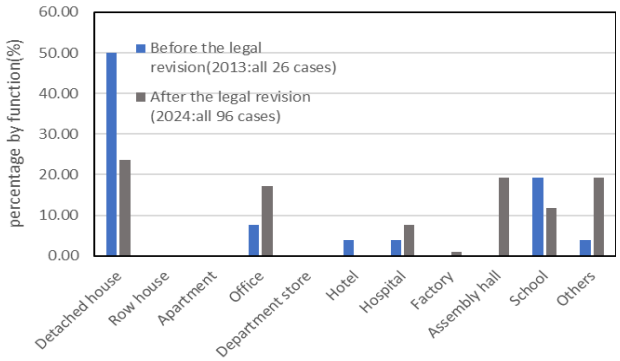


Figure 4. *Proportion of Each Use in the AIJ Award Selected Building in Japan*

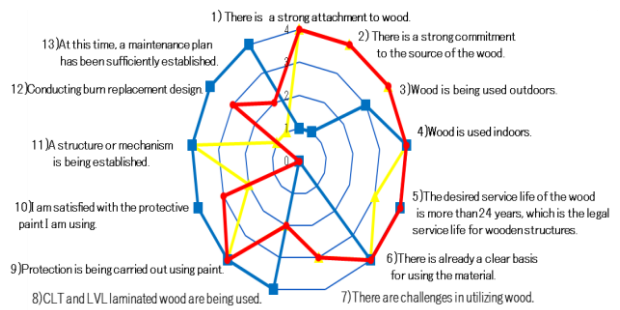


Figure 5. *Survey Results on the Application Process of Wood-based Building Materials*

3.3. Results of the Hearing Survey

Figure 6 illustrates a radar chart based on the results of the hearing survey conducted using the questionnaire shown in Table 4, focusing on the application processes of wooden building materials. In the cases of the K Town Office and Minamiaizu K, locally available timber resources - such as municipal forests and regional lumber - were utilized. All stages of the timber supply process, including tree felling, selection, and milling, were carried out by local forestry and sawmilling professionals. This approach not only promoted the effective use of regional

Table 4. *Listening Contents Based on Field Survey*

Classification	Content of the hearing based on the on-site investigation.
(1) Place of origin Collection	Hearing content based on field investigation
	Does the basic design plan specify the type of wood?
	Is there a specification of the origin of the wood in the basic design drawings, etc.?
	What is the amount of wood used (number of pieces, volume, etc.)?
	Are you using wood outdoors?
	Which part of the wood was used (roof, ceiling, exterior walls, floor, interior walls, etc.)?
(2) Processing and manufacturing	Is the lumber domestically produced or imported?
	What is the desired lifespan in years for the wood used?
	What was the actual lifespan in years (if it was replaced)?
	What is the reason for using wood?
	What are your complaints about using wood?
	What type of wood are you using (laminated wood, finishing material, CLT, flooring, etc.)?
(3) Usage and evaluation	Is the surface finishing and protection of the building timber being carried out?
	Do you know about "transparent elastic coatings" as a long-term wood protection?
	Do you know the technology that prevents discoloration of wooden building materials with transparent resin?
	When using wood as structural material, are fireproof or flame-retardant agents being used?
	What methods are being used for maintenance to prevent the wood from deteriorating?
	What methods are being used for maintenance to prevent the wood from deteriorating?
	Wood will fade in color when exposed to sunlight on buildings. Are there such places?
	Is it possible to investigate the simple measurement of color fading using color values?
	The place where the color has faded has cracks to sunlight exposure.

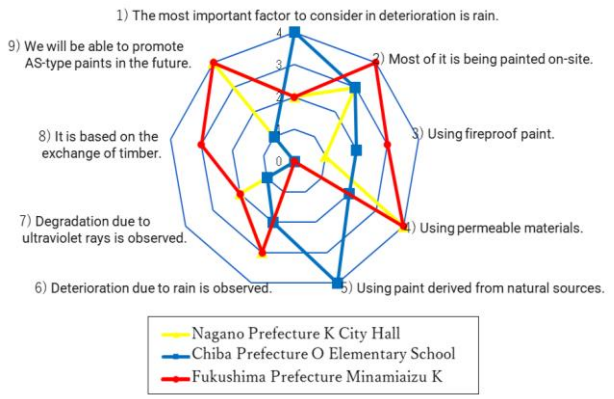


Figure 6. *Survey Results on Wood Surface Protective Coatings*

resources but also enabled the architectural projects to function as part of broader community revitalization efforts. At both the K Town Office and O Elementary School, timber was intentionally applied in areas that are

less directly exposed to rain and ultraviolet radiation, in order to preserve and showcase the natural appearance of the wood. In the interior design of O Elementary School, in addition to ensuring safety for children, various types of wood were used across different spaces as a strategy to enhance children's environmental awareness and appreciation of material diversity within learning environments. Figure 6 shows the results of the hearing survey regarding surface protective coatings for timber. At O Elementary School, due to frequent contact between children and the walls, natural-origin protective coatings were selected instead of synthetic ones, such as acrylic-silicone-based coatings. Conversely, penetrative coatings were used at both K Town Office and Minamiaizu K. The survey revealed that awareness of acrylic-silicone transparent protective coatings was extremely limited. One architect noted, “Penetrative coatings were the only option we knew of.” This finding suggests that information about suitable coatings - tailored to the purpose and placement of timber - is not sufficiently shared or recognized in practice, and that such products may be limited in availability in the current market. This points to a clear need for improved dissemination of knowledge and development of appropriate materials to support more effective timber and wooden materials use in architectural design.

4. Practical Application and Renovation Using AS-Based Transparent Protective Coating

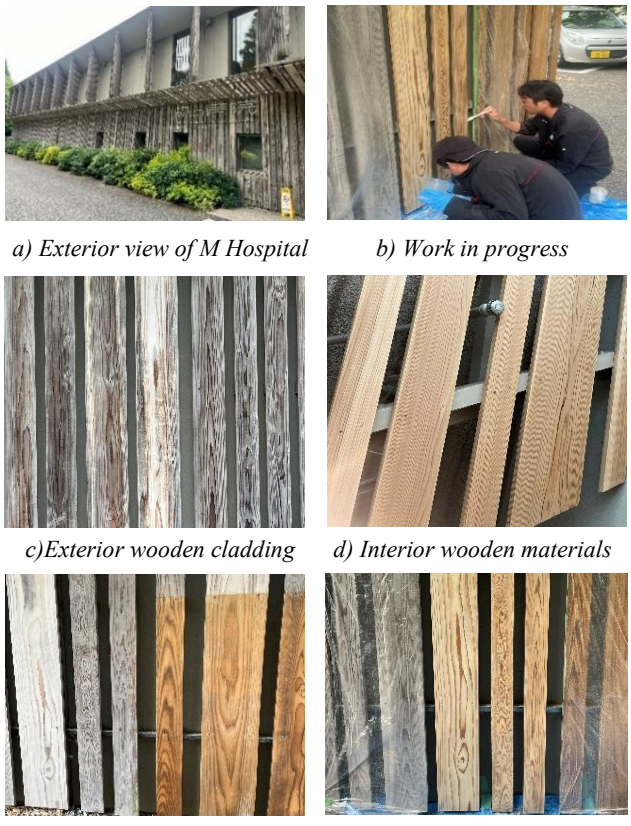
Table 5. *Overview of Facilities for Renovation Treatment*

No	Process
1	Sand the surface to remove the penetrating-type coating (planer over 100 μm)
2	Apply a sealer.
3	Apply a high-elongation acrylic-silicone primer (1st coat).
4	Apply an intermediate coat (2nd coat).
5	Apply a top coat (3rd coat).

Table 6. *Surface Renovation Process Using Acrylic- Silicone Coating Summary*

Item	Details
Hospital name	M Hospital
Year of Opening	July 2017 (8 years old)
Location	Narita City, Chiba Prefecture
Total Floor Area	Approximately 9,986 m^2

Table 5 shows an overview of the facilities where renovation work was conducted on exterior wall wood materials. Table 6 outlines the work procedures. Figure 7 shows the renovation process: (a) the exterior view of the facility, and (b) the scene during the coating work (c) and (d) compare the condition of the wood used for the interior and that used for the exterior walls. Since the exterior wood was directly exposed to rain and sunlight, color changes were observed. The objective of applying the acrylic-silicone-based transparent protective coating was to restore the natural wood appearance to a state similar to that at the time of construction. (e) shows a comparison between the exterior wall after the first recoating and the wall before renovation. During the first renovation, a wet appearance appeared after applying the primer. Therefore, in this renovation, a new method was adopted-applying the sealer with a brush and then wiping it off. This technique enhanced the visibility of the wood grain. The deteriorated wood materials showed two main



a) Exterior view of M Hospital *b) Work in progress*

c)Exterior wooden cladding *d) Interior wooden materials*

e) Before renovation and after the first renovation *f) After the second renovation*

Figure 7. *Renovation of the Facility Using a High-Elongation Acrylic-Silicone Transparent Protective Coating*

conditions: black discoloration and white weathering. Even when the same amount of sealer was used, color differences appeared depending on the wood condition, requiring adjustments to the amount and method of application. Unlike the previous renovation, after applying the primer this time, the finish, as shown in (f), achieved a clear expression of the wood’s texture and natural appearance.

5. Summary

1) The acrylic-silicone-based transparent protective coating demonstrated durability for at least seven years under exposure conditions.

2) Due to its susceptibility to climatic degradation, timber is more commonly used in interior applications rather than exterior ones.

3) Following legal revisions, timber is now applied more broadly across various building components.

4) These legal changes have also led to increased use of timber in public buildings.

5) Buildings that utilize timber tend to reflect a clear and strong rationale behind the choice of material, often

grounded in environmental or cultural values.

6) Penetrative coatings are widely recognized, whereas acrylic-silicone transparent protective coatings remain relatively unfamiliar among practitioners.

7) Although the applications and purposes of timber are becoming increasingly diverse, the range of surface protective coating options remains limited, highlighting the need for further development and dissemination.

Acknowledgements: This research is a joint project of Kogakuin University for the fiscal year 2024. I would like to take this opportunity to express my gratitude to Seven Chemical Co, Ltd: KUBOTA Shinji, Asano eiji, Nara Laborator: NARA Toshio, and the institutions in Kiso Town, Nagano Prefecture, Nagareyama City, Chiba Prefecture, and Minamiaizu, Fukushima Prefecture, who cooperated with the hearing.

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