ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 15 N° 4 2019
pp. 278-283

# STUDY OF WOODEN SURFACE CARBONIZATION USING THE TRADITIONAL JAPANESE YAKISUGI TECHNIQUE

***David EBNER***
Mendel University in Brno, Faculty of Forestry and Wood Technology
Department of Wood Science, Czech Republic

***Rene STELZER***
Salzburg University for Applied Sciences, Forest Products and Timber Construction, Austria

***Marius Catalin BARBU***
Salzburg University for Applied Sciences, Forest Products and Timber Construction, Austria
University "Transilvania" of Brasov, Faculty for Wood Engineering, Romania

***Abstract:***
*The traditional method "Yakisugi" or "Shou Sugi Ban" used for the charring of the wood surfaces, applied to European native wood species is explored. The economic and ecological aspects were also considered. This thermal treatment was designed to facilitate the wooden surface carbonization and to develop a uniform carbonized layer. Using this method, the durability of sawn timber increases significantly. The charred boards can be used as façade elements or considered as fire-resistant solutions in constructions.*

***Key words****: Yakisugi; wood surface traditional Japanese treatment; fire resistant wooden surface; carbonization.*

## INTRODUCTION

Wooden façades with all relevant constructive details define the quality in optical appearance and long durability of a cladding. The combination of constructive details and the right choice of the wood species and surface treatment is the key to a durable wooden house (Scheiding et al. 2016). A lot of combinations are possible to produce a wood facade because there is a variety of different wood species and different wood modification treatments or surface protection methods.

Yakisugi is a method of conserving both historical and modern wooden buildings in central Japan. The advantage of the traditional Japanese charring method is that fire generates a protective carbonized surface. The energy for the fire is provided by the burning lumber itself. Using the physical effect of a chimney by putting together three lumber planks in a triangular prism, filled at one side with wood shavings wrapped in newspaper, high internal temperatures can be reached without using external energy sources to carbonize the lumber surface.

The benefit of a carbon layer is to protect the surface of wood from moisture, prevent air to enter internal parts of the cross-section and improves also the flammability of wood (Špilák 2018). The charcoal layer makes the wood less susceptible to wood-decomposing fungi and protects it against moisture. For this reason, for the wooden poles a thermal treatment is necessary prior to bury them into the ground.

The carbon layer, which arises in fires of wooden buildings and construction, has a fire-retardant effect (Vavrušková and Lokaj 2009). The forming charcoal layer reduces the thermal conductivity, which prevents further burning (Niemz 1993, Buchanan 2001).

Charred wood surfaces have proved to be a protective layer for facades, especially in Japan, where they are still being used (VanderGoot 2017). The charcoal layer, which is up to 5mm thick, makes it unattractive for wood- decay fungi (Kollmann 1951), as the pH-value increases by the charring procedure (Weber and Quicker 2018). During the burning the flammable substances such as lignin, cellulose and hemicellulose and other wood chemical components are largely degraded in the first millimetres of wood. UV radiation has no altering effect anymore. With this charred surface the wood gains a protective layer (Kymäläinen 2017). Records of the exact length of durability of charred wood surface are not directly known. In Japan, 500 years old buildings were conserved due to Yakisugi method. Maintenance of these surfaces is necessary to increase their service life. The main application of charred wood surfaces is incladdings (Stelzer 2017).

Due to the exposure at high temperature the physical- and chemical properties of wood are changing (Hill 2006). The first modification of the wood properties occurs before it burns. This thermal decomposition starts at 105°C. Whereas the maximum temperatures in thermally modified timber can reach 250°C, during the carbonization the temperatures are higher. The process that leads to create a carbon layer starts at temperatures around 270°C, when the ignition temperature is reached when the wood starts to burn. Temperatures above 400°C determine the combustion with an open flame, in which the wood turns to black by the exothermic decomposition and slowly develops the carbon layer. At 500°C, the fire spreads horizontally and vertically on the surface. Exceeding 500°C, the charcoal residues are burned. From 500-550°C the tar components drive off and increase the fixed carbon (Forestry 1985).

## MATERIAL AND METHODS:

### YAKISUGI

Yakisugi is the Japanese method for superficial charring of lumber. A literally translation returns „burnt cedar”. Also known as "Shou Sugi Ban". "Sugi" is the Japanese term for cedar (*Cryptomeria japonica*), known in Europe as "Japanese cedar". The purpose of this method is to increase the durability of the wood for exterior use on buildings by charring the surface. The 3 - 5mm thick carbon layer protects the wood from the external influences. In addition, the carbon layer surface can be treated with glazes/enamels or oils. Traditionally, an oil obtained from the fruit of the khaki tree is used. Also, tung oil or flax seed varnishes are used. There are no traditional sources that describe the exact origin of this method. For example, in the grey literature is reported about this technique used for over a thousand years (Stelzer 2016).

In this traditionally Japanese process, 2 to 4m long lumber boards are tied together to form a triangular prism. These are held together with water-soaked cords (Fig. 1). The edges of the boards overlap a few millimetres and cover one part of the other board (Fig. 2). The width of the boards is between 200-300mm and the thickness varies between 12-22mm. A manufacturing process documented by the authors observations in Japan is described below. In this manner the Yakisugi manufacturer Miyazawa from Fan Landscape Inc., along with Morishita from Shinwa Inc. from Shizuoka carbonize the lumber surface.

***Fig. 1.***
***Example of a triangular prism made of lumber bound with water soaked cords (Stelzer 2016).***

***Fig. 2.***
***Details of the triangular prism made of lumber before burning (Stelzer 2016).***

After the sawn wood boards are tied together to a triangular prism, a hand full of wood shavings wrapped in newspaper is introduced in on lower end of the wood board prism which works on the same principle as a chimney (Fig. 3). The newspaper bunch is ignited using a Bunsen burner. The chimney is then placed with the lighted side on brick stones. The brick stones are arranged in a special manner, so that enough air can flow into the chimney and the newspaper package is able to fall down after the starting energy was provided (Fig. 4).

***Fig. 3.***
***Detail with the wood shavings wrapped in newspaper (Stelzer 2016).***

***Fig. 4.***
***Wooden triangular chimney placed on brick stones (Stelzer 2016).***

After the rest of the newspaper bunch fallen out of plenty of air can flow through the chimney. The rest of the wood shavings are still burning and treat the lower edges of the wooden boards. As long as the flame spread works on the inside of the chimney, the board triangular prism must be kept in an oblique position and finally set up vertically. In this way the chimney effect is generated, which keeps the fire running. To ensure a long-term burning the board prism is opened laterally, so that that more air supply is established.

Without opening on the sides, only a strong smoke would be produced and the fire is extinguished. In addition, this has the benefit that the otherwise overlapping wood board sides faces can also be charred. Using metal levers, at intervals, all wood board sides faces are opened once at a time and rotated from their position so that the overlapping edges can also be reached by the fire and carbonize in this way (Fig.5).

***Fig. 5.***
***Opening of burning chimney using metal levers (Stelzer 2016).***

***Fig. 6.***
***Laying down of the inside carbonized triangular prism and fire extinction (Stelzer 2016).***

All edges have to be opened long enough to ensure a uniform charring of the surface. Around five minutes after ignition, the 4m long burning triangular prism is laid down and the water-soaked cords are released. When the chimney collapse in this way, the fire stops (Fig.6). Water applied with a soft hand spray on the charred layer helps prevent afterglow and ashes (Fig.7). The extinguished wooden boards are stacked one above the other with the charred sides up (Fig.8). In this example, the carbon layer is left untreated and afterwards does not receive any surface treatment with oil for stabilization.

***Fig. 7.***
***Fire and afterglow extinction after opening of chimney (Stelzer 2016).***

***Fig. 8.***
***Stacking of one side carbonized wooden boards (Stelzer 2016).***

According to Morishita (2017), the sawn wood boards are previously dried to a wood moisture content (MC) of 15-20%. After charring the MC is around 18%. The raw carbon layer is not further treated with glazes or oils. Within 20 years, weathering removes the charring. After this time, a wood preservation coating is used to maintain the wood preservation (Stelzer 2016).

In addition to the method already described, there are manufacturing steps which have some differences. Depending on the width and length of the boards or the number of persons involved, various techniques have been developed for charring the surface.

These steps will be briefly presented and discussed below and relate in particular to the joining technique, the method of turning around and the types of after treatment:

- Joining technique: The connection of the board triangular prism already presented is made as described with water-soaked cords. Another type of connection to create a wood triangle which performs as a chimney can accomplish with chains and tension springs. These springs have the advantage to enable possibility to clamp wedges between the boards during the charring process. Just when only one person is involved in the process, this method is used because it allows an almost simultaneous opening of the sides for a uniform carbonization of the edges of the boards.
- Turning around: The handling of flipping the burning board triangular prism was only observed in online videos. Although this method is not necessarily used in Japan. At a length of up to approximately 2,5m, the triangular prism is turned over after half of the entire burning period on the other side of the opening. This also makes possible to carbonize the lower part of the boards more strongly, because after flipping the flames reach this area well through the chimney effect.
- After-treatment: If desired, the charred surface may be treated with natural oils to stabilize the fragile charcoal layer. This has the advantage to touch the otherwise sooty surface without becoming black.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 15 N° 4 2019
pp. 278-283

Other possible aftertreatments include coarse removal of the carbon layer by manual brushing. The top layer is then removed, cleaned with damp cloths and then oiled. These oils can be for example kaki-oil, tung oil or flux oil. To improve this procedure the oil coating is briefly heated again with a gas flame. This process produces a very dark surface, structured at the same time by the harder, lasting latewood annual rings. These boards are also used for cladding facade (Stelzer 2016).

## GAS FLAMING

Treating the wood surface with gas is less a matter of producing a purely charred surface than to receive a dark emphasis of the tree ring drawing by an additional brushing. The burning also causes a "hard and resistant surface" (Rothkamp et al. 2003).The process described below shows the preparation of Yakisugi wood from the manufacturer by flaming with a gas mixture. This mixture allows a stronger flame with higher temperatures. Charring with gas use a special customized machine (Fig.9). The planed boards are moved forward by automatically controlled conveyor rollers. Depending on the intensity of the flame, it is possible to produce different thicknesses of the charred layer by changing the speed of the conveyor rollers. The flame impinges on the board from above and the degree of charring can be determined depending on the intensity of the gas supply and feed rate (Fig.10). For boards which are too wide for the machine or which require reworking, a manual gas flame device is used.

***Fig. 9.***
***Wood charring machine using gas (Stelzer 2016).***

***Fig. 10.***
***Different gas charred surfaces (Stelzer 2016).***

In contrast to the traditional method, flaming with gas does not enable, according to Morishita, to reach the same charred layer thickness up to 5mm

## DECORATIVE SHAPING

After the carbonisation process, the wooden boards run through a brushing machine (Fig.11). This removes the soft carbon layer and leaves a structure on treated surface. In a closed chamber with an exhaustion system, individual coarse brushes are mounted horizontally. These brushes are applied many times over the carbon layer. At the same time, an amount of the earlywood is removed. A softer counter-rotating brush at the end of the procedure will eventually brush away fine particles.

***Fig. 11.***
***Brushing machine for charred wooden boards (Stelzer 2016).***

***Fig. 12.***
***Brushed charred wood board (Stelzer 2016).***

Depending on how intensively the board was charred, part of the charred, dark latewood layer remains (Fig.12). After brushing, the boards can be treated with natural oils, depending on the interior or exterior use (Fig.13). By subsequent oiling, the already emphasized structure can be emphasized once again and the colour setting of the wood can be determined. By painting the surfaces and then light brushing, another effect of a coloured wooden surface can be achieved (Fig.14). Colour schemes, are particularly suitable for interior work. In order to use coloured wooden surfaces such as this outdoors, a suitable surface finish is required, which protects against UV radiation and the effects of moisture

***Fig. 13.***
***Exampe of Yakisugi treated Sakuma (Stelzer 2016).***

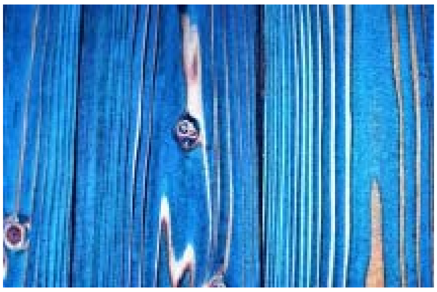

***Fig. 14.***
***Painted brushed charred brushed wooden façade in wooden surface in Asahikawa (Stelzer 2016).***

## DISCUSSION

The aim of this work was to investigate whether the traditional Japanese method "Yakisugi" can also be used in Central Europe as a chemical-free, thermal processing for wood cladding lumber facades. It has been shown that using this form of charred wood in the facade area is a very effective product, both technically and in terms of design. A protective effect is given. However, the facade timbers should be technically correct applied on the building. For certain areas of the facade where excessive moisture accumulation is expected, should be used other building materials. The ground contact should be avoided. Areas where physically surface damage is expected, for example a bicycle which is lean against the facade, should be avoided too. Any other areas of the house can be protected with charred facade cladding. In this research, buildings with both orientations (horizontal and vertical) of "Yakisugi" gladding facades were found. A further development possibility of the traditional Japanese method also for European wood species such as Spruce (*Picea Abies*) could be achieved.

Using a gas flame for charring should not be the first choice for manufacturing facade cladding boards. To achieve a consistent and uniform carbon layer would need a high consumption of gas. It's also a slow process. The advantage of an environmentally friendly method is not achievable. Furthermore, the gas consumption means an additional cost, which would increase the price for the product.

The production of charred facade boards requires some preconditions, as the process may pose a threat to the surrounding environment around the production site through the use of open flames and the formation of smoke with glowing particles. The production site cannot be chosen flexibly. The circumstances of these dangers require serious preparation. It requires sufficient safety distance to buildings, vehicles or flammable dangerous goods. Heavy smoke only occurs during the carbonization process and when the fire is extinguished. During the firing process, burning particles can be blown away by the wind into further distances (Stelzer 2016).

## ACKNOWLEDGMENT

The authors thanks for the support to Dr. Hikaru Kobori from Shizuoka University, to Terumitsu Miyazawa from Fan Landscape Inc. and to Isao Morishita from Shinwa. Inc. in Shizuoka, Japan. Also a special thanks goes to Dr. Eugenia Tudor from Salzburg Universitiy of Applied Sciences / University “Transilvania” of Brasov for the suggestions during the editing of this paper.

## REFERENCES

Scheiding W, Grabens P, Haustein T, Haustein V, Nieke N, Urban H, Weiß B (2016) Holzschutz, München: Hanser, 2016.

Niemz P (1993) Physik des Holzes und der Holzwerkstoffe, Leinfelder- Echterdingen: DRW Verlag, 1993.

Kollmann F (1951) Technologie des Holzes und der Holzwerkstoffe - Zweite Auflage, Erster Band, Berlin: Springer Verlag, 1951.

Weber K, Quicker P (2018) "Properties of biochar," in Fuel, Volume 217, pp. 240-261, Elsevier, 2018.

Kymäläinen M (2017) Surface modification of solid wood by charring, New York: Springer Science+Business, 2017.

Stelzer R (2017) "Oberflächliches verkohlen von Schittholz für einen langanhaltenden Außen- und Inneneinsatz," Masterarbeit, Fachhochschule Salzburg, Campus Kuchl, 2017.

Hill C (2006) Wood Modification: Chemical, Thermal and other Processes, West Sussex: John Wiley & Sons, 2006.

Forestry F (1985) "Industrial charcoal making," Food and Agriculture Organisation of the United Nations, Rome, 1985.

Rothkamp M, Hansemann W, Böttcher P (2003) Lack- Handbuch Holz, Leinfeld- Echterdingen: DRW Verlag, 2003.

Špilák D, Tereňová L, Dúbravská K, Majlingová A (2018) Analysis of Carbonized Layer of Wood Beams with Different Geometric Cross-Section Shape. Fire Protection and Safety, 12(2):65-81.

Vavrušková K, Lokaj A (2009) Fire Resistance of Wooden Constructions. Sborník vědeckých prácí Vysoké školy báňské – Technické Univerzity Ostrava 1:25-30.

Buchanan AH (2001) Structural design for fire safety. West Sussex: John Wiley & Sons, 2001.

VanderGoot J (2017) Architecture and the forest aesthetic: A new look at design and resilient urbanism, Bocca Raton: Taylor and Francis Group, pp. 276.