Constructive Solutions to Increase Fire Resistance of Reinforced Concrete Structures

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A B S T R A C T
This article examines structural options to improve the no flammability of reinforced concrete structures. Increasing the scale of reinforced concrete structures reduces interior space, increases the building's weight, and adds to the cost of materials, construction, and installation. The issues of assuring the fire resistance of the primary structures of unusual and high-rise buildings and structures employing methods without such flaws have been investigated. The installation of a wire mesh on the heated surface layer of the structure necessitates raising the protective layer of concrete to the reinforcement, resulting in an increase in the total weight of the building or structure, which has been scientifically assessed and recommended.

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Introduction: Today, large-scale research is being carried out all over the world in order to identify scientific and technical solutions to challenges related to fire safety. In this regard, much emphasis is placed on the use of various effective fire protection methods to protect various building structures and materials from fire, such as the application of compositions, thermal insulation, fire resistance varnishes, and other materials and their properties to structures and materials. The quick collapse of primary structures of buildings under the impact of temperature also presents certain challenges in the coordination of emergency rescue operations, according to an analysis of large fires throughout the world.

A building's or structure's ability to withstand the impacts of fire elements is determined by its set of fire resistance limits. The period from the start of the fire exposure under standard test conditions to the start of one of the standards for that structure is the fire resistance limit of that structure (filling the voids of fire barriers). The limitations of fire resistance of various reinforced concrete structures are the subject of several works, researches, and tests created by scientists and testers. However, it is not always possible to ensure that the structure's real fire resistance is within the acceptable limits in compliance with the provisions of regulatory standards in the field of fire safety in design practice. There are two alternative solutions to the problem in this scenario. The first is to strengthen the reinforced concrete structure's fire resistance by thickening the protective layer of concrete, i.e., making the structure heavier. The second alternative is to apply fire-resistant coatings that do not add to the structure's weight or produce new weight.

Material and method: In general, in accordance with the normative documents, reinforced concrete structures of high and rare facilities must have a fire resistance limit REI 150-REI 240. Most reinforced concrete structures have the required fire resistance limit due to the fact that the concrete is covered with a protective layer up to the load-bearing reinforcement. Reinforced concrete slabs and columns with a

thickness of 25-35 mm of protective layer of concrete have fire resistance limits from REI 60, R 60 to REI 90, R 90. To increase the fire resistance limits REI 240, the thickness of the protective layer of reinforced concrete slabs should be at least 70 mm, and for columns 55 mm. For tall buildings, the thickness of the concrete protective layer is 70 mm, which leads to a reduction in the internal area of the building and an increase in the mass of the structures. At the same time there is an increase in the additional weight of load-bearing structures.

The construction of high-rise structures serves the objective of increasing the internal size of a building that occupies only a tiny portion of the land plot. These are enormous and high-rise buildings with a thick protective covering of concrete, which results in a reduction in their internal space, which eventually leads to their collapse. The structure of a higher building is larger, but the inner space is smaller.

However, there is another issue with high-rise buildings: the division of space into fire compartments, which reduces interior space. Smoke extraction systems, fire extinguisher systems, and independent engineering communications in the form of elevators all demand additional room in each fire compartment.

Research results and discussion: Increases in the scale of reinforced concrete structures result in a reduction in internal space, an increase in the building's weight, and increased material and construction expenses. As a result, ensuring the fire resistance of the primary structures of rare and high-rise buildings and structures employing technologies that do not have such flaws would be a difficulty.

In some circumstances of an unusual hazard labeled "explosive destruction of concrete," "explosive destruction of concrete," or "brittle destruction of concrete" in scientific literature, the necessity to strengthen the fire resistance of reinforced concrete structures may arise. According to the findings, this phenomena represents the following:

- the explosive damage to concrete occurs as a result of the fire affecting it within 5-15 minutes. The process of concrete destruction (demolition) is interrupted by the heating of concrete slab structures in the form of slabs with an area of up to 0.005 m^2 and their spread to a distance of up to 15 m, with the spread of various explosions, cracks in the concrete are broken, burst and have a strong sound effect.

Large (sometimes up to several square meters) concrete lenses are detached from the structure on the entire surface of the impact of fire or in individual sections of it. However, in some cases, holes are formed in the walls as a result of the fire fixture being exposed. The structure can collapse completely in 15-60 minutes. This catastrophe occurs when a fire affects hard and multi-layered reinforced concrete walls, floor slabs, beams, columns and trusses.

Concrete destruction of thin walls between massive ribs or shelves; through holes in floor slabs and beam walls, as a result of which the fire resistance limit can be sharply reduced to 10-15 minutes. When the corners of structural elements collapse as a result of a fire, they affect and damage reinforced concrete columns, side slabs and beams, and when bolts and fittings are partially damaged by fire, the reinforcement is partially exposed and the surface is exposed, leading to premature demolition.

The breaking area from the structural elements is in the form of small plates up to 7 cm^2, depth up to 0.5 cm, or cone-shaped pieces with the action of a large aggregate. This type of destruction is usually not dangerous because it has almost no effect on the fire resistance limit of the structures.

An analysis of the literature sources revealed that the death of concrete in a fire was related to its moisture content, and some sources noted the effect of compressive stresses on both the external load and the degree of erosion from limiting element movement. For conventional concrete with granite aggregate, there is a 3.5% critical “critical” moisture content, so the process of concrete destruction depends on the thickness of the element. When concrete is heated, complex thermophysical and mechanical processes occur in it that do not fully explore the connections between temperature, humidity, stresses, deformations, concrete properties, and manufacturing technologies.

The development of the science of construction has significantly reduced the consumption of materials in reinforced concrete structures, while maintaining the strength and other properties at the required level. Numerous thin-layered, precessive structures have emerged, and monolithic reinforced concrete

structures are common, in which concrete hardening occurs under external environmental conditions. However, the high humidity of the concrete is maintained for a long time, during which time a fire can occur, which can lead to an explosive destructive process.

The breakdown of concrete is also affected by the external load of the reinforcement and the thickness of the products produced. In the manufacture of structures, cracks are formed under the fittings, which develop under the influence of temperature. In addition, if the product receives an external pressure load before heating, the length of the initial cracks will increase. When the product is heated on both sides of the element with a small thickness and high humidity of concrete, its temperature effect also increases.

An increase in cement consumption per unit volume of concrete or the replacement of a dense aggregate with a pore increases the initial moisture content of the concrete and its abrasion when heated. A large value of the temperature gradient, e.g., 250°C (see) when the equilibrium humidity of concrete is equal to or greater than its sorption moisture (JV> JS), can lead to the collapse of concrete with a crack length of only 4 mm.

Thus, as a result of explosive collapse of concrete, reinforced concrete structures in a fire, the fire resistance limit of reinforced concrete structures is sharply reduced and often does not meet the requirements of the standards. As mentioned above, this is due to their cutting, rapid heating of the working fittings or the appearance of holes in the barrier elements, which contribute to their complete destruction and the spread of fire in adjacent rooms. The destruction of concrete in a fire can have a physical and psychological impact on people and lead to an increase in human casualties. When developing new reinforced concrete structures using heavy concrete, there is no guarantee that they will not be destroyed prematurely in the future due to fire. The impact of fire on reinforced concrete structural elements can lead to the following main consequences: a) a decrease in the mechanical properties of concrete and reinforcement; b) erosion of concrete due to cracking or burning (e.g. protective layer); c) formation of temperature and compression cracks; d) loss of initial voltage of the armature; e) deterioration of the joint working conditions of concrete and reinforcement.

Much work has been done to study the explosive destruction (collapse) of concrete. In this work, it is taken into account that when the concrete is exposed to the temperature of the fire, it undergoes various physicochemical processes, which in turn affect the crack gaps. A number of studies have shown that under the influence of fire temperature in cement stone can develop both structural and destructive processes. Construction-forming processes include additional hydration reactions, an increase in the solid phase volume, and the strengthening of the structural bonds of individual minerals. Temperature deformations of destructive-cement stone, unhydrated grains of Portland cement clinker, moisture gradients in the direction of heat flow, lead to the development of internal stresses under the influence of general shrinkage of the system during heating. As a result, the internal structure of the cement stone changes either in the direction of reducing the total volume of the pores and their average size, or in the direction of increasing these parameters.

The research provides an analysis of the results of research on the mechanism of explosion failure of concrete. It has been scientifically proven that this phenomenon is the result of a complex effect of building structures on capillary-porous materials, mechanical loads, excess vapor pressure in the wet evaporation zone inside the heated structure during a high-temperature fire. An approximate general scheme of explosive damage to the integrity of an element under fire conditions: a) the distribution of the effect of the explosion on the integrity of the temperature, a) pressure, the amount of moisture in the section of the heated element; b) the distribution of the degree of decomposition of the material under the influence of explosion as a whole; c) the occurrence of an explosion-related process on its integrity:

It was noted that explosive destruction of concrete occurs within 5-10 minutes from the onset of exposure to “Standard Fire” temperatures, ranging from 8 to 17 Mpa, within the development of internal pressure. The given pressure values are dangerous for concrete. Based on these results, a methodology for calculating the probability of explosive collapse of concrete and reinforced concrete structures has been developed and recommendations for protection against this process have been given.

Conclusion and suggestions: It has been found that the recommendations given do not always apply to reduce the risk factor of concrete explosion. For example:

1. Based on the following firefighting measures, i.e. installation of water curtains, provision of concrete and reinforced concrete structures with fire protection sprinklers or drains, it is less relevant at present because they cannot be installed along the perimeter of all load-bearing structures. If we hypothetically assume the installation of such protective equipment in a high-rise building, the effective internal area will be reduced, the facility will need to be supplied with water, increase the load-bearing capacity of building structures, reliability of continuous operation (maintenance costs); that the value of the building and the value of its use can be multiplied many times over.

As a result of lowering the humidity level in the room, the probability of the concrete exploding is very low, because the humidity of the concrete is related to the humidity outside the air. The installation of a wire mesh on the layer on the heated surface of the structure requires that the protective layer of concrete be increased to the reinforcement, which leads to an increase in the total weight of the building or structure. Laying a heat-insulating mortar with different layers of lightweight concrete on the surface of the structure leads to the fact that the occurrence of high temperatures during a fire leads to the spread of cracks, exceeding the phase separation limit, inside the structure (the layer of mortar is laid on the concrete surface). Although most of the plaster mixes are designed on the basis of cement alibastre, the heating of the reinforcement is accelerated to provide the required surface adhesion, and the formation of a plastic hinge eventually leads to the collapse of the structure. Its use in refractory concrete with shamite filler and the dispersive strengthening of the concrete on the heated surface will eventually lead to a change in the mechanical definition of the reinforced concrete. It should also be noted that as a result of the use of heat-resistant concrete, we would have solved the problem of ensuring fire resistance, but the cost of their production would be several times more expensive than the conventional method. The above recommendations are very difficult to put into practice and they will not always be able to prevent the concrete from exploding and breaking during a fire.

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