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# Fire properties of wood-based panels

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**Abstract:** The paper presents considerations related to the charring rate and charring depth of wood-based materials. It discusses grounds of research methods and presents the course of analytical calculations based on European standard regulations.

*Keywords:* charring rate, charring depth, OSB panel, fire

## INTRODUCTION

Wood-based panels are materials made of wood scraps, bonded with adhesives using pressure and high temperature. They are used in construction, transport and in the furniture industry. The advantages of such materials include high strength, durability, stability of parameters, and simple installation. One of the types of wood-based panels are the *Oriented Strand Boards – OSB.* The OSB is a multilayer panel made of strip-shaped wood chips bonded with adhesives. In the outer layers of the board the wood strands are arranged parallel to the length or width of the board, while in the internal layer the wood flakes are arranged randomly or at the right angle to the outer layer strands [2]. OSB panels have a wide range of applications in the construction industry, especially in buildings made in the timber frame technology, where they are used for finishing walls, floors and ceilings. Additionally, OSBs are used for roof panelling and for construction of structural elements, i.e. lattice structures, I-beams and girders, as well as interior fittings.

## FIRE PROPERTIES OF OSB PANELS

The use of OSB panels in the above mentioned applications entails the necessity of putting special attention to the general properties characteristic to timber and wood-based materials which can be especially important in terms of fire safety of buildings.

The basic property of timber is its flammability. Burning of timber is a multi-stage process, where at the beginning its surface undergoes charring, creating a thick layer of pyrolytic carbon. The produced layer, thanks to its low heat transfer properties, reduces inflow of oxygen to the deeper part of the element, which remains unexposed to thermal influence, thus reducing the temperature rise of the timber element. This process is accompanied by two stages: endothermic and exothermic one [7].

The first, endothermic stage, proceeds in temperatures below 100°C due to the high content of moisture (ca. 15%) – this is when the timber drying process occurs. Afterwards, when the temperature exceeds 125°C, volatile substances start to be released, which causes degassing of the timber substance, with the process being intensified in temperatures above 150°C. Another, exothermic stage, is the beginning of the burning process, when at the temperature of 250°C the timber surface reaches its flash point and flammable gases are produced. OSB panels with the minimum density of 600 kg/m$^3$ and minimum thickness of 9 mm, in accordance with the European standard [5], are classified in the reaction to fire class D-s2 or $D_{FL}$-$_{S1}$ which corresponds to the designation of "inflammable" [6].

Direct influence of fire on all surfaces of the wood-based material is determined according to the charring depth and charring rate, in accordance with standard EN 1995-1-2 [1], and the publications based *inter alia* on standard [8], [9] and [10].

The charring depth shall be measured from the outer surface of the element, up to the border between the charring layer and the non-charring part of the element (char-line). The charring depth can be calculated using the following formulas:

- for one-dimensional charring (Fig. 1)

$$d_{\mathrm{char},0} = \beta_0 \cdot \mathrm{t} \tag{1}$$

- for the notional charring which incorporates the effect of corner roundings (Fig. 2)

$$d_{\mathrm{char,n}} = \beta_n \cdot \mathrm{t} \tag{2}$$

where:

| | |
|---|---|
| $d_{char,0}$ | - is the design charring depth for one-dimensional charring [mm] |
| $d_{char,n}$ | - is the notional design charring depth, which incorporates the effect of corner roundings [mm] |
| $\beta_0$ | - is the one-dimensional charring rate under standard fire exposure [mm/min], |
| $\beta_n$ | - is the notional design charring rate, the magnitude of which includes for the effect of corner roundings and fissures[mm/min] |
| t | - is the time of fire exposure [min]. |

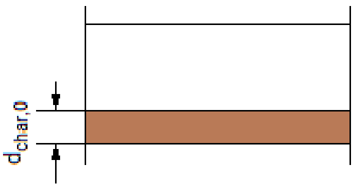


**Fig. 1** One-dimensional charring of wide cress section ( fire exposure on one side).

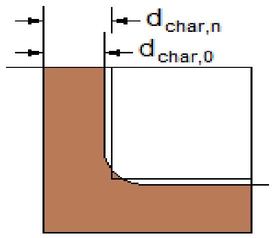


**Fig. 2** Charring depth for one-dimensional charring and notional charring depth

In accordance with the standard [1], the unidirectional charring depth for wood-based panels, with pre-defined characteristic density of 450 kg/m$^3$ and panel thickness of 20 mm, is 0.9 mm/min. For cases not conforming with the criteria, charring rate is calculated using the following formula:

$$\beta_{0,pt} = \beta_0 \cdot k_p \cdot k_h \tag{3}$$

therefore:

$$k_p = \sqrt{\frac{450}{\rho_k}} \tag{4}$$

$$k_h = \sqrt{\frac{20}{h_p}} \tag{5}$$

$\rho_k$ - is the characteristic density [kg/m$^3$]

$h_p$ - is the panel thickness [mm]

When the declared/measured OSB panel thickness is not available, the density coefficient used in formula (3) is based on characteristic densities contained in standard EN 12369. For

OSB/3 panels designed for application in moist conditions, regardless of their thickness $\rho_k = 550$ kg/m$^3$.

## Laboratory tests

The Fire Testing Laboratory of the Building Research Institute carried out charring rate tests of OSB/3 wood-based panels of nominal thickness: 12 mm (13.3 mm), 18 mm (18.7 mm), 22 mm (22.7 mm) and density of 630 kg/m$^3$.

The sample elements were exposed to one-sided heating conditions according to the standard temperature-time curve [4].

During the tests, the temperatures at the depths (counted from the exposed side) of 5, 10, 15, and 20 mm were measured (depending on the panel thickness), using a 5-minute measurement interval.

Temperature distributions for the tested panels are shown in the following diagrams:

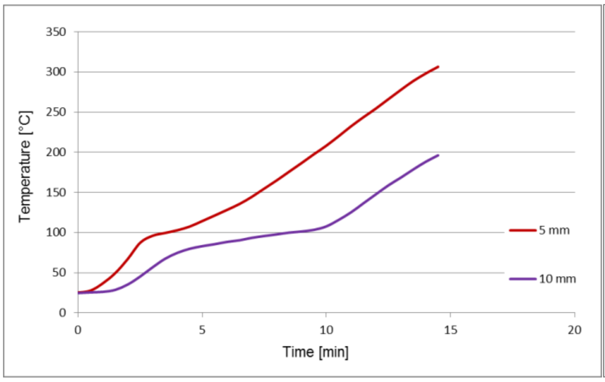


**Fig. 3** Diagram of temperatures in the OSB/3 panel of 13.3 mm in thickness.

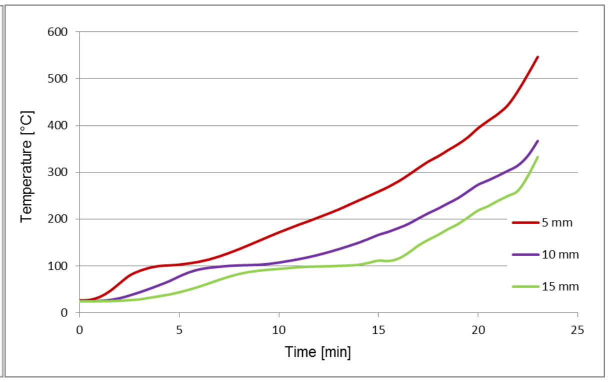


**Fig. 4** Diagram of temperatures in the OSB/3 panel of 18.7 mm in thickness.

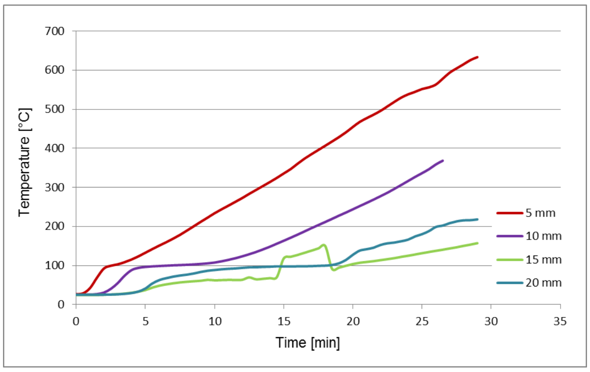


**Fig. 5** Diagram of temperatures in the OSB/3 panel of 22.7 mm in thickness.

Based on the obtained temperature measurements, the variable charring rate in function of the panel thickness was determined, as presented in Tables 1 - 3.

**Table 1.** Results of charring depth measurements for 13.3 mm panel

| Charring depth [mm] | Charring time [min] | Charring rate [mm/min] |
|---|---|---|
| 0 - 6.3 | 9.6 | 0.65 |
| 6.3 -11.3 | 4.9 | 1.02 |

**Table 2.** Results of charring depth measurements for 18.7 mm panel

| Charring depth [mm] | Charring time [min] | Charring rate [mm/min] |
|---|---|---|
| 0 - 5.7 | 10.7 | 0.54 |
| 5.7 - 10.7 | 6.2 | 0.80 |

| | | |
|---|---|---|
| 10.7 - 15.7 | 5.8 | 0.87 |

**Table 3.** Results of charring depth measurements for 22.7 mm panel

| Charring depth [mm] | Charring time [min] | Charring rate [mm/min] |
|---|---|---|
| 0 - 5.7 | 8.49 | 0.67 |
| 5.7 - 10.7 | 8.79 | 0.57 |
| 10.7 - 15.7 | 5.93 | 0.84 |
| 15.7 - 20.7 | 5.48 | 0.91 |

Table 4 presents charring rate obtained based on the performed tests and empirical formulas.

**Table 4.** Mean charring rate vs. OSB/3 panel thickness

| Panel thickness [mm] | Average charring rate of the tested OSB/3 panels [mm/min] | Charring rate [mm/min] of OSB/3 panels calculated acc. to the standard [1] |
|---|---|---|
| 13.3 | 0.78 | 0.93 |
| 18.7 | 0.69 | 0.78 |
| 22.7 | 0.72 | 0.71 |

The charring depth considering the values from Table 4 and duration of fire influence on the OSB/3 panels, assumed in accordance with the test duration for each panel, are presented in Table 5.

**Table 5.** Charring depth considering two values of charring rate

| Panel thickness [mm] | $d_{char,0}$ (test) [mm] | $d_{char,0}$ (standard [1]) [mm] | t [min] |
|---|---|---|---|
| 13.3 | 10.92 | 13.02 | 14 |
| 18.7 | 15.18 | 18.17 | 23 |
| 22.7 | 20.88 | 20.59 | 29 |

According to the obtained results and observations made during the tests, it is assumed that charring of the OSB/3 panels has started at temperature $T_{char}$ = 200°C.

## CONCLUSIONS

Charring rate assessed using the empirical formulas contained in the standard [1] is higher than the actual value estimated using the experimental method. Considering that the so assessed charring rate is higher than the actual speed, it allows to safely use such obtained charring rate in strength calculations of load bearing structures in fire conditions.

Analysis of times and estimated charring rate of panels shows that in the first stage of the charring process the speed is ca. 0.6 mm/min. In the next stage charring time increases and at the same time charring rate slightly rises. The increase of charring time is caused by creation of a carbonized layer (pyrolytic carbon layer) which insulates the thermally intact panel layers. During further heating, charring rate rises, which is caused by falling off of the charring panel layers, consequently revealing the deeper layers of the panel previously not exposed to thermal influence.

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