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APPLICATION OF THE CALCULATING METHOD FOR DETERMINING THE CLASS OF FIRE RESISTANCE OF WOODEN BEAMS

The article is devoted to the behavior of wooden beams with fire protection in case of fire. The results of calculations of the geometry of the charcoal zone of fragments of wooden beams of various configurations with fire protection are presented.

***Key words**: fire resistance, fire bio protection, scheme of measuring geometric parameters of the charred zone of samples.*

Introduction. Researches [1; 2; 3] show that wooden beams in buildings with wooden structures are one of the most crucial elements to which special requirements for fire resistance are needed. Among the most common means of fire protection of wood, the most widespread are fire and bio protecting impregnations [4, 5]. The mechanism of such means is based on slowing down of burning processes on the surface of elements of wooden structures. Nevertheless, over time the thermal effects of fire-treated layer is subjected to decomposition and charring process extends to the unprotected layers, whereby the beam is still destroyed. Considering this, the parameters for predicting the charring zone, which is one of the main parameters for calculating fire resistance limits of wooden beams according to the standard must be indicated [6].

Raising the problem and its solution. The purpose of this article is an example a calculation technique for predicting geometric configuration of the zone of charring of wooden beams with fireproof impregnation when exposed to fire with a standard temperature regime.

To achieve this goal, we have set following tasks:

- present the existing methodology experimental researches of fragments of wooden bearing beams with integrated protection against heat and fire, biological damage to the wood and determine the temperature in the inner layers of samples and the thickness of the charred layer;
- on the basis of the test results, to reveal the regularities of growth of the thickness of the charred layer;
- to develop a methodology for calculating geometric configuration of the charred zone for different sizes of beams .

Results. To study the behavior of wooden beams, their fragments were used, the scheme and the form of which are shown in Fig. 1. Test samples were made of pine bars with dimensions of 200*65*400 mm, and plywood with dimensions of 400*400*16 mm.

For the tests, a heating installation, which is a steel chamber with dimensions of 500 × 500 × 500 mm was used. On the back side, the chamber has a hole which diameter is 60 mm for installing the burner nozzle. On the inside, the walls of the chamber are protected with a layer of non-combustible insulation "Conlit 150" produced by Rockwool company with thickness of 100 mm to minimize heat loss, which also protects it from high temperatures. General view of the installation for fire tests of fragments of wooden beams with fireproof impregnation under the standard temperature regime [7].

Using the measurements, the average lateral thickness and the average end thickness of the charred layer were calculated, the graphs of the dependences on exposure time. Analyzing the graphs it can be seen that the dependencies of the thicknesses of charring on time are similar. Charring of wood with impregnation occurs much more slowly. Impregnation of the type 4 [8].

When predicting geometric configuration of the charred zone there was a hypothesis the idea of which was an assumption that, when the charring behavior depends on temperature, the charring zone must be limited to a certain isotherm. To implement this hypothesis, it is

necessary to construct isotherms in the cross section of the fragment. In this case, two methods can be used: by solving a heat conduction equation, or by approximating isotherms by means of interpolation functionals. To solve the heat conduction problem, the thermophysical characteristics of wood with fire protection which are unknown are required therefore, the second method was used [8].

To approximate the isotherms, we used a functional of the form:

$$y(x) = y_0\left(1-\left(\frac{x}{x_0}\right)^p\right)^{1/p}, \qquad (1)$$

where x_0 and y_0 – coordinates on the axes x and y at their intersection by an approximating curve; p – exponent determined by approximating curve.

A graphic representation of curves set by the expression is given in [9].

Using this approach and measurements of temperature at the reference points of the section during the tests [9], interpolation of temperature distributions was carried out.

For prediction of the charred zone of the beam fragments, measurements of the charring thicknesses. Comparing the measured thicknesses of the charred layer and found temperature distributions, critical charring temperatures were determined using the formula:

$$T_{\text{кр},i} = T_{0i} + (T_{gi} - T_{0i})\left[\frac{0{,}5a - d(i)}{0{,}5a}\right]^{Q_{gi}} \qquad (2)$$

where T_{0i}, T_{gi} – the temperature of the first and last points of the control section line in i moment of time; a – section width; Q_{gi} – exponent of approximating parabola in i moment of time; $d(i)$ – dependence of lateral thickness on exposure time [10].

Dependencies of the thickness of charring on time were obtained on the basis of regression analysis. The parameters of regression dependences are given in [10].

The dependencies of rate of the side charring on time were obtained by differentiating the regression dependences described in Table 2 [10]. The parameters of the obtained dependences are given in Table. 3 [10].

Using the data of Table 2 [10] and the developed calculation method, charring zones for the tested fragments were set. The results are shown Table 1.

Table 1 – Fire resistance class for wooden beams without taking into account the carbonization zone

Type of wooden beams	fire resistance class, min
Sample without impregnation	9
Sample with impregnation «Neomid 450-1»	28
Sample with impregnation «Senezh»	31
Sample with impregnation «Strazh-2» (BS13)	33

Data tab 1 indicate that fire retardants have a noticeable effect on increasing the fire resistance of wooden beams, but this effect is insufficient as it does not allow for providing the required fire resistance limit for required fire resistance classes R 45 and R 60.

In view of the conduct of the study, it is possible to formulate the main provisions of the method of estimation of fire resistance of wooden beams with fireproof impregnations. The implementation of the proposed method requires the implementation of such procedures.

1. Determination of temperature distributions at each control moment of the development of a fire using the solution of the heat equation (1) using one of the numerical methods, finite differences, or finite elements.

2. By the formula (2) of the experimental dependencies of the type shown in Table. 1 actual work for one or another type of fire retardant is determined by the critical temperature at each control point of the time of fire development.

3. The isoterm, corresponding to the determined critical temperature, determines the configuration of the carbonating zone that is cut off by this isotherm at each control moment of the fire development.

4. Under the temperature field in the non-charred zone, the strength and deformation characteristics of the wood are determined in accordance with the method described in the previous paragraph of the actual work at each control point of the time of the development of the fire.

5. The method of increasing deformation determines the bearing capacity of a wooden beams with fire protection at each control point of the time of fire development.

6. Based on the values obtained, the curve of reducing the bearing capacity with the time of the development of the fire is constructed.

7. By comparison at each time of the development of the fire of the bearing capacity of the beam and the operating load is determined by the time when the operating load becomes equal to or greater than the carrying capacity, which will be the time of the onset of the limiting state of its loss.

According to the algorithm of the proposed method, the temperature distributions given in Fig. 1.

Applying the approach for determining the configuration of the charcoal zone, charcoal zones were determined for the cross section of beams with and without fire retardant impregnations. The results are presented in Fig. 2.

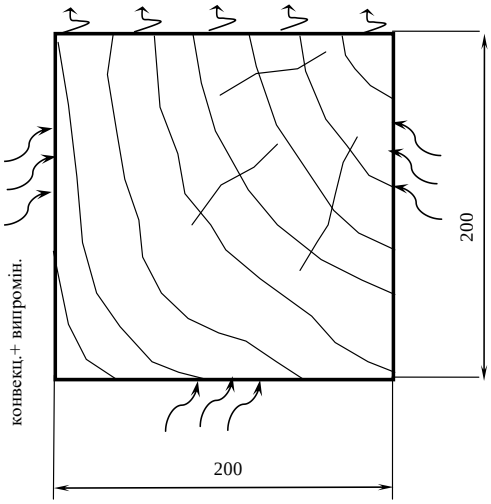

Fig. 1 – The calculation scheme of the section of a wooden beam for the elaboration of procedures of the proposed method of calculation of fire resistance

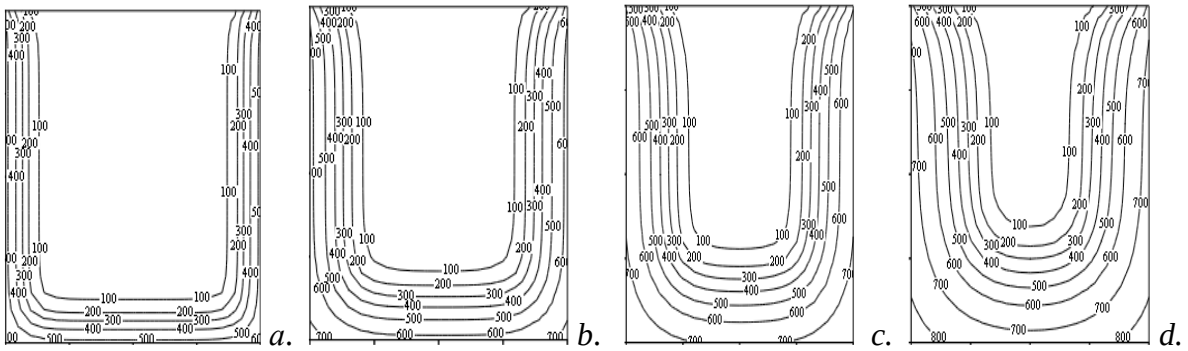

Fig. 2 – Temperature distributions in the section of a wooden beam and the corresponding scale at time points: a - 15 min; b - 30 min; c - 45 minutes; d - 60 min

From the data on the configuration of the carbonized section of the cross section, one can see that the type III fire protection means possess the greatest fire-protection ability.

Using the obtained configurations of the charcoal zone, we can determine the distributions of the mechanical characteristics of the cross section of the beam, the fire resistance, which is subject to the estimation by the method proposed by us. Fire resistance class, defined by the graphs in Fig. 3 are reduced to the table. 2

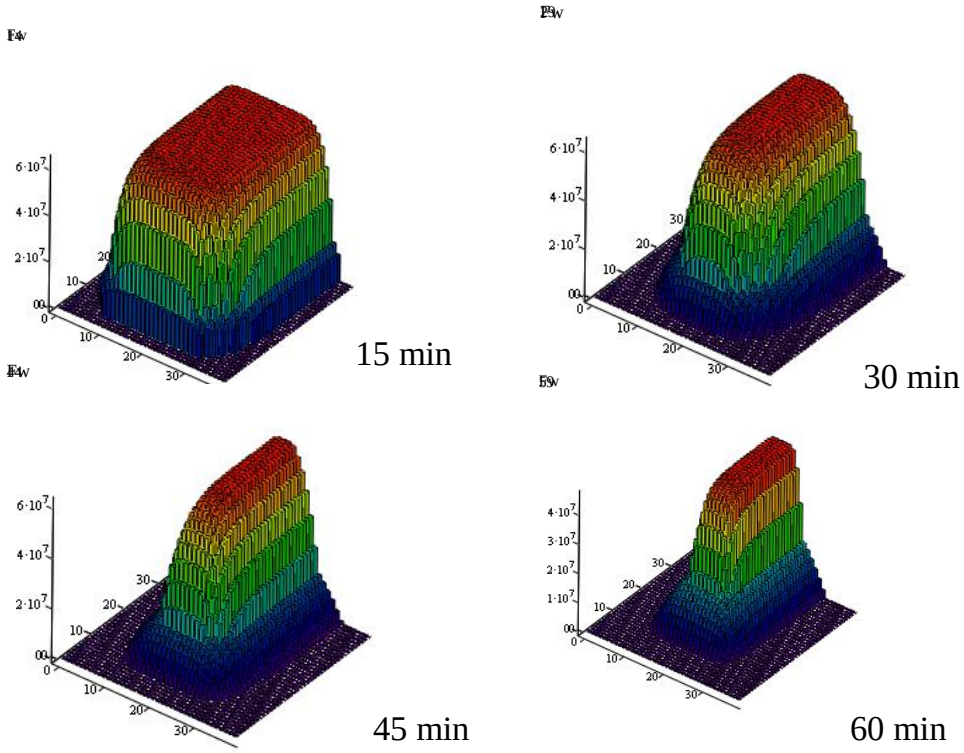

Fig. 3 – Typical distributions of wood strength in the section of beams with and without fire retardation at different times of fire exposure to fire.

Table 2 – Fire resistance class for wooden beams section 200x200 with and without fire protection

Type of wooden beams	fire resistance class, min
Sample without impregnation	31
Sample with impregnation «Neomid 450-1»	33
Sample with impregnation «Senezh»	35
Sample with impregnation «Strazh-2» (BS13)	36

Conclusions.

1. The method of estimation of fire resistance of wooden beams with fireproof impregnation is developed;

2. Fireproof impregnation has a noticeable effect when increasing the fire resistance of wooden beams, but this effect is insufficient as it does not allow to provide the required fire resistance limit for required fire resistance classes R 45 and R 60;

3. The most effective in increasing the fire resistance of the beam, the fragment of which was investigated, is a fire retardant impregnation of the III type;

4. Increase of the width of the section of a wooden beam to 200 mm leads to a significant reduction in the effectiveness of fireproof impregnations to improve the fire resistance class, as it increases by a maximum of 2-3 minutes;

5. The proposed method for assessing fire resistance of fireproof wooden beams is most effectively used for beams with a width of a cross section not more than 200 mm.

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ПРИМЕНЕНИЕ РАСЧЕТНОГО МЕТОДА ОПРЕДЕЛЕНИЯ КЛАССА ОГНЕСТОЙКОСТИ ДЕРЕВЯННЫХ БАЛОК

Статья посвящена исследованию поведения деревянных балок с огнезащитой в условиях пожара по стандартной температурной кривой. Представлены результаты огневых испытаний и расчетов геометрии зоны обугливания фрагментов деревянных балок различной конфигурации с трема огнезащитными средствами, позволяющими определить закономерность эффективности огнезащитного пропитки для повышения класса огнестойкости данной конструкции.

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ЗАСТОСУВАННЯ РОЗРАХУНКОВОГО МЕТОДУ ВИЗНАЧЕННЯ КЛАСУ ВОГНЕСТІЙКОСТІ ДЕРЕВ'ЯНИХ БАЛОК

Стаття присвячена дослідженням поведінки дерев'яних балок з вогнезахистом в умовах пожежі за стандартною температурною кривою. Представлені результати вогневих випробувань та розрахунків геометрії зони обвуглення фрагментів дерев'яних балок різної конфігурації з трьома вогнезахисними засобами, що дозволяє визначити закономірність ефективності вогнезахисного просочення для підвищення класу вогнестійкості даної конструкції.