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Saburou Uesugi · Toshiro Harada · Yoshitomo Namiki

Fire resistance of sugi covering materials for structural steel

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Abstract Glued laminated timbers (glulam) or planks 50mm thick were added to structural steel columns and beams as covering materials. The wood used in the glulam was sugi (*Cryptomeria japonica* D. Don) laminated with resorcinol resin adhesive between woods and epoxy resin adhesive between wood and steel. The 50mm thick planks of sugi around the steel were fixed with spirally threaded nails (screws), and 25mm long wood plugs were used to cover the tops of the nails. The 50mm thick glulam showed 1h of fire resistance. The temperatures of the flanges and webs of steel were 100°C at 1h and 200°C after 4h. The epoxy resin used to bond the wood and steel was an appropriate adhesive from a recycling perspective because it is easy to separate or peel from the steel.

Key words Fire resistance · Sugi · Steel · Glulam · Epoxy resin adhesive

Introduction

The revision of the Building Standards Law of Japan removed the material restrictions on wood that is used as a fire-resistant material. It may be able to utilize the wood as a thermal insulator substituted for the plasterboard or other mineral boards.

The purpose of this research was to improve the fire resistance of wood as a thermal insulator in steel frame buildings. The steel bears the structural strength, and the wood is utilized as a covering material because wood is an excellent insulating material against heat and dew condensation.

S. Uesugi (✉) · T. Harada
Forestry and Forest Products Research Institute, Tsukuba, Ibaraki 305-8687, Japan
Tel. +81-298-73-3211; Fax +81-298-74-3720
e-mail: uesugi@ffpri.affrc.go.jp

Y. Namiki
Mie Prefecture Science and Technology Promotion Center, Forest Research Division, Mie 515-2602, Japan

Materials and methods

Specimens

Sugi glued laminated timber (*Cryptomeria japonica* D. Don) was bonded with shaped steel (Japanese Industrial Standard JIS G 3192: 100 × 50 × 5 × 7mm); the dimensions of the cross section of the specimen were 150 × 200mm and 2000mm length as the column and beam (I) in Fig. 1.

Sugi glued laminated timber was produced with a compression pressure of 7.5kg/cm^2 using a resorcinol resin adhesive and the 23- or 35-mm thickness sugi planks with 12% or less moisture content. It was bonded to the steel by epoxy resin adhesive at room temperature.

As a simple covering method, the beam (II) was adapted as illustrated in Fig. 1. It was composed of steel and planks of 50mm thickness, and there was a vacant space between webs. The planks were joined at the center of it with the shiplap joint generally used in the joint of the board; they were fixed with 90mm long 4.5mm diameter spirally threaded nails (screws), and its top was plugged with a wood plug of 10mm diameter and 25mm length.

Fire test

The fire test was carried out along a heating temperature curve following JIS A1304 and ISO 834 for nonloading. Beams were exposed on three sides, with the upper side being in contact with the ceiling; the column was exposed on four sides, as appropriate.

The beam (I) was exposed for 1h and was kept in the furnace for 3h without any air supply. The column was exposed for 1h and the beam (II) for 1h and kept for 3h with an air supply. The temperature of the flanges, webs, and 25mm depth of the wood interior were measured with the K thermocouples. The performance criteria of

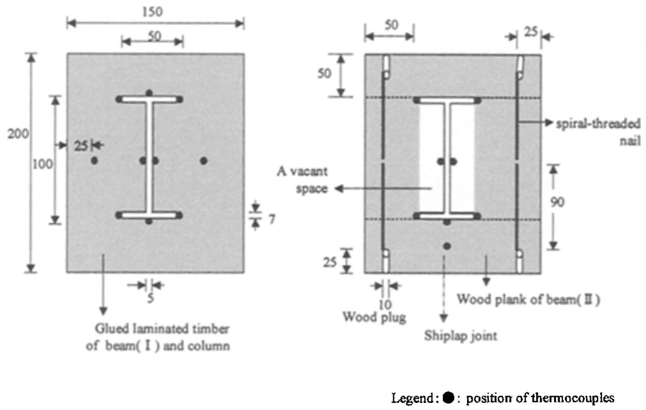

Fig. 1. Location of thermocouples (units are millimeters)

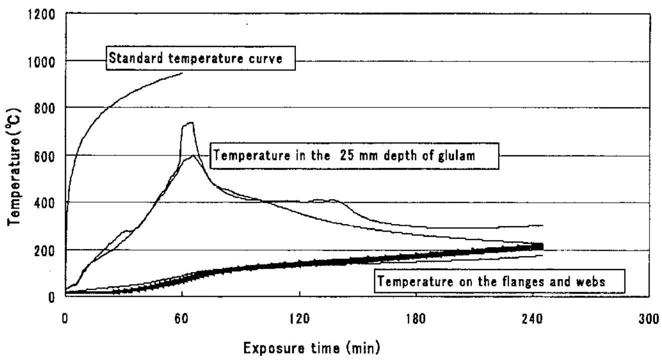

Fig. 2. Temperature of flanges, webs, and the 25 mm depth in the beam (I)

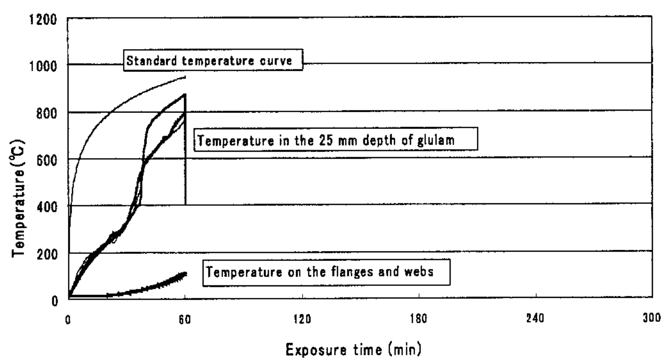

Fig. 3. Temperature of flanges, webs, and the 25 mm depth in the column

specimens were that the maximum temperature of the flanges and webs measured did not exceed 450°C and that the average temperature did not exceed 350°C.

Results and discussion

The temperature of the flanges, webs, and 25 mm depth of the glulams are shown in Figs. 2 and 3. When wood is exposed to high temperatures, it chars and eventually

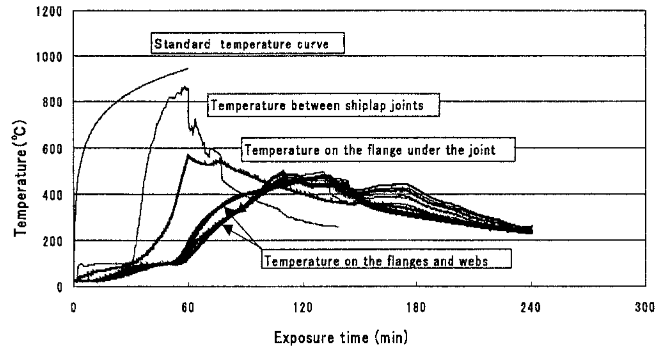

Fig. 4. Temperature of flanges, webs, and the 25 mm depth in the beam (II)

flames; it decomposes to provide an insulating layer of char that decreases the degradation of the wood.

It took 4–6 min for the beam (I) and 9 min for the column of the laminated wood interior at 25 mm depth to reach 100°C. The beam (I) was kept in the furnace for 3 h after 1 h of heating, so the temperatures of the webs and flanges reached a temperature of about 200°C. This temperature was in the safe range and did not exceed the critical average temperature (350°C) or the critical maximum temperature (450°C) for the steel in the construction.

Figures 2 and 3 also show the temperature rising so both flanges and webs reached 100°C but the temperatures in the 25 mm depth of the glulam reached >100°C after about 5 min. The increased internal temperature seems to have been caused by heat coming from the stainless steel protected tube used for the thermocouple. The beam (I) and column with the laminated wood covering satisfied the above-mentioned performance criteria and showed equal or better performance than the two fire retardant-treated particleboards covering the steel frames.[1]

The load-carrying capacity of structural steel members depends on the temperature; hence the char layer is the main factor in the fire resistance of steel members. The char layer has an insulating effect, and the covering effects of glulam showed good protection against thermal attack. Figure 4 shows that the temperature between the shiplap joints of the beam (II) rose quickly and reached 100°C in 29 min, and the flange temperature behind the joint reached 100°C in 31 min. The rise of this web temperature shows that the covering planks around the steel had burned out in 30 min. When the wood surface is ignited, the shiplap joint causes strong shrinkage and a change in dimensions. After that the jointed parts burn easily and cause flame propagation through the space between webs. Therefore, fire resistance could not be sufficiently maintained in the shiplap joint of the planks because of the covering.

The temperature of the flanges and webs rose after 60 min because the planks had charred or burned. The charring rate was obtained from the remaining cross section of the column and beam (I). The charring rate of the column was 0.67 mm/min, and these values showed the glulam to be good thermal insulation material.

Epoxy resin is thermoplastic adhesive; and it is possible that the glulam, which was bonded by the epoxy resin adhesive, peeled or separated easily from steel when the temperature of the steel product reached 100°C. Epoxy resin is an appropriate adhesive for recycling these materials.

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Reference

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