Flame resistant of larch plywood according to Main Ingredients of Fire retardant paint

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Abstracts: The aims of this study is to comparative analyze the flame resistant of Larix kamperi according to fire retardant paints with different main components. Wood, an eco friendly traditional material, has been proven to reduce carbon, drawing attention as a solution to climate change, an international environmental issue. Wood is used as a material for buildings as furniture, interior, and furniture, and greatly satisfied users who require eco-friendliness. However, wood is a factor that increases the fire load in a fire. In previous studies, the fire vulnerability of Cryptomeria japonica, Pinus densiflora, MDF, OSB, cork board, and plain wood plywood was analyzed. As a result, wood without flame retardant treatment was vulnerable to fire. To compensate for this problem, we intend to secure an evacuation time by delaying the ignition time in case of a fire. Accordingly, Flame retardant treatment is implemented in accordance with Article 20 of 「the Enforcement Decree of the Act on the maintenance and Safety Management of Firefighting Facilities」. The main flame-retardant paint used is bromine, a halogen compound, and has high flame resistant. However, it is subject to environmental regulations due to the problem of soot and smoke generation. Eco friendly fire retardant paint are continuously being developed to escape regulations. Therefore, it is necessary to measure the effect of the flame resistant by treating the developed fire retardant paint for each tree species. So, three types of fire retardant paint with different main components are selected and treated on a larch plywood to analyze flame resistant. In this study, after flame time, after glow time, char length, and char area were measured in accordance with Standard of the Nation Fire Agency of Republic Korea. The main components of fire retardant paint are ammonium polyphosphate, emulsion resin, and phosphorus based mixture. Based on each theoretical application amount, 150g/m^2, 180g/m^2, and 180g/m^2 were applied as the flame retardant paint. As a control group, a test specimen that was not with flame retardant treatment was set. The results are as follows. First, ammonium polyphosphate was the most excellent flame resistant. Second, as a result of flame retardant treatment the phosphorus mixture with the same main ingredient on the same type of larch plywood, the effect of flame resistant was different depending on the technology development of each manufacturer. Third, all larch plywood satisfied the flame resistant regardless of the presence or absence of flame retardant treatment. This seems to be because *Larix Kamperi* itself has a property that does not burn easily. It is expected that the results of this study will be used as basic data for the production of semi noncombustible material suitable for flame resistant Standard of the Nation Fire Agency of Republic Korea in the future.

Keywords: *Larix kamperi, larch plywood, after flame time, after glow time, char length, char area*

1. INTRODUCTION

Wood is attracting great attention as an eco-friendly traditional material. The reason is that the carbon reduction effect has been proven and emerges as a way to solve climate change, an international environmental issue. [18] According to the construction permit status of Korean Statistical Information Service(KOSIS) by year, the number of construction permits for wooden buildings in Korea was 12,845 as of 2021. [14] It has now increased about 10 times compared to 10 years ago. This suggests that Korea's wood utilization has increased as much. According to Korea's current laws, 「Green Buildings Construction Support Act」, 「Act on the Sustainable Use of Timber」, and 「Act on Value Enhancement of Han-ok and other Architectural Assets」, the use of wood as building materials is "recommended." [18] With the trend of the times, wood is actively used as eco-friendly furniture, interior, and building materials. [22]

While using wood as an indoor space and building material, it is possible to increase the satisfaction of users who require eco-friendliness. However, Wood material is a factor to increase the fire load in fire. [7] To supplement this problem, it is implemented in accordance with Article 20 of 「Enforcement Decree of the Act on the Maintenance and Safety management of Firefighting Facility. [7] This is to secure an evacuation time by delaying the ignition time in the event of a fire.

In a previous study, the combustion characteristics of wood were analyzed using a Cone Calorimeter. The

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combustion characteristics of Shorea spp., Cryptomeria japonica, and Pinus densiflora were analyzed. As a result, Cryptomeria japonica, Pinus densiflora were carbonized with black charcoal when heated to 50 kW/m^2. On the other hand, Shorea spp. had a strong resistance to heat. Unlike Cryptomeria japonica, Pinus densiflora, they showed signs of carbonization at regular intervals. [8] Another previous study analyzed the fire vulnerability of MDF, OSB, cork board, and general wood plywood using a 45° Meckel's burner. As a result, the MDF greatly exceeded the char area of 5,000mm^2, which is stipulated in Standard of the Nation Fire Agency of Republic Korea. [7] In addition, as a result of measuring the char area and char length, OSB, cork board, and general wood plywood also did not meet Standard of the Nation Fire Agency of Republic Korea. [4] Wood is mainly used as a building material, so combustion characteristics were analyzed. As a result, wood that was not with flame retardant treatment was vulnerable to fire.

In order to compensate for the fire vulnerability of such wood, flame retardant treatment is mainly performed. [21] Flame retardant treatment is mainly applied with a brush, roller brush, air spray, and airless spray on the surface of wood and wood plywood. [19] The fire retardant paint mainly used is a bromine based halogen compound and has high flame resistant. [10] However, halogen based fire retardant paint, including bromine, are subject to environmental regulations. [2] The reason is that in the event of a fire, toxic and harmful gases such as dioxin are incidentally generated, and there is a problem of soot and smoke generation. As a way to solve this problem, it is necessary to develop an eco-friendly inorganic fire retardant paint made of a non-halogen compound. [10] This trend can also be confirmed in the current patent trend of fire retardant paint. Halogen-based fire retardant paint are gradually decreasing, and patent trends for inorganic fire retardant paint are gradually increasing. [13]

According to previous studies, combustion characteristics were different for each tree species. [8] In addition, flame retardant treatment is actively implemented as a way to compensate for the fire vulnerability of wood. In addition, it was confirmed that eco-friendly fire retardant paint were being developed to escape environmental regulation when performing flame retardant treatment. However, attempts to find the flame resistant of wood by tree species according to the developed fire retardant paint are insufficient. Therefore, it is judged that it is necessary to analyze the flame resistant of eco-friendly fire retardant paint targeting plywood by tree species.

In this study, three types of fire retardant paint were selected and tested on larch plywood. A flame retardant treatment is performed based on each theoretical coating amount to analyze the flame resistant according to the main component of the paint. The reason why larch plywood was selected is that it is widely used as a general wood.

2. SPECIMENS AND EXPERIMENTAL METHODS

2.1 SPECIMENS

Wood can be processed in various shapes and has aesthetic value due to its pattern. Therefore, it has been used as a building material such as interior and exterior materials, and furniture materials for construction since ancient times. Today, wood is widely used in the field as an eco-friendly material. In addition, Korea also recommends the use of wood as a policy. According to this trend, flame resistant according to fire retardant paint was tested on larch plywood. The reason why larch plywood was selected is that it is used in various ways, such as interior and exterior, mold use, ruba and flooring use. [1]

There is another reason for choosing the larch plywood. *Larix kamperi* is a representative tree species for wood production in Korea due to its excellent growth and high economic value. [15] It is also a species of afforestation that is distributed throughout Korea. As of 2018, the consumption of *Larix kamperi* in Korea is 412,000m^3. This is about 9% of the total Korean wood consumed, and it is small in size. However, the proportion of *Larix kamperi* used for general sanctions accounted for 68 percent of the total. The added value is that high. [15] This proves that the value of *Larix kamperi* is excellent as architectural and indoor furniture.

In addition, in 2020, the National Institute of Forest Research held the 『1st Forest Resource Circulation Economy

Industry, Research, and Policy Communication Forum』. The discussions at the talks are as follows. First, the value chain of Larix kamperi was enhanced at every stage from seed to distribution. Second, it was decided not only to increase the demand for *Larix kamperi* but also to expand the market for *Larix kamperi*. In summary, the importance of policy efforts for a stable supply of *Larix kamperi* was discussed. This is the time when the Korea Forest Service and local governments agreed that the policy needs a long-term vision, clear goals, and specific implementation measures for industrial use and creation. The policy efforts mentioned above are to establish a virtuous cycle utilization system for *Larix kamperi*. [15] It is expected that the supply of larch plywood will increase in the future. [11] Therefore, it is expected that the position of larch will increase with eco-friendly materials.

Therefore, in this study, three types of fire retardant paints with different main components were selected for larch plywood and the flame resistant was tested. The main components of each fire retardant paint used in the experiment are ammonium polyphosphate, emulsion resin, and phosphorus mixture. [3], [12], [16]

2.2 EXPERIMENTAL ENVIRONMENTS AND METHODS

An experiment was conducted to compare the flame resistant of the fire retardant paint according to the main ingredient according to Article 20 (2) of the Fire Prevention, 「Act On Fire Prevention and Installation, Maintenance, and Safety control of Firefighting Systems」 (Fire Protection Agency Notice No. 2021-7). The experimental sequence is as follows. First, larch plywood was prepared 190mm transverse, 290mm length, and 12mm thickness. Second, the selected three types of fire retardant paints were applied three times, 150g/m^2, 180g/m^2, and 180g/m^2, based on the theoretical application amount, according to the technical data of each manufacturer. After that, it was dried at room temperature for 24 hours. Finally, larch plywood, which was not used fire retardant paint, was treated as a control group. The detailed flame retardant treatment methods for the experiment specimen are summarized in Table 1.

After the preparation of the specimen was completed, flame resistant was tested using a 45° Meckel's burner. First, the larch plywood was dried in a thermostat at 40±2°C for 1 hour. Second, put silica gel in a desiccator for 2 hours. Finally, the specimen was taken out and experimented, and repeated three times. The environmental temperature of the laboratory was 20.0±15.0°C and the humidity was 50±30% RH. The overall experimental process is shown in Figure 1.

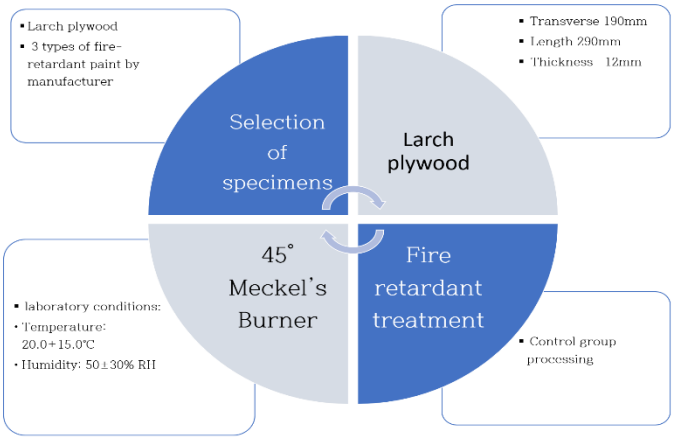


Figure 1. The overall process of an experiment.

Table 1. List of specimens used in this study.

Specimen[1)]	Samples		Fire reatardant condition[2)]	Treatment method
	Plywood	Main components of fire retardant paint		
A	larch plywood	-	-	brush painting
B		ammonium polyphosphate	150g/m^2	brush painting
C		emulsion resin	180g/m^2	brush painting
D		a phosphorus-based mixture	180g/m^2	brush painting

[1)] A is unprocessed, B is a fire retardant paint with ammonium polyphosphate as the main ingredient, C is a fire retardant paint mainly composed of emulsion resin, D is a birch plywood treated with a fire retardant paint containing a phosphorus-based mixture as the main component.
[2)] The theoretical application amount is derived based on the technical data of the fire retardant paint provided by the manufacturer of each fire retardant paint.

Table 2. List of specimens used in this study.

Category	after flame time	after glow time	char length	char area
Definition	Until the flame stops burning	When don't raise the flame, Until the flame stops burning	the length of the longest straight line	Calculation of Area after Photographing Char Area
Criteria	Within 10 seconds	Within 30 seconds	Within 200mm	Within 5,000 mm^2

2.3 Standard for Flame Resistant Using 45° Meckel's Burner

The flame resistant was measured through 45° Meckel's burner according to Article 20 (2) of 「Act on Fire Prevention and Installation, Maintenance, and Safety Control of Firefighting System」 (Fire Protection Agency Notice No. 2021-7). The specimen was fixed to the test support frame, and the flame length of the burner was 65mm, so that the tip of the flame was in contact with the center of the lower specimen. Next, heat the specimen for 120 seconds. Then, after flame time, after glow time, char length, and char area are measured according to the flame resistant standard of the Nation Fire Agency of Republic of Korea. the flame resistant of wood and plywood must meet after flame time within 10 seconds, after glow time within 30 seconds, char length within 200mm, and char area within 5,000mm2. Table 2 summarizes the flame resistant standards for wood and wood plywood.

3. EXPERIMENTAL RESULTS AND CONSIDERATIONS

The flame resistant of the fire retardant paint according to the main ingredients was compared for the larch plywood. After flame time, after glow time, char length, and char area were measured using 45° Meckel's burner. The results are presented in Figure 2.

Both after flame time and after glow time were measured to be 0 seconds. Regardless of whether or not it was treated with flame retardant treatment, all of Standard of the Nation Fire Agency of Republic Korea were satisfied. In general, ignition temperature of each tree species is different. Based on this, it is estimated that both after flame time and after glow time of the larch plywood were measured to be 0 seconds because Larix kamperi is a tree species that spreads at 650°. [9] However, when measuring after glow time, the criterion of the time until the combustion without flame stops is very ambiguous. Therefore, it is highly controversial to judge the flame resistant by after glow time. Therefore, it is necessary to prepare more detailed standard of after glow time. [6]

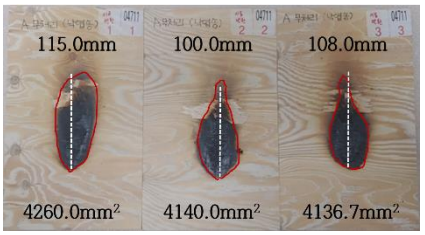
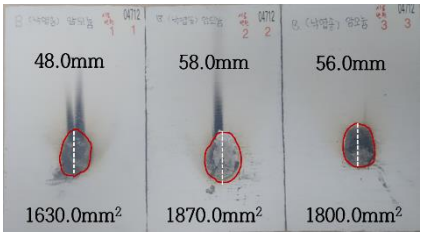
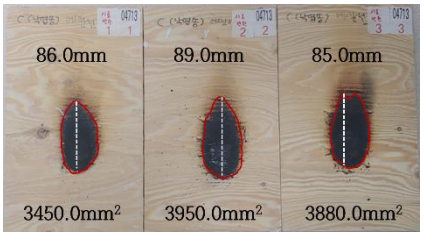
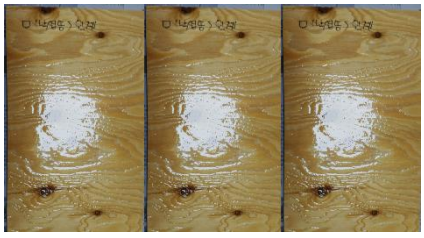
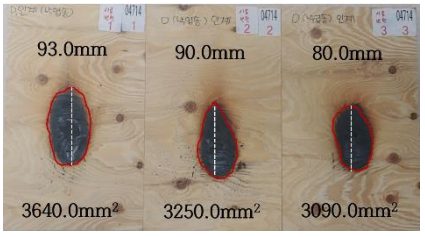
Specimen[1)]	Before the experiment	after the experiment
A		
	(a) Control group (no processing)	
B		
	(b) Ammonium polyphosphate treatment	
C		
	(c) emulsion resin treatment	
D		
	(d) phosphorus mixture treatment	

Figure 2. Before and after the experiment of the specimen.

The Char length was measured in the range of 107.7mm in 'A', and in the range of 54.0 to 87.7mm in 'B to D' treated with fire retardant paints with different main components. That is, regardless of the presence or absence of flame retardant treatment, all standards for flame resistant were satisfied. The results of comparing the char lengths of the control group ‘A’ and the flame retardant treatment ‘B to D’ are as follows. The char length decreased to 49.9% for 'B', 19.5% for 'C', and 18.6% for 'D'. Compared to the case in which the flame retardant treatment was not performed, the fire retardant paints mainly composed of emulsion resin and phosphorus based mixture also had excellent flame resistant. In particular, the flame resistant of a fire retardant paint containing ammonium polyphosphate as a main component was remarkably excellent.

The char area was measured in the range of ‘A’ to 4,136.7mm^2, and ‘B to D’ to which flame retardant paints with different main components were treated was measured in the range of 1,766.7 to 3,760.0mm^2. In other words, it satisfied the standard of the Nation Fire Agency of Republic Korea. As a result of comparing the char area of the

flame retardant treatment 'B to D' and the control group 'A', 'B' decreased the most to 57.3%. On the other hand, 'C' showed a small decrease of 9.1%.

As a result, the performance of the fire retardant paint used in this study according to the Article 20 (2) of 「Act on Fire Prevention and Installation, Maintenance, and Safety Control of Firefighting System」 satisfied 'the standard of the Nation Fire Agency of Republic Korea (Notification No. 2021-7)'. However, the flame resistant was different depending on the main components of the fire retardant paint. 'B' had a better effect of flame resistant than 'C' and 'D'.

According to previous studies, there is an experiment in which a used fire retardant paint composed of guanidine and polyphosphate is treated on a larch plywood. As a result, even though 500g/m^2 was applied, it was reported that it was not suitable for standard of the flame resistant. [5] When a phosphorus based fire retardant paint consisting of a phosphorus and boron-based compound was treated on larch plywood of about 300g/m^2, standard of the flame resistant was met with a char length of 100.9mm and a char area of 4,019mm^2. [17] In this study, as a result of treating 180g/m2 of the phosphorus-based mixture on larch plywood, the char length was 87.7mm and the char area was 3,326.7mm^2, satisfying standard of the flame resistant. Even for fire resistant paints composed of same phosphorus, it is believed that the effect of flame resistant varies depending on the technology development of fire retardant paints by manufacturers.

On the other hand, according to the results of this study, larch plywood, which was not treated with flame retardant treatment, also satisfied the standards for flame resistant. In other words, it was judged to be suitable. This is because *Larix kamperi* belongs to *Larix* spp. In general, *Larix* spp. is known to have an arboreal thick bark and low resin content, so it is not easily burned. [20] Therefore, in the case of tree species that are resistant to fire, it should be discussed whether it is meaningful to perform flame retardant treatment.

In summary, there was a difference in flame resistant depending on the main component of the fire retardant paint. In addition, even for paints with the same components, flame resistant was different depending on the technology development of each manufacturer.

Table 3. Flame resistant according to fire retardant paint by manufacturer.

Sortation		specimen			
		A	B	C	D
after flame time (second)	One-time	0.0	0.0	0.0	0.0
	Twice	0.0	0.0	0.0	0.0
	Three-times	0.0	0.0	0.0	0.0
	Average	0.0	0.0	0.0	0.0
after glow time (second)	One-time	0.0	0.0	0.0	0.0
	Twice	0.0	0.0	0.0	0.0
	Three-times	0.0	0.0	0.0	0.0
	Average	0.0	0.0	0.0	0.0
char length (mm)	One-time	115.0	48.0	86.0	93.0
	Twice	100.0	58.0	89.0	90.0
	Three-times	108.0	56.0	85.0	80.0
	Average	107.7	54.0	86.7	87.7
char area (mm^2)	One-time	4260.0	1630.0	3450.0	3640.0
	Twice	4140.0	1870.0	3950.0	3250.0
	Three-times	4010.0	1800.0	3880.0	3090.0

	Average	4136.7	1766.7	3760.0	3326.7
Judged of Suitability [1),2)]		suitable	suitable	suitable	suitable

[1)] Pursuant to Article 20 (2) of 「Act On Fire Prevention and Installation, Maintenance, and Safety control of Firefighting Systems」(Fire Protection Agency Notice No. 2021-7), In the case of plywood, after flame time shall be within 10 seconds, after glow time shall be within 30 seconds, char length shall be within 200mm, and char area shall be within 5,000mm^2.
[2)] The experiment was repeated three times, and suitability was evaluated based on the average value of the results.

Therefore, it is judged that additional research is needed to compare the effects of flame resistant by treating fire retardant paints by manufacturer on various tree species. Based on this, basic data will be prepared to select fire retardant paints for each manufacturer that have a high flame resistant effect for each tree species in the future.

4. CONCLUSION

The purpose of this study is to compare the flame resistant according to the main components of fire retardant paint for larch plywood. The reason why the larch plywood was selected is that it is used for various purposes such as interior and exterior, mold use, ruba, and flooring. [1] The following conclusions were drawn by measuring the after flame time, after glow time, char length, and char area of the larch plywood according to Article 20 (2) of 「Act On Fire Prevention and Installation, Maintenance, and Safety Control of Firefighting System」 (Fire Protection Agency Notice No. 2021-7).

(1) Both the after flame time and the after glow time were measured to be 0.0 seconds regardless of whether it was treated with flame retardant treatment. In other words, it satisfied standard of the Nation fire Agency of Republic Korea. This is Larix kamperi with the characteristics of catching fire at 650℃ [9] and is estimated to have an effect on the after flame time and the after glow time.

(2) The char length and char area were measured to be the smallest in a larch plywood treated with a fire retardant paint containing ammonium polyphosphate as a main component. That is, ammonium polyphosphate had the best flame resistant effect.

(3) The results of comparing previous studies with this study are as follows. As a result of flame retardant treatment with a phosphorus based mixture with the same main ingredient for the same larch plywood, it was confirmed that the effect of flame resistant varies depending on each manufacturer's technology development.

(4) *Larix kamperi* satisfied all standard of the Nation Fire Agency of Republic Korea regardless of the presence or absence of flame retardant treatment. This is because Larix kamperi itself has a property that does not burn easily.

The conclusions for this study are as follows. As a result of confirming the flame resistant according to the main component of fire retardant paint in larch plywood, it was found that the flame resistant of the fire retardant paint varies depending on the main component. In order to prepare basic data for the production of semi-noncombustible material that meets flame resistant standard of the Nation Fire Agency of Republic Korea, it is necessary to secure objective data analyzing the flame resistant of various tree species according to fire retardant paints.

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