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INVESTIGATION AND MANAGEMENT OF FIRE RISKS AT SITES WITH APPLICATION OF TRANSLUCENT BUILDING STRUCTURES

Abstract. On the base of analyses on the development of the construction industry as well as fires occurring in Kazakhstan, the article justifies the areas of fire prevention related to technical regulation that is the certification of materials, construction structures and engineering systems.

The translucent building structures have increasing application in modern construction techniques. For such structures, the most vulnerable indicator is the fire resistance limit. A technical solution is offered to increase this indicator by using water irrigation. On the base of existing international and national regulatory documents, a number of methods has been developed for experimental determination of the actual fire resistance limit by cooling of structures with water in case of fire.

Large-scaled fire researches have been carried out to determine the actual limit of fire resistance of the translucent partition made of tempered glass "Float" with the thickness of 12 mm, M1 grade both in the presence of water irrigation and in the absence thereof. The tests were carried out under standard and actual fire conditions. Optimal parameters of water irrigation are determined. On the base of research results, it is proposed to improve the construction standards in this field as well as methodological documents in the field of certification tests.

Key words: fire safety, translucent structures, fire tests, fire resistance.

Introduction. The objective criterion for the socio-economic development of society is the indicators of construction industry. Modern Kazakhstan demonstrates clearly this thesis. According to statistical data, the scope of the performed construction works is growing every year in the country. The growth rates is shown in the diagram (figure 1) [1].

Moreover, the crucial part of commissioned construction sites refers to the social welfare and residential facilities. Thus, in 2019 it was completed the construction of 45515 new buildings, where 42739 buildings are residential and 2776 buildings are non-residential, it has commissioned for operation of 71 comprehensive schools, 69 pre-schools, 35 outpatient clinics and three hospitals [1].

The capacity within the construction industry allows to design and build unique objects, both in terms of architectural design as in application of new, unique materials, structures and systems. Along with its indisputable importance for the country, the construction industry has a high risk of dangerous factors. The extensive application of new modern substances, materials and articles, produced from them having high fire hazard class, leads to increase the potential ignition sources and increase the risk of exposure of their dangerous factors to humans, increase in the size of socio-economic and environmental consequences from them.

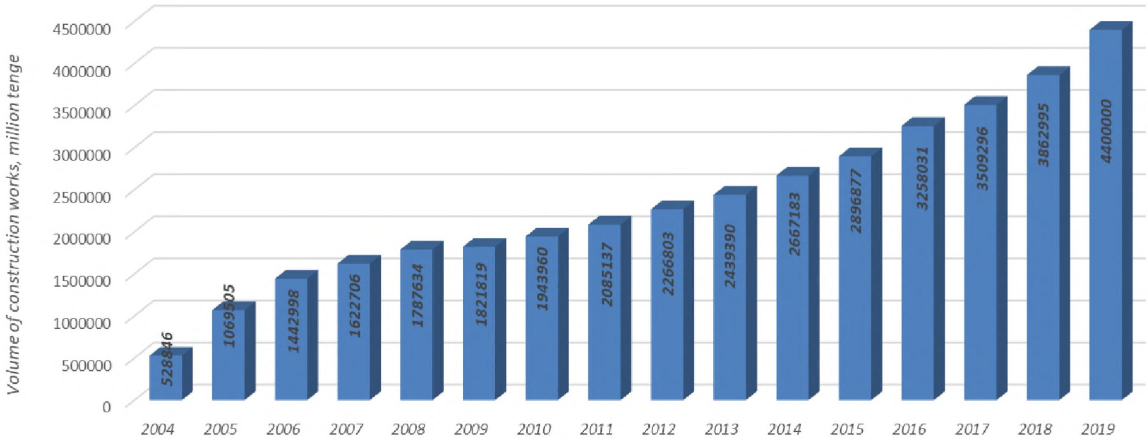

Figure 1 – Statistical data on the scope of construction works performed in the Republic of Kazakhstan from 2004 to 2019

According to the data from the Committee of Emergency Situations of the Ministry of Internal Affairs of the Republic of Kazakhstan for 2019 there are registered 9 415 fires in the residential sector of the country which has caused material damage in the amount of more than 1.52 billion tenge. In the case of fires, 280 people died and 322 were injured, representing 85.8 and 82.5 percentages of total fire victims respectively. Fires in housing and public buildings account for more than 70% of the total number of fires in the country [2].

Figure 2 and 3 show the diagrams of fire distribution by the objects occurred in 2018-2019 and the dynamics of fires in the residential sector over the last 5 years [2]. Despite the downward trend in fires in recent years, the total number of fires remains quite high. These data force us to look for new ways on improvement of fire prevention.

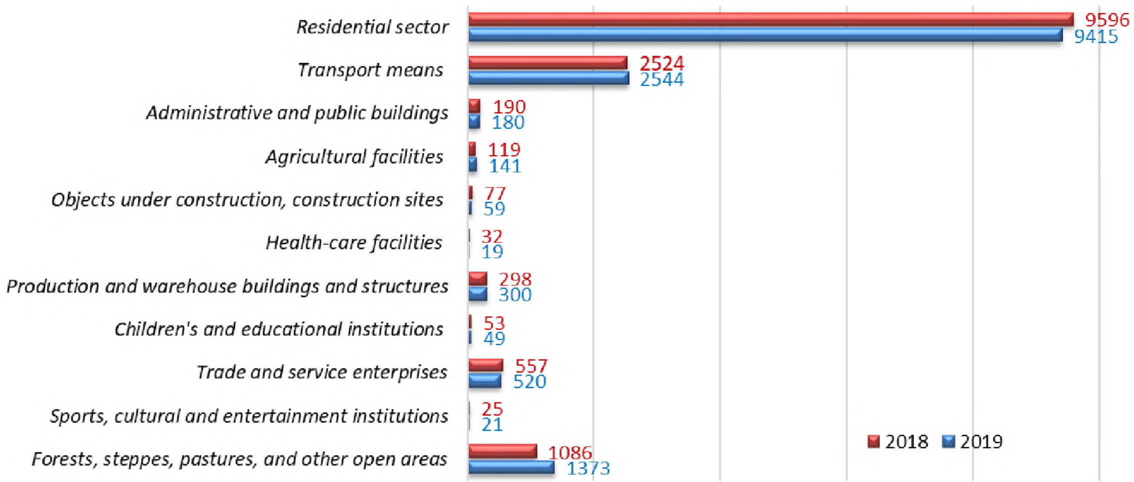

Figure 2 – Fire distribution occured by objects

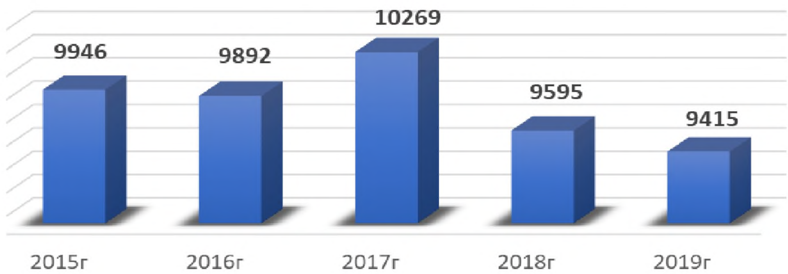

Figure 3 – Fire dynamics in the residential sector over the last 5 years

Fire safety issues continue to be sufficiently relevant as evidenced by publications both domestic and foreign [3-6].

The provision of fire safety of buildings and structures at the design, construction and commissioning stages is an extremely important task, because the mistakes made are sometimes not reversible.

In the context of solving the challenges of reducing the pressure on business, minimizing the control and oversight functions of state bodies, including state fire authorities, ensuring the safety of products and services supplied to the market, the technical regulation system is becoming a technological process. Its main tasks include ensuring the safety of products and processes for human life and health and the environment, ensuring the national security, preventing the actions that mislead the consumers about product safety and quality, etc. [7].

Construction facilities, especially those with mass presence of people, as a rule unique on architectural solution and use of modern technological materials and constructions, should comply with requirements of technical regulations on the "General requirements for fire safety " and "Requirements for the safety of fire-fighting equipment for the protection of objects " [8, 9]. They should be built with certified construction structures, finishing materials and building engineering equipment, including fire protection systems to ensure the required level of safety. Requirements to ensure an adequate level of fire safety also apply to the elements of filling the openings of buildings and partitions.

Methodology. In connection with it, experimental and theoretical researches on fire hazard indicators and limits of fire resistance of translucent building structures have been carried out (hereinafter - TBS) as well as the influence on these indicators of irrigation by the fire sprinklers of the automatic extinguishing system. The object of the research is a translucent building structure made of thermostatic glass.

Fire resistance problems, including glass structures, have been investigated by other authors [10-14] using different mathematical modelling methods [15-19].

Our earlier analysis of the mathematical models for predicting the behaviour of TBS in fire conditions for the purpose to determining their limits for fire resistance both in normal condition and in water irrigation has shown the need for large-scale fire tests [20].

For fire researches, a number of criteria and parameters for the fire resistance of the translucent partition have been developed including a research of the dynamic effects of water irrigation on TBS, fire resistance in standard and real fire conditions, real fire conditions, fire resistance during irrigation of the automatic water-extinguishing system in standard fire conditions.

The basic regulatory document for testing is National Standard of the Republic of Kazakhstan ST RK 2219-2012 "Civil Structures. Constructions for enclosing structures and filling openings with the light-transmitting elements. Fire resistance test procedure" [21]. This document sets out in full the methodology and tools for the fire test. To conduct the tests, the standard methodology has been refined and validated, and the laboratory installation has been supplemented by system of water irrigation and drainage from the installation of unused water.

In order to obtain reliable results of experimental researches, the development of methods and direct tests were carried out together with the laboratory of "RD-Fire Group" LLP which is accredited for conducting such tests.

In the course of fire tests, it was tested TBS made of tempered glass "Float" with the thickness of 12 mm, M1 grade producer: Russia.

Experimental researches. The first experiment was carried out for the TBS made of tempered glass "Float" with a thickness of 12 mm, M1 grade, mounted in the opening of the test-stand without using water irrigation. Figure 4 shows a fragment of full-scale fire tests. Figure 5 shows the temperature schedule of the kiln during the cellulosic fire test in which it is clear that by 8 minutes the actual temperature has begun to exceed the design temperature for the standard (hydrocarbon) fire.

It has been established that the maximum average volume temperature of the cellulose fire was 560°C, and at this temperature the glass fracture does not occur. The above-mentioned average fire temperature occurs at 16 minutes of fire with a fire load corresponding to 50 kg/m^2 for public buildings when converted to wood. It follows from this that the fire resistance limit of E15 glass without irrigation will guarantee safe evacuation of people through the emergency exit routes without exposure to the dangerous fire factors associated with the destruction of the partition. However, the limit on the fire resistance of E15 glass allows to guarantee with great margin of the stability of the glass partition for the time required for the supply of water from the automatic fire extinguishing installation which is equal to 180 sec.

Figure 6 shows the dynamics of temperature changes on the non-heated surface of the sample as well as its average and maximum values. On the graph the horizontal straight lines correspond to the critical temperatures at which the thermal insulation capacity of TBS made from the tempered glass is lost at the 10th minute.

Figure 4 – Fragment of test to determine the actual fire resistance limit of glass under the real fire load

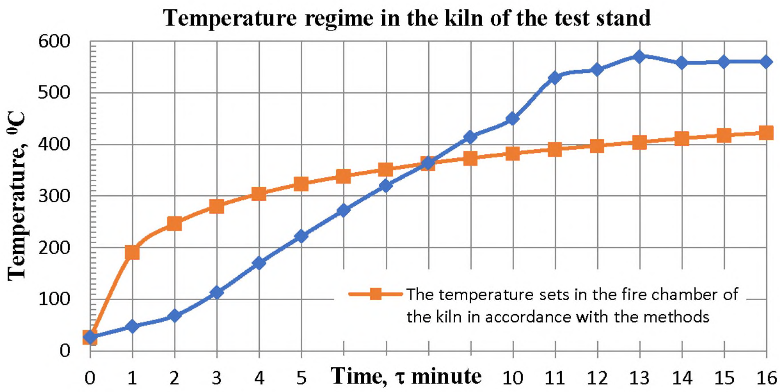

Figure 5 – Temperature regime in the kiln of the test - stand.

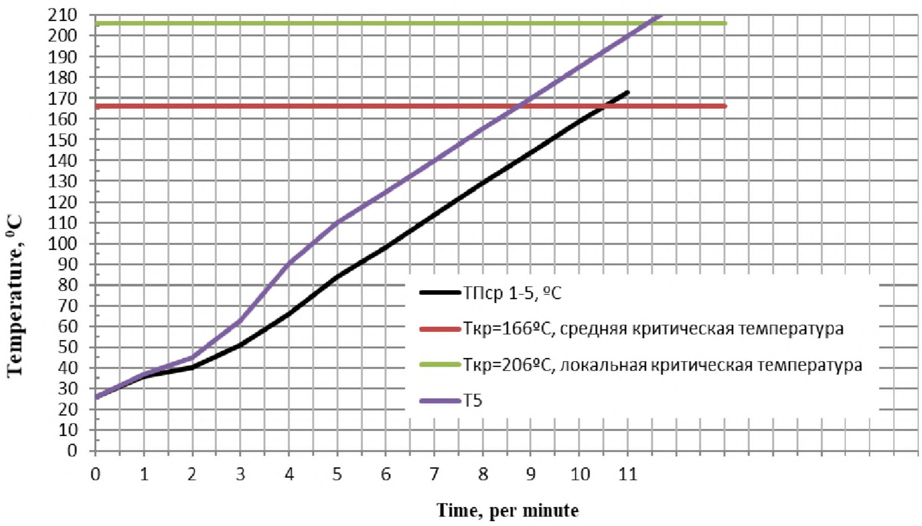

Figure 6 – The results of temperature measurements on the non-heated surface of the sample

A structural failure was recorded at 16 minutes of the experiment.

Thus, based on the results of the passed tests, the actual limit of fire resistance for TBS was determined from the tempered glass "Float" without the effect of water irrigation, it was 10 minutes on the base of heat-insulating capacity and 15 minutes on the base of structure integrity loss.

The next round of experiments was carried out with the water irrigation of TBS. The temperatures set in the fire chamber of the kiln during this test are shown in figure 7. We would like to note that the positive effect of irrigation is achieved if the whole structure is included in the irrigation map.

The graph (see figure 7) shows that the actual fire temperature in the fire chamber when using irrigation is reduced by 2.4 times relative to the temperature of the standard fire. For example, the maximum average temperature in the fire chamber of the kiln was equal to 369 °C at 46 minutes and the temperature on the non-combustible surface of the glass being irrigated was equal to 166 °C (see figure 8). In view of the above we can make the following conclusion:

- irrigation of the glass partition allows to reduce the average volume temperature of the fire by 2.4 times;
- within 46 minutes the temperature of the glass partition does not reach the critical values at which it is predicted possible collapse. (T_f = 166 °C ≤ T_{kr} = 560 °C, where T_f is the actual temperature, T_{kr} is the critical temperature at which the structure breaks down);
- The maximum permissible value of heat flow density W (radiation) for 46 minutes corresponding (3.5 ± 0.2) kW/m^2, is not reached. (see figure 9).

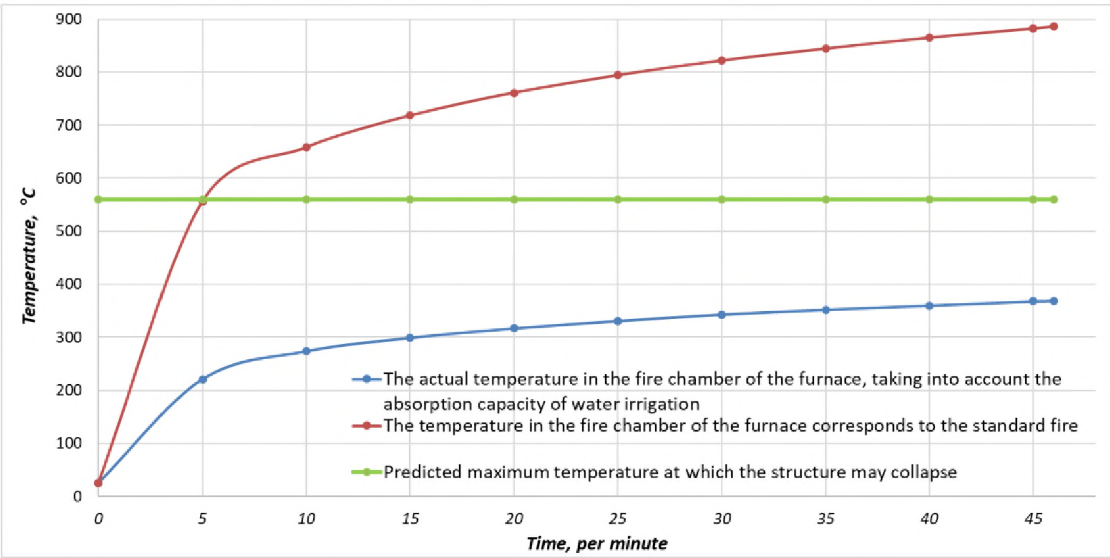

Figure 7 – Temperature regime in the fire chamber of the test stand when using surface irrigation of the glass partition

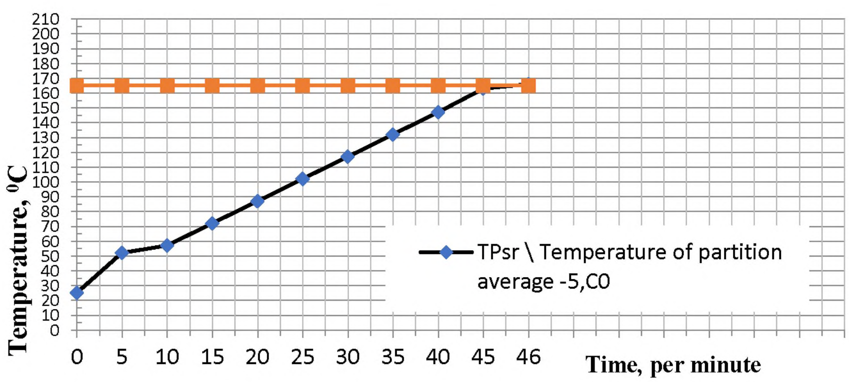

Figure 8 – The results of temperature measurements on the non-heated surface of the sample using irrigation.

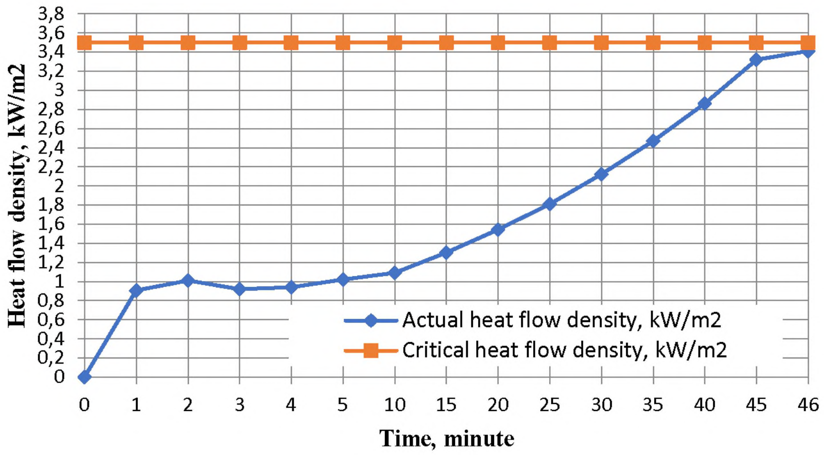

Figure 9 – The results on measurements of the thermal insulation loss (W) due to reaching the achievement of permissible heat flow density (radiation)

During the hydraulic tests on the effects of water irrigation on the glass structure, it is established that vibration occurred to its leakproofness is not recorded.

Conclusion. The conducted researches provide us with grounds to propose rationing the fire resistance limits of translucent building structures to water irrigation provided that the whole structure will be included in the irrigation map as well as to improve the methods of testing systems of "translucent building structure – water irrigation" for fire resistance.

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ЖАРЫҚ ӨТКІЗГІШ ҚҰРЫЛЫМДАРДЫ ҚОЛДАНУ НЕГІЗІНДЕ ӨРТ ҚАТЕРІН ЗЕРТТЕУ ЖӘНЕ БАСҚАРУ

Аннотация. Мақалада құрылыс индустриясының дамуы, Қазақстанда болып тұратын өрт жағдайы бойынша мәліметтер келтірілген. Аталған мәліметтер талдамасы құрылыс, сондай-ақ, қоғамдық және тұрғын-жай ғимарат мақсатындағы нысандарда адамға қауіпті факторлардың туу қатерін жоғары дәрежелеу қорытындысын жасауға мүмкіндік береді. Өрт қауіпсіздігін қамтамасыз ету мәселелерінің Қазақстанда және басқа елдерде өзектілігі айқындалуда.

Өрт жағдайын талдау негізінде өрттің алдын алу бағытының бірі техникалық реттеуге байланысты болып келеді, атап айтқанда, материал, құрылыс құрылымы және инженерлік құрылғылар мен жүйелердің құрылым саласында қолданылатын міндетті сертификаттау қамтылады. Өрт қауіпсіздігі көрсеткіштері бойынша сынақта негізделген сертификаттау құрылыста қолданылатын объектілер, әсіресе, адамдардың ауқымды қатысуы, технологиялық материалдар мен құрылымдардың техникалық регламент талаптарына сәйкес келуін қамтамасыз етеді. Өрт қауіпсіздігін жеткілікті деңгейде қамтамасыз ету бойынша талаптар ғимарат ойығы мен қалқанын толтыру элементтеріне жатады.

Заманауи құрылыста бірегей сәулет объектілерін қолдану үшін жарықөткізгіш құрылыстық құрылымдар көп қолданылады. Мұндай құрылымдар үшін әлсіз көрсеткіштер өртке төзімділік шегі болып саналады.

Жарықөткізгіш құрылымдардың өртке төзімділік көрсеткішін арттыру тәсілінің бірі болып суландыруды қолдану бойынша техникалық шешім ұсынылады.

Ғимараттағы өрттің жылу режимінің қолданыстағы математикалық моделінің талдамасы, әсіресе, сумен салқындату әсерінің есебімен, ірі ауқымды эксперименттік зерттеу жүргізу қажеттілігін көрсетті. Бұрын өткізілген эксперименттер зертханалық категорияға жатады және ғимараттар бойынша өрттің алдын алуға бағытталған нормативті талаптарды жеткілікті қамти алмайды.

Құрылыс құрылымдарының отқа төзімділігінің нақты шегін анықтау ортасында қолданыстағы ұлттық стандарттар қолданылмайды, себебі өрт кезінде суландыру үрдісін қарастырмайды. Сондықтан қолданыстағы халықаралық және ұлттық нормативтік құжаттар негізінде өрт кезінде құрылымдарды сумен салқындату арқылы нақты шегін эксперименттік анықтау бойынша әдістер қатары өңделді.

Зерттеу барысында жарықөткізгіш қалқанының өртке төзімділігінің нақты шегін анықтау бойынша өрттік полигондық, ірі ауқымды зерттеулер келтірілген, суландыру барысында М1 маркалы, 12 мм қалыңдықты, «Флоат» термошыңдалған шыны арқылы орындалған. Сынақтар стандартты және нақты өрт кезінде жүргізілді. Зерттеу жүргізу кезінде стандартты және нақты өрт шарттары шығарылды:

Зерттеу нәтижесінде анықталды:

1. Шыны 560 °С целлюлозалы өрттің орташа көлемді температура кезінде сынбайды. Ағашқа санағанда 50 кг/м^2 қоғамдық ғимарат үшін сәйкесінше өрттік жүктеу кезінде жоғарыда көрсетілген өрттің орташа көлемді температурасына жетуі өрттің 16 минутында орын алады. Суландыру есебінсіз Е15 шынының өртке төзімділік шегі қалқандардың бұзылуына байланысты өрттің қауіпті факторларының әсерінсіз эвакуациялау жолдары бойынша адамды қауіпсіз эвакуациялауға кепілдік береді. Сонымен қатар Е15 әйнегінің өртке төзімділік шегі 180 сек. тең өрт сөндірудің автоматты қондырғысынан қажетті суды беру үшін шыны қалқанның тұрақтылығын қамтамасыз етеді.

2. Зерттеуде жарықөткізгіш құрылымдарын суландыру жұмыстары пештің от камерасында температуралық режим стандартты өрт режиміне сәйкес келді. Бұл ретте суландыру кезінде от камерасындағы өрттің нақты температурасы стандартты өрт температурасына қатысты 2,4 есе төмендейді. Шыны қалқан температурасы 46 минутта оның ықтимал құлау болжамы сыни мәнге жетпейді.

Зерттеулер нәтижесі бойынша оңтайлы суландыру параметрлері анықталды. Зерттеу нәтижелері негізінде мұндай ортадағы құрылыстық нормалаудың жетілдіру жолдары, сондай-ақ сертификатталған сынақ ортасындағы әдістемелік құжаттар ұсынылады.

Түйін сөздер: өрт қауіпсіздігі, жарық өткізгіш құрылымдар, өрт сынағы, өртке төзімділік.

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ИССЛЕДОВАНИЯ И УПРАВЛЕНИЕ ПОЖАРНЫМИ РИСКАМИ НА ОБЪЕКТАХ С ПРИМЕНЕНИЕМ СВЕТОПРОЗРАЧНЫХ КОНСТРУКЦИЙ

Аннотация. В статье приведены данные по развитию строительной индустрии, а также по пожарам, происходящим в Казахстане. Анализ представленных данных позволяет сделать выводы высокой степени риска возникновения опасных факторов для людей на объектах строительства, в особенности зданиях общественного и жилого назначения. Вопросы обеспечения пожарной безопасности продолжают быть достаточно актуальными как в Казахстане, так и в других странах.

На основе анализов пожаров обосновывается, что одним из направлений работы по профилактике пожаров является направление, связанное с техническим регулированием, а именно обязательной сертификацией применяемых в строительной отрасли материалов, строительных конструкций и инженерного оборудования и систем. Сертификация, основанная на испытаниях по показателям пожарной опасности, обеспечит соответствие применяемых при строительстве объектов, в особенности с массовым пребыванием людей, технологичных материалов и конструкций требованиям технических регламентов. Требования по обеспечению достаточного уровня пожарной безопасности относятся и к элементам заполнения проемов зданий и перегородок.

В современном строительстве, как правило, для уникальных по архитектурному решению и использованию объектов, все большее применение находят светопрозрачные строительные конструкции. Для таких конструкций наиболее уязвимым показателем является предел огнестойкости.

Одним из способов повышения показателя предела огнестойкости светопрозрачных конструкций предлагается техническое решение по применению водяного орошения.

Анализ существующих математических моделей теплового режима пожара в помещении, особенно с учетом эффекта охлаждения водой, показал необходимость проведения крупномасштабных экспериментальных исследований. Ранеепроводимые эксперименты относятся к категории лабораторных и не могут в достаточном объеме обосновать нормативные требования, направленные на предотвращение пожара по зданию.

Действующие национальные стандарты в области определения фактического предела огнестойкости строительных конструкций не могут быть применены, потому что не предусматривают процесс водяного орошения при пожаре. Поэтому на основе существующих международных и национальных нормативных документов разработан ряд методик по экспериментальному определению фактического предела огнестойкости при охлаждении светопрозрачной конструкции водой при пожаре.

В ходе исследований проведены крупномасштабные, огневые исследования по определению фактического предела огнестойкости светопрозрачной перегородки, выполненной из термозакаленного стекла «Флоат», толщиной 12 мм, марки М1 как при наличии водяного орошения, так и при его отсутствии. При проведении исследований воспроизводились условия стандартного и фактического пожара.

В результате исследования определено:

1. Разрушения стекла при максимальной среднеобъемной температуре целлюлозного пожара 560 °С не происходит. Достижение вышеуказанной среднеобъемной температуры пожара возникает на 16 минуте пожара при пожарной нагрузке, соответствующей для общественных зданий 50 кг/м^2 при перерасчете на древесину. Предел огнестойкости стекла Е15 без учета орошения позволит гарантировать безопасную эвакуацию людей по эвакуационным путям без воздействия на них опасных факторов пожара, связанных с разрушением перегородки. Вместе с тем, предел огнестойкости стекла Е15 позволяет с большим запасом гарантировать обеспечение устойчивости стеклянной перегородки на время необходимого для подачи воды от автоматической установки пожаротушения равной 180 сек.

2. При исследованиях с применением водяного орошения светопрозрачных конструкций температурный режим в огневой камере печи соответствовал режиму стандартного пожара. При этом фактическая температура пожара в огневой камере при использовании орошения снижается в 2,4 раза по отношению к температуре стандартного пожара. Температура стеклянной перегородки в течении 46 минут не достигает критичных значений, при которой прогнозируется ее возможное обрушение.

По результатам исследований определены оптимальные параметры водяного орошения.

На основе результатов исследований предлагаются пути совершенствования строительного нормирования в данной сфере, а также методических документов в области сертификационных испытаний.

Ключевые слова: пожарная безопасность, светопрозрачные конструкции, огневые испытания, огнестойкость.

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