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Efficient Using of Wood by Underwater Shock Wave

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Cryptomeria japonica D. Don which is called "Sugi" or "Japanese cedar" generally contains the extremely high moisture content in its black heartwood. Because the bordered pit membrane on the tracheid blockades the water road, Sugi is hard to dry. This is the reason why sugi is not used easily as an architectural material. The bordered pit membrane is selectively destroyed by the underwater shock wave that is a wave of the pressure transmitted at the speed that exceeds speed of sound. The tracheid functions again as the water road, and dryness is improved by selective destruction without changing its strength because the pit membrane doesn't influence strength. This technology makes Sugi available as an architectural material. The thinning is a heavy-duty work because it maintains the forest to health by delivering sunlight to ground and growing the undergrowth. It is necessary to establish use of the thinned wood to thin the forest. The reforming technology using the underwater shock wave load is suitable for the use of the thinned wood. Cultivating maintenance of the forest, the environment and people's healthy livings by promoting the use of domestically produced thinned wood in the building in Japan becomes possible.
Key words: Underwater Shock Wave, dryness, Noncombustible material

1. INTRODUCTION

Wood is a material of carbon neutral. Therefore, the use of wood attracts attention as measures against the environmental problem such as the reductions in the greenhouse gas recently. Especially, positive use of the thinned wood is requested from respect in the forest maintenance, and various measures are being executed by the Forestry Agency. However, according to the document of the Forestry Agency, the thinned wood carried out and used is only about 40-50 percent of the whole. The application field of the thinned wood includes the building material, the biomass energy, the fishing bank, and so on. However, because the demand for cheap import wood occupies the majority of the market, the demand for the domestic lumber with a high cost is flagging as the building material that is the main application field. Therefore, it is necessary to achieve following matters to promote the consumption of the doméstic wood and to raise the rate of self-sufficiency. First, the lowering the cost of the wood drying to make it useful as a building material is necessary. In addition, the added value such as noncombustibility is necessary. The demand for the domestic wood can be improved by answering modern consumer needs to secure the safety and reassurances.

The representative of the thinned wood of Japan is Sugi. It is necessary to dry it up to the moisture content of 20% based on the JAS standard to use wood as a building material. A lot of necessary fuels are part of the reason for a high domestic lumber cost in the artificial seasoning of wood. The cost of air-drying is still high because it requires time and is controlled by the weather. High cost is necessary to dry the Japanese wood cause of the environment of Japanese great humidity. Therefore, the Japanese wood is at a heavy disadvantage in price competition against the cheap import wood.

2.UNDERWATER SHOCK WAVE

The water pass of the conifer is the concatenation of short pipes and is called the tracheid. The tracheid connects to another tracheid that is adjacent by the bordered pit of the wall (Fig.1A). Water is sucked in going along in the tracheid through the bordered pit. However, because the bordered pit is blockaded in the heartwood, the water pass is cut (Fig.1B). As a result, the heartwood becomes a saturated condition by water, and wood is not dried easily. By using the underwater shock wave loading, only the blockaded bordered pit is selectively destroyed (Fig.1C). The improvement of the permeability of drying characteristics and the chemical is tried by securing the water pass using underwater shock wave loading. The scanning electron microscope (SEM) photographs of the bordered pit before and after the underwater shock wave loading are shown in Fig. 2. Drying characteristics by the underwater shock wave loading was published by Itoh, 2003 [1], and so on. In this research, the improvement of wood by the injection of the chemical is described.

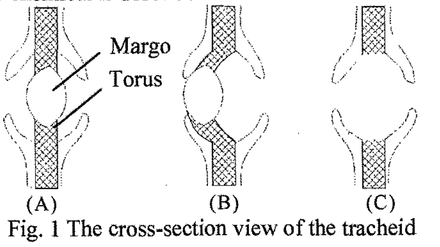
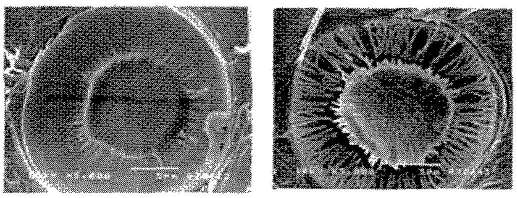


Fig. 1 The cross-section view of the tracheid



(A) Untreated (B) Treated

Fig. 2 The SEM photographs of the bordered pit membrane

Fig. 3 shows the schematic diagram of the underwater shock wave loading device. The sugi board from Kumamoto prefecture of 1800mm in length, 15mm in thickness, and 18mm in width was used as a sample. The detonating cord made of The Japan Carlit Co., Ltd. (explosion velocity 6308m/s) was used in the source of the underwater shock wave, and the 6th percussion cap made of Asahi Kasei Corporation was used for detonation. The distance between sample and the detonating cord is 300mm, and the pressure of underwater shock wave is 37MPa[2].

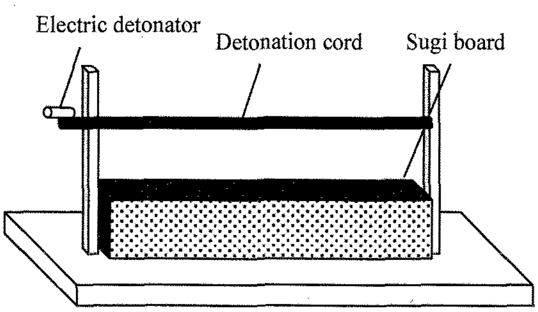


Fig. 3 The underwater shock wave loading device.

3. THE INJECTION OF FLAMEPROOFING AGENT

3.1 Experiments

After the underwater shock wave loading, the wood sample was cut as the examination sample (1000mm x 100mm x 12mm and 1000mm x 100mm x 15mm) for burning test. In addition, both ends of the examination sample were sealed by silicon. Boron system flameproofing agent solution PHN140 and the examination sample were put in the agent injection device (Fig. 4). Afterwards, the agent injection device was pressurized in 0.5MPa by using the air conditioner presser. The pressurizing time is 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours and 6 hours.

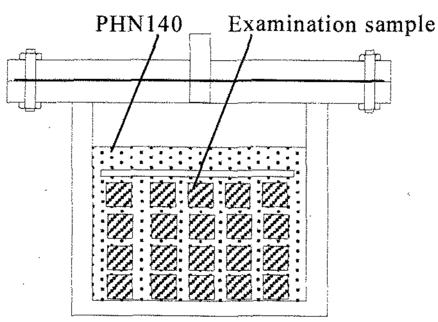


Fig. 4 The agent injection device

3.2 Result

Fig. 5 shows the result of injection. The line chart shows the injection weight and the bar chart shows the injection density. W of the sample number (e.g. W12S, W15M) shows the amount of injection, ρ (e.g. ρ12S, ρ15M) shows the injection density, and the number shows the thickness of the board (e.g. ρ12S shows 12mm thickness). The treated sample is shown by S (e.g. W12S, ρ15S), and the untreated one is shown by M (e.g. W12M, ρ15M). The improvement of the shock wave processing sample permeability is seen immediately after beginning. The maximum amount of the injection of W15S shows 1.5 times of other samples. The effect of the underwater shock wave loading in permeability becomes visible clearly in the thicker examination sample.

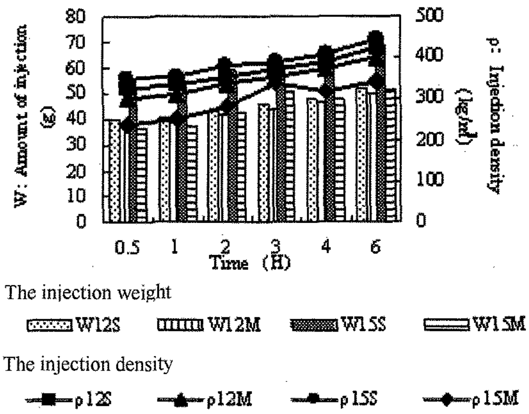


Fig. 5 Result of injection

4. BURNING TEST

4.1 Standards

The sugi material injected the flameproofing agent was evaluated by using the cone calorimeter by the heat build-up examination (ISO5660-1) based on the Building Standard Law of Japan[3]. The standard is shown below.

1) The gross calorie value in the demand time must be lower than 8MJ/m^2 after it begins to heat it.

2) Do not exceed 200KW/m^2 as the highest heat release rate continues for 10 seconds in the demand time after it begins to heat it.

3) There must be neither crack nor damage that gets in the demand time on the reverse harmful on fire prevention after it begins to heat it.

Demand time is 5 minutes in the fire retardant material, 10 minutes in the quasi-noncombustible material, 20 minutes in the noncombustible material.

4.2 The gross calorie value

Fig. 6 shows the result of the gross calorie value. In the examination sample number, the first number shows the injected volume (kg/m^3), and next is board thickness. The result of passing to the noncombustible material standard was obtained by two samples (307t15 and 295t15, both were treated by the underwater shock wave). 324t12 (treated) and 258t12 (untreated) passed the quasi-noncombustible material standard. 86t12 (treated) and 71t15 (untreated) passed the fire retardant material standard. Non-injected 0t15 did not pass even the fire retardant material standard.

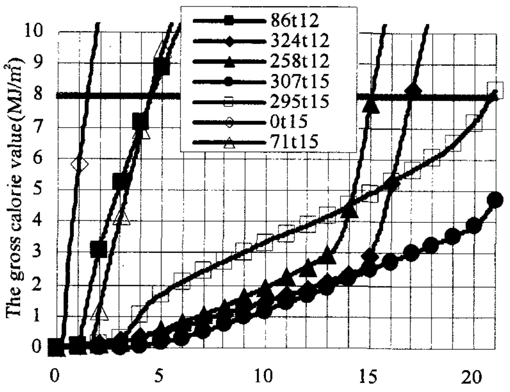


Fig. 6 The result of the gross calorie value

4.3 The heat release rate

Fig. 7 shows the result of the heat release rate. The calorie value of non-injected 0t15 reached 200KW/m^2 after passes 9 minutes. Therefore, this sample did not pass the standards of quasi-noncombustible material. All other samples have passed the standards of quasi-noncombustible material.

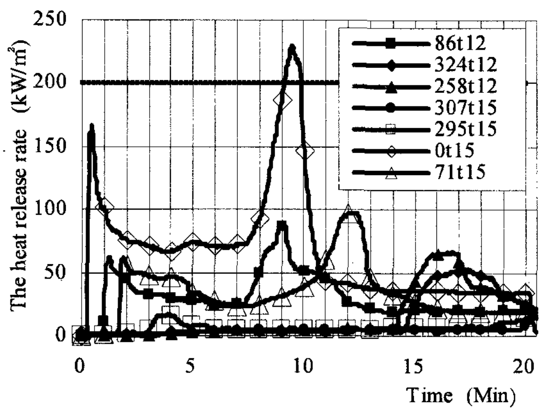


Fig. 7 The result of the heat release rate

5. DISCUSSION

The result concerning the gross calorie value is described below. Some of samples passed the recognition standard about the calorie value by injecting the flameproofing agent. The amount of the injected flameproofing agent correlates with the calorie value when the thickness of the board is same. The underwater shock wave loading influences the amount of the injected flameproofing agent by selective destruction of the blockaded bordered pit[4].

Table 1 shows the amount of injected agent and presence of the underwater shock wave loading in excellent results of the burning test. The amount of the injected flameproofing agent of 258t12 is the least with 31.97g because it was not treated by the underwater shock wave loading. Both 307t15 and 295t15 passed the standard of the noncombustible material although their injected agents are lesser than 324t12 (quasi-noncombustible) in unit volume (Kg/m^3). Therefore, to pass the noncombustible material standard, the necessary content of flameproofing agent should be considered not only by unit volume but also by one board. Fig. 8 shows the result of the mass measurement. The quasi-noncombustible sample (324t12, 258t12) ignited when the mass became 50g or less. Therefore, to pass the noncombustible material standard, it is necessary to maintain the mass of 50g or more in 20 minutes. The amount of a mass decrease in both of noncombustible samples (307t15 and 295t15) is approximated to $Y=-0.0465X-0.0614$ (X = Time (sec), Y = the amount of a mass decrease). It is calculated when the mass of about 56g decreases for 20 minutes when board thickness is 12mm. From Fig. 6, the mass is assumed to be 50g when all flameproofing agent in wood is consumed. Therefore, to pass to the noncombustible material standard, the mass that contained the flameproofing agent at the time of the start of the examination has to be 106g or more.

Table 1. The relation between the amount of injected agent and the underwater shock wave loading

Sample No.	PHN140 (Kg/m^3)	PHN140 (g/sample)	Shock wave	Result
324t12	324	39.93	T	Q
258t12	258	31.97	U	Q
307t15	307	47.56	T	N
295t15	295	45.67	T	N

T: The underwater shock wave loading treated
U: The underwater shock wave loading un-treated
Q: Passed standard of the quasi-noncombustible
N: Passed standard of the noncombustible

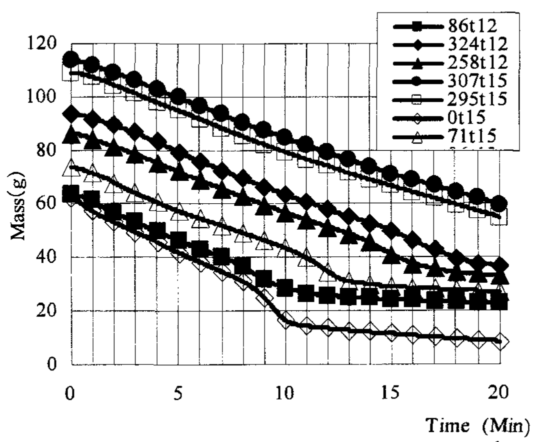


Fig. 8 The result of the mass measurement result

The result concerning the heat release rate is described below. All of flameproofing agent injected samples passed the standard of the fire retardant material or more in the heat release rate, and a non-injected sample did not pass. That is, the presence of the flameproofing agent determined a passing status regardless of the presence of the underwater shock wave loading.

6. CONCLUSION

The underwater shock wave was loaded to the sugi board and tested its noncombustibility by injecting the boron system flameproofing agent solution PHN140. The sample into which the flameproofing agent (PHN140) of 295Kg/m^3 or more was injected passed the noncombustible material standard. Therefore, the sample that contains PHN140 of 106g or more and the size of 100mm width, 100mm height and 120mm thickness is thought to pass noncombustible material standard.

Burning test under various conditions of injections will be done continuously, and the best condition of injection is clarified.

7. References

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