Fire Safety in Pre-trial Detention Facilities

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Abstract. This article describes the main provisions for assessing the safety of people during the evacuation from the buildings and structures in the event of a fire. The analysis of normative and scientific bases in the ensuring the safety of people during the evacuation showed the absence of psychophysiological patterns of behaviour and movement of people in the buildings of pre-trial detention facilities necessary to assess the estimated values of fire risk. The data presented in the methodology for assessing fire risks do not allow to reliably assess the probability of evacuating people in the event of a fire in such institutions, since the mode of operation of the facility is not taken into account. The key factor determining timely evacuation is the time of the beginning of the evacuation, depending on the behavioural aspects of the main functional contingent. The absence of such studies determines the need for field observations and experiments in the field of evacuation of people from the buildings of pre-trial detention facilities.

1. Introduction
The new millennium in Russia was marked by the adoption of a series of federal safety laws based on the risk assessment. The beginning was made by the adoption on Federal Law of the Russian Federation of 27.12.2002 No.184-FZ "On technical regulation", which establishes that technical regulations are adopted with a view to:

- the protection of life and health of citizens, property of individuals and legal entities, state or municipal property;
- the environmental protection, life and health of animals and plants;
- “Prevention of misleading purchasers.”

Realizing these goals in relation to construction projects, the Federal Law of the Russian Federation of 30.12.2009 No.384-FZ "Technical regulation on the safety of buildings and structures" puts forward (article 3) the requirements for ensuring:

1) the mechanical safety;
2) the fire safety;
3) the safety in hazardous natural processes and phenomena and (or) anthropogenic impacts; etc.

2. Methodology
Summarizing the requirements of federal safety laws, based on risk assessment, we see that the federal legislation of Russia provides for the need to ensure the safety of people in buildings and structures:

- when operating under normal conditions,
• with the threat of dangerous natural processes,
• in case of the fire.

According to the protocol No. 1, dated March 25, 2010 of the meeting of the working group of representatives of the Ministry of Regional Development and the Ministry of Emergencies of the Russian Federation to consider the draft of the Federal Law of the Russian Federation of 22.07.2008 No.123-FZ "Technical regulation on fire safety requirements" and normative documents on fire safety, the following decision was recorded:

In order to avoid duplication and contradictions in the documents establishing the fire safety requirements, it is considered appropriate to use as documents ensuring compliance with the requirements of the Federal Law of the Russian Federation of 30.12.2009 No.384-FZ "Technical regulation on the safety of buildings and structures", codes of practice in the field of fire safety.

Federal law specifies fire safety requirements [1]. Moreover, the fire safety of the buildings and structures is considered to be ensured if all the requirements of federal laws and regulations on fire safety are met. In the event that it is impossible to comply with the requirements of regulatory documents on fire safety, their justification is allowed by the calculation of the fire risks [1, article 6], where the main component is the probability of evacuation of people, the determination of which requires a reliable assessment of the safety of people. In accordance with article 53 the safety of people during evacuation is a determining factor in the formation of the space-planning structure of evacuation routes and exits in the buildings and structures [1].

The timeliness and freedom from the obstruction are two criteria for the safety of people during evacuation. The timeliness and freedom from the obstruction are expressed by the ratios:

\[
    t_{ev} \leq t_{add} \leq t_{bl}
\]

\[
    D_t \leq D_{add}
\]

where:
• \( t_{ev} \) - time of evacuation of people, determined by the moment of the beginning of evacuation and the time of movement of people from their places of residence to the cross section of the evacuation route, after which the safety of evacuated people is ensured, min;
• \( t_{add} \) - the permissible time spent by people in the system (or subsystem) of evacuation routes (premises, floors, staircases, buildings) under consideration. If the permissible duration of evacuation is determined by the dynamics of dangerous factors in an emergency (for example, fire), then the time for these factors to reach levels that are dangerous to human health or life becomes necessary to complete the evacuation. Allowable time can be determined not only by dangerous, but also by technological requirements. But first of all, it is determined by the physical and psychophysiological capabilities of a person;
• \( t_{bl} \) - time of blocking escape routes by hazardous fire factors (HFF);
• \( D_t \) is the estimated value of the density of people on any part of the evacuation route;
• \( D_{add} \) - the permissible density of people on the site, determined by the required level of their comfort or safety of their stay in clusters.

To evaluate these criteria (1) and (2), software packages have been developed that allow reproducing the dynamics of the increase in HFF and the process of movement of people in buildings and structures. PyroSim or Pathfinder allow you to most adequately simulate the evacuation of people with the simultaneous spread of HFF along the evacuation routes.
Based on the provisions indicated above, it can be concluded that the fire protection system is such a system in which a person is not only an object of protection, but also a participant in his defence, as well as a participant in the protection of another person in need of assistance, since the system is forced to use his physical abilities to achieve the goals of his functioning. In this case, when a person’s life is in the hands of himself or in the hands of another person (rescuer), the geometric dimensions of the path (length, width, height, slope, etc.) that will need to be overcome will play a decisive role for successful rescue or evacuation. to be in a safe place from the AFP, and the psychophysiological capabilities of people. In this regard, requirements should be imposed on evacuation routes that would ensure not only the safe conduct of evacuation, but also the salvation of the main functional contingent located in them.

According to the paragraph 4.1.3 of the Code of rules - SP (in Russian) 1.13130.2009, the protection of people on the evacuation routes is ensured by a complex of space-planning, ergonomic, structural, engineering and organizational measures. The evacuation routes within the premises must ensure the safe evacuation of people through the evacuation exits from the premises without taking into account the fire extinguishing and smoke protection used in it.

When applying expressions 1 and 2, it is also taken into account that the maximum permissible duration of the accumulation on the evacuation paths $t_{acc}$ is 6 min (if it is exceeded, compression asphyxiation is possible) for the contingent consisting of healthy and active adults. In the flow of such people, clusters, as a rule, begin to form when the density $D_i$ reaches more than 5 people in summer clothes per m$^2$. The maximum intensity of movement of adults $q_{max}$, which is the criterion for determining the minimum required width of the evacuation routes, is in the range of the flux density $D_{add}$ - 4-5 people/m$^2$.

The regularities of the relationship between the parameters of human flows were discovered as a result of studies performed by V.V. Kholshechevnikov during his dissertation for the Doctor’s degree. For the first time in the history of studies of human flows, he analysed psychophysiological systems that could determine the essence of the relationships between the parameters of human flows manifested under different conditions and gave a mathematical description of the human flow as a stochastic process, and the main functional relationship $V = f(D)$ in the form elementary random function. The general psychophysical law of Weber - Fechner was chosen as the main psychophysical law that describes the relationship of changes in the speed of people’s movement with density, taking into account the emotional state and the type of path, as the most appropriate. The formula for determining the speed of human flow is the following:

$$V_{e} = V_{0} \left(1 - a \ln \frac{D_j}{D_{0j}} \right)$$

where

- $V_{e}$ – random value of the speed of free movement (in the absence of the influence of surrounding people), depending on the type of path (j) and the level of emotional state (e) of people, m/min;
- $a_j$ – coefficient, which is determining the degree of influence of flux density when moving along the j-th type of path;
- $D_j$ – current value of flux density, people/m$^2$;
- $D_{0j}$ – threshold value of the flux density, upon reaching which the density becomes a factor affecting the speed of movement, people/m$^2$. 

$$\bar{V}_{e} = \bar{V}_{0j} \left(1 - a_j \ln \frac{D_j}{D_{0j}} \right)$$
The established pattern formed the basis for normalizing evacuation routes and exits in the event of a fire. Thus, the fire protection system is such a system in which a person is not only an object of protection, but a participant in his defense (self-defense), since the system is forced to use its natural capabilities (without evacuating the fire risk value, it is 2-3 orders of magnitude lower than the standard value) to achieve the goals of its functioning.

3. Results and discussions

The methodology makes it possible to assess fire risks for all buildings of various classes of functional fire hazard [2]. But the applicability of this methodology to institutions providing isolation of suspects, accused, defendants and convicts (pre-trial detention facilities) is doubtful. Firstly, similar institutions according to clause 22.6 of the Code of rules - SP (in Russian) 247.1325800.2016 “Detention facilities of the penitentiary system. Design Rules” refers to the class of functional fire hazard - F1.2, for which the methodology defines the time for the start of evacuation in the range from 2 to 3 minutes, depending on the type of the systems of warning and evacuation control. Class F1.2 includes the sleeping buildings of sanatoriums and rest houses of a general type of motels, boarding houses, campsites, hotels and hostels.

4. Conclusions

Accordingly, the use of the data presented in the methodology does not correspond to the real mode of operation of the facility. The time for the start of evacuation in such institutions primarily depends on the psychological characteristics of the person and the opening time of the cells for detainees, which leads to a significant increase in the time spent on the start of the evacuation. For example, a fire in 2015 in a pre-trial detention centre No. 1 in Ulyanovsk claimed the lives of four people, with eight people injured. The cause of the fire was a short circuit in the electrical wiring, the cause of death was poisoning with toxic combustion products as a result of untimely people entering the safe zone, where the time for the start of the evacuation became a key factor. Secondly, in the methodology there are no psychophysiological regularities of the movement of human flows in the pre-trial detention facilities buildings. The use of motion parameters of adult healthy people will lead to an unreasonable assessment of the fire safety of such buildings in connection with the heterogeneity of the composition of human flows in the pre-trial detention facilities buildings.

Studies on the study of the psychophysical laws of behaviour and movement of people in case of fire in the pre-trial detention facilities buildings were not found in both domestic and foreign literature [3-17]. The study of this issue is very relevant, since without taking into account the above aspects, it is impossible to correctly assess the calculated values of a firefighter during the design, construction and operation of pre-trial detention facilities.

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