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Transformable fire barriers in buildings and structures

Трансформируемые противопожарные преграды в сооружениях и строениях

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Abstract. Fire curtains are used in case of fire to create a temporary barrier in open technological openings, openings of buildings and structures. The paper presents the results of tests for fire resistance of samples of fire curtains. The ability of intumescent formulations to effectively prevent the spread of heat has been studied. The article presents the results of testing various compositions of Intumescent fire retardant coating (IFRC) with the addition of latex for fire curtains based on silica fiber. The temperature of samples from the non-heated side did not exceed 260 °C (the temperature in the furnace of the test facility did not exceed 1200 °C). The temperature of the sample with the addition of TiO2 at the end of the test did not rise above 196 °C. The results obtained in the work are compared with similar tests of other researchers for the period 2012–2017 fire curtains based on silica fiber.

Аннотация. Трансформируемые противопожарные преграды (противопожарные шторы) используется в случае пожара для создания временного барьера в открытых технологических проемах, проемах зданий и сооружений. В работе представлены результаты испытаний на огнестойкость образцов противопожарных штор. Изучена способность вспучивающихся составов эффективно предотвращать распространение тепла. В статье представлены результаты испытаний различных композиций интумесцентного вспучивающегося состава с добавлением латекса для противопожарных штор на основе кремнеземного волокна. Температура образцов с не обогреваемой стороны не превышала 260 °C (температура в печи испытательной установке не превышала 1200 °C). Температура образца с добавлением TiO2 по окончанию испытания не поднялась выше 196 °C. Результаты, полученные в работе, сравниваются с аналогичными испытаниями других исследователей за период 2012–2017 противопожарных штор на основе кремнеземного волокна.

1. *Introduction*

As practice shows, the most effective way of simultaneous provision of safe evacuation of people in case of fire and preservation of material values is the measures established by Federal Law No. 123-FZ [1] to limit the spread of fire, within the framework for which provision is made for the installation of fire barriers - building structures with a standard fire resistance limit.

Fire protection is aimed at finding the most effective, economically feasible and technically sound methods and means of preventing fires and their elimination with minimal damage with the most rational use of forces and technical means of extinguishing [2–7]. Automatic fire curtains are designed to divide sections of premises and structures into fire compartments for the purpose of localizing a fire, as well as filling openings in fire barriers. If a fire occurs, due to a signal from a fire alarm sensor or a signal from a fire station, the blind automatically falls and locates the fire. In [8] the statistics of fires in the cultural and entertainment facilities, and describes the various options for action in case of fire. One of the most important is a method to increase the evacuation of people from buildings. It involves the use of indoor fire barriers.

In the proposed article [9], the basic advantages of using fire-prevention curtains, as well as prospects for their development. After this are the main technical characteristics of fire barriers.

The authors of [10–12] bring the characteristics of modern fire-prevention structures used to improve the fire safety of buildings and structures. Also described are the design features of fire protection gates, doors, windows, curtains.

The authors [13] developed a mathematical model that describes the physical processes occurring in the fire curtain in the fire and determine its fire. The effectiveness of fire curtains investigated by the authors in [14–19]. With CUrisk model, the authors in [20] analyzed the development of the fire, the model is able to provide data about the failure of fire curtains and calculate the possible options for the spread of hazards fire. In his articles [21–23], the authors consider the materials of which can be made passive fire protection, as well as describe the testing methods of fire barriers in fire conditions.

Such curtains are made of fireproof sheet, which consists of glass fibers. In the initial position, the firewall is wound on a shaft of steel. The shaft is housed in a galvanized case made of steel sheet. Mounted on a wall, ceiling, suspended ceilings. The curtain fabric at the lower end has a special cutting bar. It allows you to keep the canvas unfolded. Bottom edges do not bend, do not let smoke pass. In the collapsed state, the tire is hidden among the recesses of the hull structure, so it is not visible.

Fireproof curtains are often designed as part of engineering and technical measures when developing special technical conditions.

Traditional fire protection solutions with curtains:

• separation of spaces into fire compartments;

• overlapping of window, door, elevator and other openings;

• fencing atriums, escalators, stairs;

• as a fire curtain for the separation of the auditorium and the stage space;

• the formation of pockets for collecting smoke in the under-ceiling space;

• protection against fire from nearby and adjacent buildings;

• protection of openings in fire walls, incl. when the conveyors are installed in them;

• protection of places of increased fire danger;

• as an alternative to glass fire barriers, fireproof windows and fireproof gates.

Fire-prevention curtains are used in production and logistics complexes, in parking lots and at gas stations, at railway stations, in film-concert complexes, museums, in hotel, trade and multifunctional complexes.

The purpose of this work is the development of a flame retardant polymer composition for the treatment of the silica core of a fire curtain, which will increase the fire resistance of the structure.

2. *Methods*

Testing of experimental samples of fire curtains with intumescent composition was carried out to determine the limiting states of the samples presented on the basis of the test method of the national standard of Russia 53307-2009 Fire doors and gates. Test methods for fire resistance [24] with certain assumptions. The furnace temperature, according to ISO 834-1: 1999, Fire-resistance tests – Part 1: General requirements [25], must be monitored and controlled in such a way that it corresponds to the ratio 1.

$$T = 345\log_{10}(8t+1) + 20 \tag{1}$$

where

T – is the average furnace temperature, degrees Celsius;

t – is the time, un minutes.

3. Results and Discussion

Tests have been carried out on the development of an intumescent type fire retardant composition that can become the backbone of a fire retardant curtain when applied to a silica fiber. Under fire conditions, the fireproof composition significantly expands in volume with the formation of a heat-insulating foam-coke layer. The expansion process takes place with a significant endothermic effect, and the resulting heat-insulating layer has a thermal conductivity close in value to the thermal conductivity of the air. According to a number of authors [26], the heat transfer towards the protected surface is reduced by up to 100 times due to the foam box. Before application of the intumescent compound to the sample of the fire curtain, it was mixed with a latex solution to obtain a 4: 1 ratio to achieve elasticity.

Intumescent compositions have been manufactured and tested, the formulations of which are given in Table 1.

Table 1. Shows the comparative information about the Intumescent composition

№	Name	Content,%			
		Sample № 1	Sample № 2	Sample № 3	Sample № 4
1	Graphite IR	-	12	-	-
2	Vermiculite	-	8	-	-
3	Pentaerythritol	10	8	-	-
4	Melamine	10	8	-	-
5	Titanium dioxide	5	5	12	15
6	Ammonium polyphosphate	25	21	10	12
7	Dispersant	0.02	0.02	0.02	0.03
8	Defoamer	0.02	0.02	0.02	0.05
9	Biocide	0.02	0.02	0.02	0.03
10	Thickener	0.03	-	0.03	0.04
11	Aluminum hydroxide	-	-	21	18
12	Vinyl Dispersion	30	30	32	30
13	Plasticizer	4	5	5	3
14	Coalescent	1	-	1	1
15	Microtalk	4	2	5	6

Previously, samples of fire retardants were applied to pieces of 10 to 10 cm foil for testing for flexibility, swelling and ignition. The composition was applied evenly over the entire area of the foil until a thickness of 1 mm was reached. The results are shown in Table 2.

Table 2. Study of intumescent formulations for flexibility, flammability and intumescence

№	Name	Sample № 1	Sample № 2	Sample № 3	Sample № 4
1	Cracked	Yes	No	No	No
2	Flammable	No	No	No	No
3	Height of foam coke	No	3mm	5 mm	5mm

These compositions were applied to a silica cloth, a dry film thickness of 1 mm was achieved. After this, the intumescent properties of the web were tested. For fire tests, the composition was applied to silica cloth 10 × 10 cm on both sides with one layer. The test results were taken as the mean temperature over the area from the unheated side of the samples.

Tools, equipment for testing.

• micrometer;

• gas burner with sample chamber;

• Stopwatch;

• pyrometer ADA TemPro 550;

• ruler.

A visual inspection of each sample for uniformity and homogeneity of the application of the flame retardant coating was carried out. The color of each sample is fixed.

The tests were performed alternately for each sample.

The sample was fixed around the perimeter of the fire chamber. The length of the burner flame was preset within 40–60 mm. When the burner was switched on, the stopwatch was turned on at the same time. The flame temperature of the butane burner is up to 1200 °C. The test flame retention time is 60 min. During the experiment, visual observation of the sample was carried out and recorded:

• intensity of smoke evolution;

• the presence of dropping;

• burning of the sample;

• temperature on the unheated side of the sample.

At the end of the experiment, the area of flame damage was measured.

Sample No.1 before fire test, exposure to flame in the test installation, formed foam with unheated side and state of the silica/glass fiber from the heated side (about 1200 ° C) after the tests are presents on Figures 1–4.

Based on the test results, the temperature curves are plotted (Fig. 5). At the entrance of the test, the intensity of the smoke was low / moderate. Combustion of samples 1–2 was not observed throughout the entire experiment.

Figure 1. Sample No.1 before fire test

Figure 2. Exposure to flame in the test installation

Figure 3. Formed foam with unheated side

Figure 4. The state of the silica/glass fiber from the heated side (about 1200 ° C) after the tests

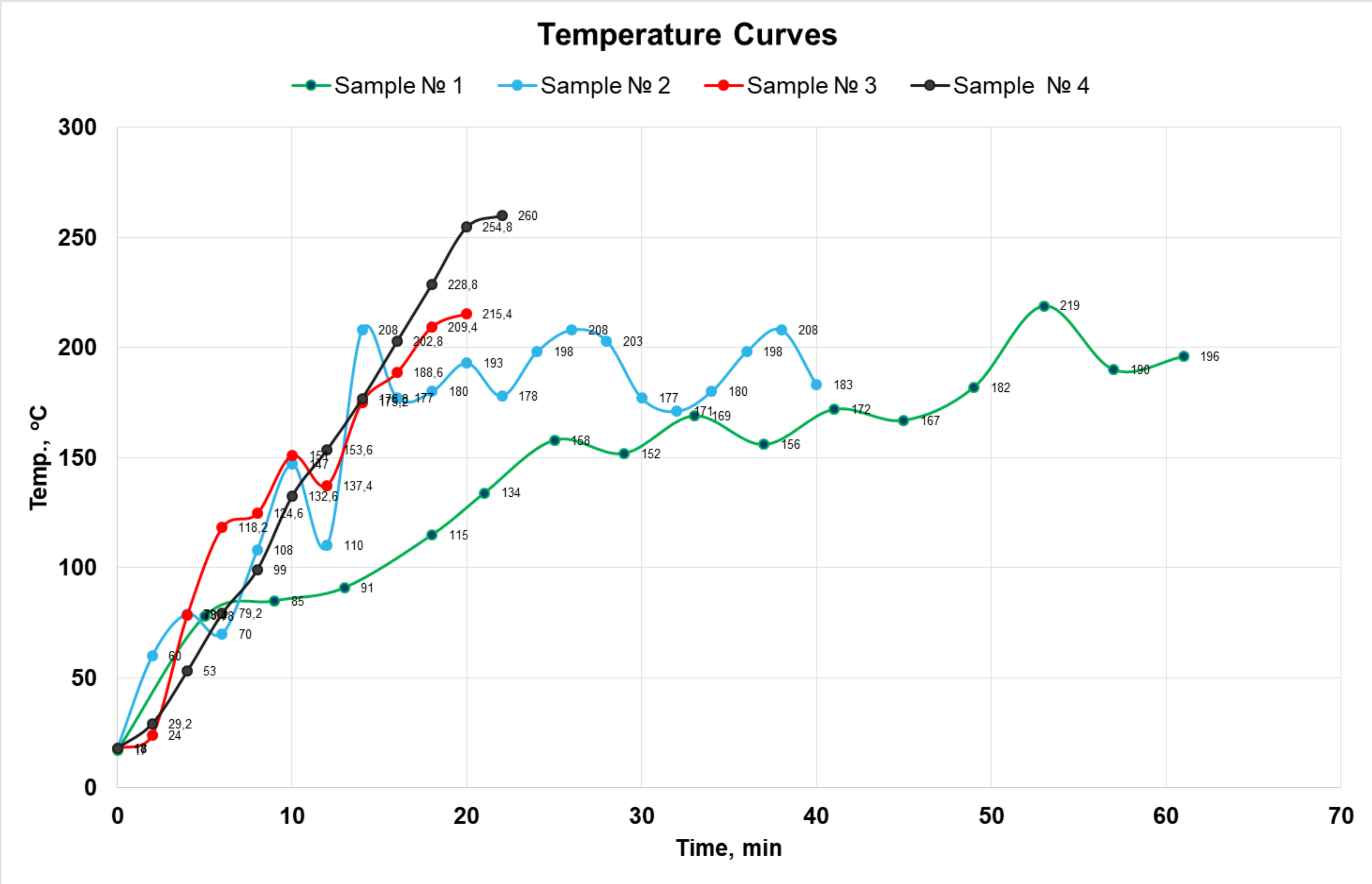

Figure 5. Temperatures curves

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Sample No. 1, fire curtain with Intumescent composition (Pentaerythritol, melamine, titanium dioxide, ammonium polyphosphate, dispersant, defoamer, biocide, thickener, vinyl dispersion, plasticizer, coalescent, microtalk): During the tests, there was no sign of loss of integrity (E), as well as loss of thermal insulation (I). The maximum temperature of 219 °C was recorded at the 53 minute test. The temperature from the unheated side of the sample averaged 196 °C on the average in the 60th minute of the test. Sample No. 2 fire curtain with Intumescent composition (graphite IR, pentaerythritol, melamine, titanium dioxide, ammonium polyphosphate, dispersant, defoamer, biocide, vinyl dispersion, plasticizer, coalescent, microtalk): At the 40th minute of the test, there were signs of loss of integrity (E) and signs of loss of thermal insulation (I) did not come. The maximum temperature of 208 °C was recorded on the 26th and 38th minute of the test. The temperature from the unheated side of the sample averaged 183 °C on the average in the 40 minute test. Sample No. 3, fire curtain with Intumescent composition (Vermiculite, graphite IR, pentaerythritol, melamine, titanium dioxide, ammonium polyphosphate, dispersant, defoamer, biocide, thickener, vinyl dispersion, plasticizer, microtalk, aluminum hydroxide): On the 20th minute of the test, there were signs of loss of integrity (E) and signs of loss of thermal insulation (I) did not come. The maximum temperature of 215.4 °C was recorded on the 20th minute of the test. Sample No. 4 fire curtain with Intumescent composition (Vermiculite, graphite IR, pentaerythritol, melamine, ammonium polyphosphate, dispersant, defoamer, biocide, thickener, vinyl dispersion, plasticizer, microtalk, aluminum hydroxide): During the 23 minute test, there were signs of loss of integrity (E) and signs of loss of thermal insulation (I) did not come. The maximum temperature of 260 °C was recorded on the 23 minute test.

In [27–28] the author investigates the characteristics of intumescent composition, the qualitative difference of which is the addition of fiberglass to the composition. One of the presented intumescent compositions provided thermal insulation protection of the steel sample to 197 °C.

This paper [29] described the thermal efficiency of alumina and kaolin clay filler based on Intumescent fire retardant coating. Results showed that by using small quantity of fillers; physically good char structure with uniform expansion was achieved as illustrated by furnace test and it was stable for 2h. Under conditions of heat exposure of 500 °C, the samples of the compositions provided thermal insulation in the range from 100 to 200 °C.

The work [30–31] describes the tests of the intumescent composition in the temperature range 950–1100 °C. Published results are comparable with those obtained in the present work. The temperature of the samples with the intumescent residue presented did not rise above 150 °C. With the exception of the applicability of the formulation to the transformable fire-resistant structures such as fire curtains.

This paper [33–35] discuss the synergistic effects of titanium dioxide (TiO2) and zinc borate on thermal stability and water resistance of intumescent fire retardant coatings. As in Ref. [35], we used in our Sample No. 1 5 % TiO2. The composition in [35] protects the surface during testing and the sample temperature does not rise above 150 °C. The comparison results paper [27, 29, 30, 35] are shown in Figure 6.

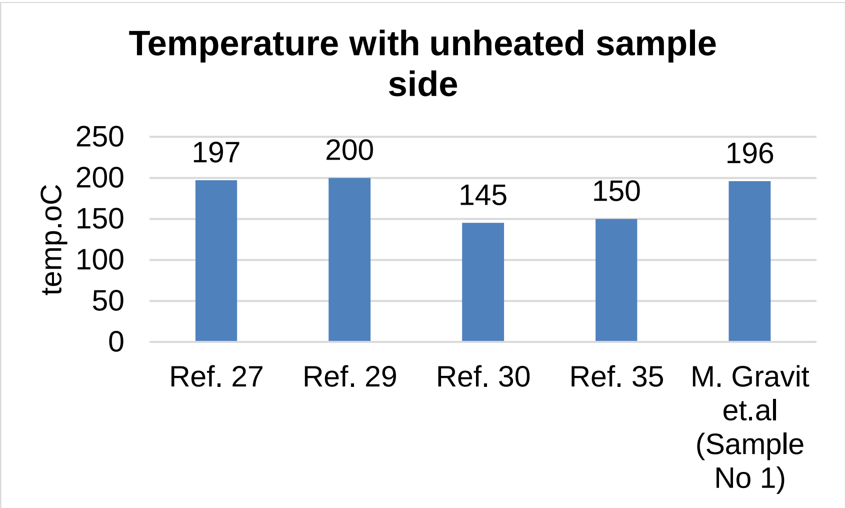

Figure 6. Comparison results of maximum temperature

The results obtained in present work are comparable with similar studies also in the presented work the composition contains latex for maintaining the elasticity, which influenced the nature of intumescence and fireproof properties.

4. Conclusions

The obtained results testify to the effectiveness of applied composition No. 1 (Pentaerythritol, melamine, titanium dioxide, ammonium polyphosphate, dispersant, defoamer, biocide, thickener, vinyl dispersion, plasticizer, coalescent, microtalk). This will be used in the design of a full-scale experiment where the temperature field on the unheated side of the fire curtain of 9 m^2 will be investigated. Previously, tests were conducted to study the thermosetting of silica tissue. When field tests of silica cloth without special treatment and without coating by intumescent composition, the shrinkage corresponds to the declared range of the manufacturer [36].

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