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Research of the process of spread of fire on beams of wood of fire-protected intumescent coatings

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Abstract. The article presents the results of the protection of wooden building structures with intumescent coatings for the resistance to high-temperature flame resistance. The essence of the method of determining the effectiveness of the coating was the impact of standardized flames on fireproof wood and the definition of values. Based on the data obtained, criteria were established that correspond to the degree of damage to the specimens and the increase in the combustion temperature, resulting in a decrease in weight loss. To determine the effectiveness of fire protection in the developed coatings studies on the combustibility of wood in terms of weight loss and flue gas temperature were conducted, and it was found that with coating the degree of damage to the samples in length does not exceed 26%, the degree of damage by mass does not exceed 2% and the flue gas temperature does not exceed 115°C. However, a protective layer that is of considerable thickness to the building structure should be applied to ensure its protection, since, at a higher intensity of thermal action, the fire resistance of the wood may decrease due to the formation of a low coke layer. Full-scale tests using model specimens of wooden beams under the action of a high-temperature flame furnace have shown that the intumescent coating can withstand high temperatures, effectively preventing the penetration of heat into the material due to the formation of a swollen coke layer, which affects the speed and depth of the temperature.

1. Introduction

Reducing the fire risk of wooden construction is not only economical but also social and environmental. Today, the search for the latest high-efficiency means of fire protection of wood is intensively underway. But fire protection today must not only ensure the standard fire resistance of wood, but also preserve its operational parameters, address environmental safety and durability. Therefore, an important problem of ensuring the life and safety of construction sites is the development, from an economic, technological and environmental point of view, of inflatable flame retardants for building structures, which can be used not only on par with existing analogues, but also be highly effective in special fields of construction, which makes it possible to prevent man-made accidents [1-4].

In recent years, the proposed research direction known works that are aimed at creating flame retardants, which in the process of heating, form a coke insulation layer on the surface of the wood. The presence of such a layer allows to slow down the warming of the material (steel structure) and to preserve its functions in the fire for a specified period of time and converts the wood to combustible materials [5].

The simplest fire retardants based on inorganic binders contain bound water, which evaporates during heating and blocks heat transfer to the protective surface. As a binder, mainly use sodium liquid glass, Portland cement, alumina cement, phosphate and aluminosilicate binders are used [6-9]. Such materials are characterized by a slight elasticity, with the action of the temperature factor in the environment emit only water vapor [10]. However, such coatings are short-lived and inefficient and do not provide sufficient adhesion strength because they have a large temperature coefficient of linear expansion. Instead, coatings based on inorganic and organic substances are capable of forming a flattened coke layer on the protected surface, which significantly reduces the heat transfer processes of [11].

The effectiveness of the use of flame retardants based on organic substances is shown in works [12], where due to the action of flame retardants and foamers can have a significant effect on the formation of the foam coke layer, namely to increase its stability, density and durability due to modification of polymer additives [13-14]. These studies are aimed at the production of polymer-inorganic flame retardants, which can't provide fire resistance and smoke-forming capacity of wooden building structures for a long time.

Therefore, the establishment of long-term thermal effects on thermal conductivity and the effectiveness of fire protection is an unresolved component of ensuring the fire resistance of building structures, which necessitated research in this area.

2. Determine the purpose and objectives of the study

The research is aimed to determine the features of fire protection of wooden structures against the effects of high temperature with long-term impact on the intumescent coating.

To achieve the goal, the following tasks were solved:

− to establish the features of combustion of fire-protected wood when treated with intumescent coating;

− determine the limits of fire propagation for building enclosure structures treated with intumescent coating, with long-term thermal action, characterized by high-temperature effect.

3. Raw materials and test methods

To establish the flammability group of the wooden building structure, samples of wood untreated and treated with a flame retardant intumescent coating based on organic and mineral substances with a flow rate of 260 g/m^2 were used.

To determine the fire propagation limit for building enclosure structures, three specimens of pine beams were tested (Figure 1), on which the fire protection coating "FAIRWOL-WOOD" was applied:

− sample No. 1 − beam with a cross section of 180×50 mm and a length of 2 m. The average value of the thickness of the coating (dry state) is 1.21 mm.

− sample No. 2 − beam with a cross section of 180×50 mm and a length of 2 m. The average value of the coating thickness (dry state) is 0.72 mm.

− sample No. 3 − beam with a cross section of 180×50 mm and a length of 2 m. The average thickness of the coating (dry state) is 1.42 mm.

Figure 1. The fireproof pine beam from the side of the kiln before testing.

The determination of combustibility of building materials was carried out according to [15].

The essence of the method lies in the determined resistance of the samples after thermal action in the fire chamber according to the following parameters: flue gas temperature, degree of damage in length, degree of damage in mass, duration of self-combustion.

Building materials, depending on the values of flammability parameters, are divided into four groups of flammability G1, G2, G3, G4 in accordance with table 1.

Table 1. Classification of combustible building materials

Material combustion groups	Flammability parameters			
	Flue gas temperature	The degree of damage in length	The degree of damage by mass	Duration of self-burning
G1	<135	<65	<20	0
G2	<235	<85	<50	<30
G3	<250	>85	<80	<60
G4	>250	>85	>80	>60

Materials should be attributed to a specific flammability group, provided that all values of the parameters set in Table 1 are complied with.

Determination of the fire propagation limit for building enclosures was carried out according to the method described in DBN B.1.1-7:2016 “Fire safety of construction objects. General requirements” [16].

The essence of the test method is to determine the extent of damage to the beams beyond the boundaries of the fire zone under conditions that correspond to the temperature regime for 15.0 ± 0.5 min.

For testing of rod structures (beams, etc.), the specimens should have a length of 1500…2000 mm and a thickness according to the technical documentation. The samples were placed in the openings of the firing furnace under the furnace coating so that the length of the control zone (the part leaving the furnace) was not less than 750 mm (figure 2).

Damage is considered to be charring, melting and burning of the materials of the sample to a depth of more than 2 mm.

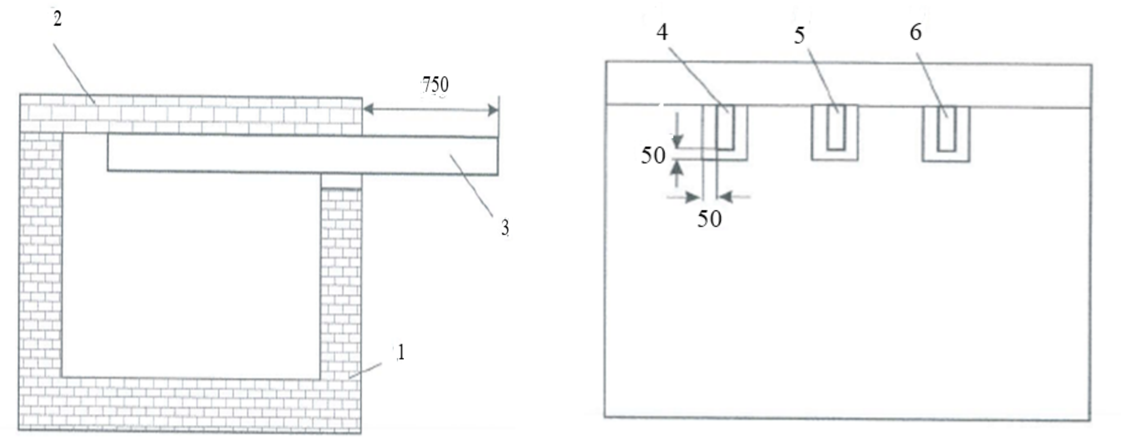

Figure 2. Location of samples of beams in the furnace: 1 – oven; 2 − cover of the furnace; 3 − samples of beams; 4 − sample No. 1; 5 − sample No. 2; 6 − sample No 3.

Beyond the fire spread beams are divided into three groups:
− M0 (fire spread is 0 cm);
− M1 (M ≤ 250 mm);
− M2 (M> 250 mm).

4. Results and discussion

For more complete information on the combustibility of wood as a building material, a study was conducted in accordance with of untreated and flame retardant intumescent coatings based on organic and mineral substances of wood samples. During the studies, the temperature of the flue gases, the duration of self-burning of the samples, the length of damage and the weight loss of the samples were determined (figure 3).

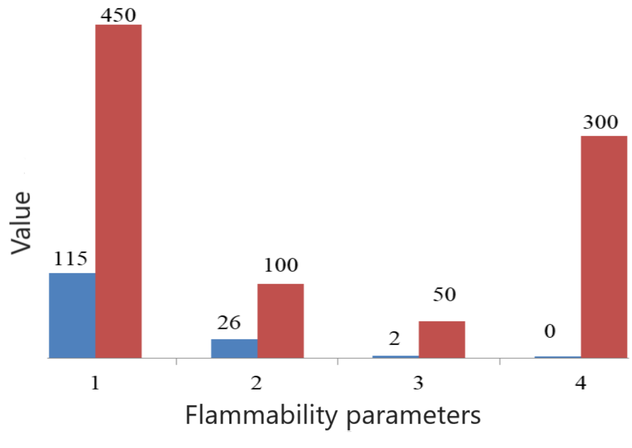

Figure 3. Determination of combustibility of wood according to [7] (blue − flame retardant wood, red − untreated wood): 1 − flue gas temperature (T, ºC); 2 − the degree of damage of the samples in length (SL, %); 3 − the degree of damage by weight (Sm, %); 4 − duration of self-combustion (τ, s).

Samples of white material measuring 1000 mm × 190 mm, with an average thickness of 20.3 mm, were tested (figure 4). Material samples were fixed on a non-combustible basis (asbestos-cement sheet 10 mm thick). The conditioning of the samples was carried out at an air temperature (23 ± 2) °C and a relative humidity (50 ± 5)% for 48 hours.

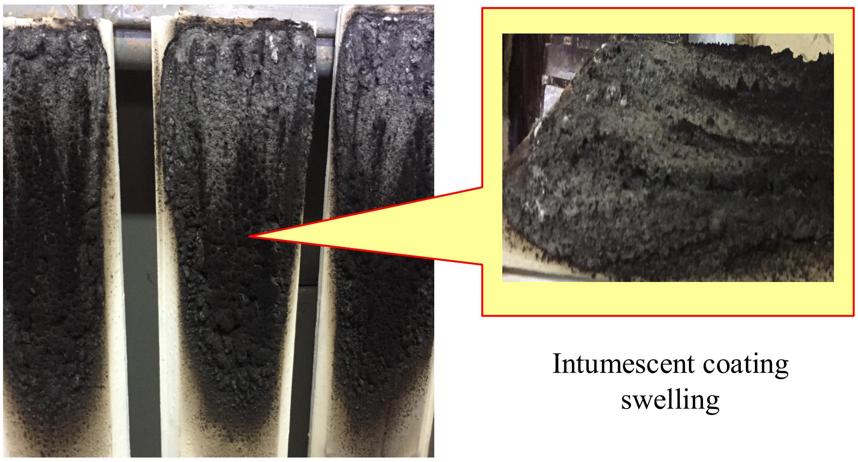

Figure 4. Test results of the model specimen treated with flame retardant intumescent coating.

As a result of researches (figure 3, 4) it is established that wood which is protected by intumescent coating on the basis of organic and mineral substances is a building material of low flammability (G1), and untreated wood is classified as a building material of high flammability (G4).

The results of measurements of temperatures in the furnace are shown in figure 5.

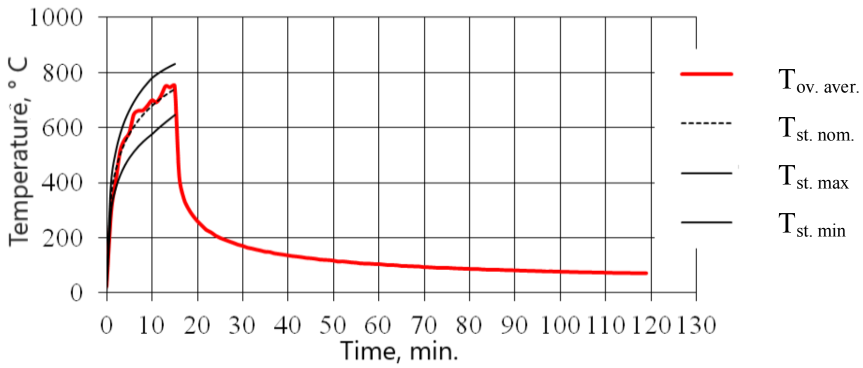

Figure 5. Temperature in the furnace.

The results of fire exposure are shown in figure 6.

(a) (b)

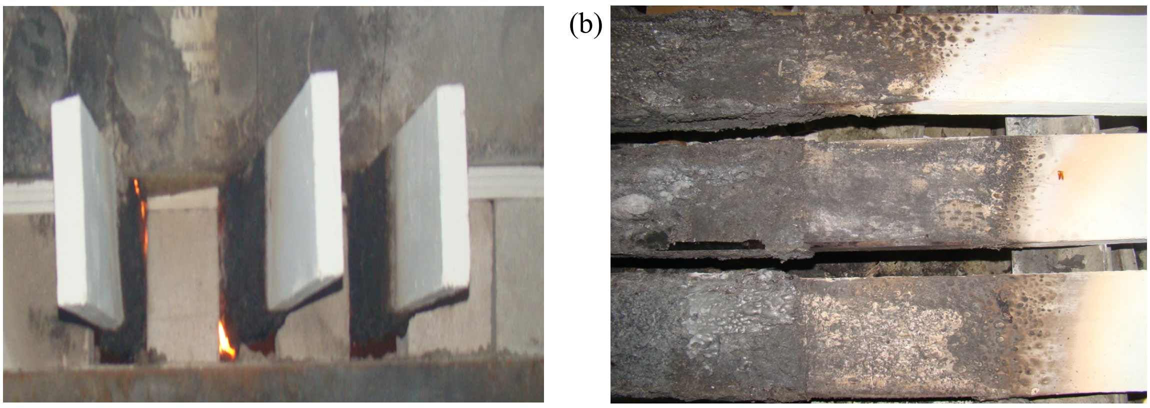

Figure 6. Specimen appearance: a – during tests; b – after firing.

The average thickness of the swollen coating layer in the area of fire exposure on sample No. 1 was 16 mm, sample No. 2 − 11 mm, and sample No. 3 − 18 mm. Damage (charring, melting and burning of beams) of samples No. 1 and No. 3 in the control zone did not occur. Damage (charring, melting and burning of the beam) of sample No. 2 in the control zone was 19.8 mm in length (only the lower corners of the beam were damaged). The limit of spread of fire on the samples No. 1 and No. 3 is 0×1.2 = 0 cm. The limit of fire spread on the sample No. 2 is 19.8×1.2 = 24 cm.

As a result of the obtained data, it is established that pine beams of section 180x50 mm, on which the fire protection coating "FAIRWOL-WOOD" with a thickness (dry state) of 1.21 and 1.42 mm is applied, outside the fire propagation range belongs to the group M0.

Beam of pine wood with a cross section of 180×50 mm, on which the fire protection coating "FAIRWOL-WOOD" with a thickness (dry state) of 0.72 mm is applied.

5. Conclusion

These studies established the effectiveness of mixtures of organo-mineral mixtures as fire retardants for wood, in particular:

− in case of heat exposure from standard burner fire on specimens treated with intumescent coating, flue gas temperature, degree of damage of the samples by length, degree of damage by mass, duration of self-combustion did not exceed the specified value, however, a protective layer should be used to ensure its protection, since with greater intensity of thermal action, the fire resistance of the wood may be reduced due to the formation of a young coke layer;

− full-scale tests using model specimens of wooden beams under the action of high-temperature flame furnace have shown that the intumescent coating can withstand high temperatures, effectively prevents the penetration of heat to the material due to the formation of a swollen layer of coke, which affects the speed and the depth of temperature absorption.

Further research will focus on studying the processes of forming the protective layer structure and establishing a connection between the nature of the components and the properties of coatings such as the formation of foaming coke, as well as resistance to heat and weather.

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