Verification of the Construction and Architectural Component of the Design of the Fire Protection Regulations

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Abstract. A systematic study of compliance with the planning standards of the construction and architectural component of the design of fire protection regulation according to the basic indicators that ensure fire resistance and fire safety of the building has been carried out. Detailed audit was conducted to verify evacuation routes and passages at the facility to the fire protection regulations. A detailed audit on the verification of protective barriers against smoke to the fire protection regulations has been implemented. Verification studies are implemented on a specific object. The required degree of fire resistance of the objects of various functionality has been fixed. The survey of compliance of building structures, evacuation routes and passageways, smoke barriers with regulations and guarantees of fire protection have been presented. It is established that the required degree of fire resistance of a multifunctional shopping and office center depends on the height of the building and the maximum floor area of all its parts of various functional fire hazards. During the compliance check of the multifunctional shopping and office center, violations of the requirements of norms and rules on fire safety were revealed.

1. Introduction
The site allocated for the facility construction is located in the Kalininsky district of Tver. The site is limited:

- on the south side - by Kholmogorov street;
- on the western side - by the fence of the Metallurg garden;
- from the northern and north-eastern sides - by an auto-cooperative;
- on the east side - by the territory of the ASPEK administrative building.

The object is oriented with the main facade on Kholmogorov street. Entrances/exits to the territory are organized from the Kholmogorov street. On the territory of the facility the project provides two special open areas for temporary storage of and employee scars for 147 and 331 parking spaces, respectively. The coverage of the driveways is two-layer asphalt concrete based on rubble and sand.

Techno-economic standard of cadastral land ownership:

- footage of the territory according to the lines of the construction zone is 33077.0 sq. m;
• the area of the object's layout is 11,973.5 sq. m;
• parking lots and driveways 11605 sq. m.
The total area of the Object is 42,450 sq. m.
The object is equipped with:
• automatic fire extinguishing device filled with water sprinkler;
• external and internal fire-fighting water supply;
• fire alarm system;
• a warning and evacuation control system of the third type;
• smoke protection, which includes exhaust and supply smoke ventilation systems. It should be provided for: galleries; atrium; corridors without natural lighting, through which more than 50 people can be evacuated; storerooms with an area of more than 200 sq. m located in the above-ground floors; car parking at the level of minus 3,600.
The main building structures and products, as well as their characteristics are presented in table 1.

**Table 1.** Characteristics of the main building structures and products in accordance with [1-6].

| Structure name                          | Material                                                                                                                                 |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| 1 Building foundations                  | Monolithic reinforced concrete slab 600 mm thick on a natural foundation                                                               |
| 2 External walls of the underground part of the building | Monolithic reinforced concrete with a thickness of 300 mm with polystyrene foam insulation \( \delta = 70 \text{ mm} \) |
| 3 Building frame                        | Monolithic reinforced concrete frame with beamless monolithic ceilings                                                                |
| 4 Outer walls of the overground part of the building at the level of 0.000 | Three-layer wall:<br>- internal layer 200 mm thick made of foam concrete blocks R90  
- insulation 120 mm thick made of mineral wool slabs (Rockwool)  
FACADE BATTS, VENTI BATTS  
- finishing layer - "Senardzhi" plaster, "Apukobond" composite panels |
| 5 Roof                                  | Flat combined roof:<br>- 2 layers of technoplast  
- screed made of reinforced cement-sand mortar \( \delta = 30 \text{ mm} \)  
- expanded clay ramp  
- insulation (calculated thickness) made of non-combustible mineral wool boards PPZ 200 240 mm thick  
- vaporbarrier |
| 6 Floor slabs                           | Monolithic reinforced concrete REI45                                                                                                    |
| 7 Elevatorshafts                        | Monolithic reinforced concrete                                                                                                                                                                                                 |
| 8 Stairs                                | Monolithic reinforced concrete R 60                                                                                                                                                                                   |
| 9 Partitions                            | Foam concrete blocks in accordance with GOST 2150-89 thick. 100 mm. In wet rooms partition besser blocks SKC-3R                                                                                                             |
| 10 Elevators                            | Freight elevators produced by Karacharovsky plant  
- lifting capacity 1000 kg, \( V = 0.5 \text{ m/s} \) with a machine room at the top  
- with a lifting capacity of 500 kg, \( V = 0.5 \text{ m/s} \) with a machine room at the top |
| 11 Escalators                           | Schindler escalators (floor height 4.50 m, step width 800 mm, tilt angle 350, balustrade height 1000 mm)                                                                                                                  |
| 12 Internal walls of staircases         | Brick. Platforms and marches made of monolithic reinforced concrete REI 90                                                                                                                                            |
| 13 Ceilings                             | Suspended ("Armstrong", "Grilyato")                                                                                                                                                                                       |
| 14 Floor slabs                          | Monolithic reinforced concrete R 15                                                                                                                                                                                   |
The estimated capacity of electricity consumers is 1,000 kW. Including electrical receivers of the 1st category of power supply reliability - 50 kW, 2nd category - 950 kW. The power supply of the facility is provided from a projected stand-alone transformer substation with a capacity of 2 1000 kVA [7, 8, 9, 10].

Drawings of specific design and construction solutions for the office center were developed by the architectural studio "PROJECT" [11, 12, 13].

The multifunctional retail and office center, located on the first kilometer of Rublevo-Uspenskoe shosse in the Odintsovo district of the Moscow region, is an 18-storey building (the basement is included in the above-ground floors of the building) with six underground floors, including a parking lot [14, 15, 16, 17].

The designed complex has the following characteristics [18, 19, 20, 21].

The height of the building is 69.5 m (the height is determined by the upper mark of the building roof transparent for light).

The building area of the aboveground part of the building is 7800 m².

The building area of the underground part of the building is 13369 m².

Fire resistance grade - I with increased fire resistance limits of load-bearing structures and fire barriers up to R/REI 180 [22, 23, 24, 25].

Classes of functional fire hazard of accommodated premises groups:
- from mark -24.60 to mark -8.10 (6 floors) - underground built-in attached parking lot F 5.2;
- at mark -4.80 - supermarket F 3.1, bank premises F 3.5, technical and warehouse rooms F 5.2;
- at mark 0.00 - trade enterprises F 3.1, technical and utility rooms;
- at mark 4.80 - public catering establishments F 3.2;
- from mark 8.70 to mark 67.20 - office premises F 4.3;
- at mark. 69.50 an exploited roof (1300 m²) with technical rooms and a platform for the rescue team of the helicopter cabin are provided.

Staircase and elevator blocks are the cores of rigidity and are located in the center of the building. Glass curtain facade is planar glazing with a hinged metal supporting frame. The number of office space per person is 12.0 m², which is 8 people per 100 m² of office space. The number of parking spaces per 100 m² of office space is 10.0 spaces [26, 27, 28, 29].

For communication between the floors of the fire compartments of the complex in the center of the building, elevators and staircases are provided. They are located in the staircase-elevator blocks and represent the core of stiffness. A system of escalators is also provided for communication between the basement, 1st and 2nd floors of the building [30, 31, 32, 33].

The staircases of the office center connecting the underground and aboveground floors of the building are the follows [34, 35, 36, 37].

Staircase No. 1 (in axes 3-4/E-Zh): internal, in a smoke-resistant type H2 staircase connecting all the underground and aboveground floors of the building and leading from the vestibule and the corridor outside at elevation -4.80 m.

Staircase No. 2 (in axes 6-7/E-Zh): internal, in a smoke-resistant type H2 staircase connecting all the underground and above-ground floors of the building.

Staircase No. 3 (in axes 10-11/E-Zh): internal, in a smoke-resistant type H2 staircase connecting all the underground and above-ground floors of the building.

Staircase No. 4 (in axes 14-15/E-Zh): internal, in a smoke-resistant type H2 staircase connecting all underground and aboveground floors of the building and leading from the basement through the vestibule and the corridor outside at elevation -4.80 m.

Staircase No. 5 (in axes 16-17/E-Zh): internal, in a smoke-free in a smoke-resistant type H2 staircase connecting all the underground and aboveground floors of the building and leading from the first floor through the vestibule-gate directly outside at elevation 0.00 m. Description of the complex's lifts: the complex's lifts connect all underground and above-ground floors [38, 39, 40, 41, 42, 43].
2. Audit for verification of evacuation routes and passageways at the facility to the fire protection regulations

The human safety condition is considered fulfilled if, in accordance with [44]:

\[ \tau_r \leq \tau_o, \]  

(1)

where \( \tau_r \) is the design duration of personnel removal from the facility building, min.; \( \tau_o \) is the obligatory time duration of the personnel removal from the building of the facility, regulated by the risk of fire spreading in time, specifically by its characteristics - hazardous fire factors (HFF), min.

Compliance with this condition is checked in the graduation thesis using the calculations:

\[ n_f \geq n_{req}, \]  

(2)

where \( n_f \) and \( n_{req} \) are the actual and required number of emergency exits.

\[ \delta_f \geq \delta_{req}, \]  

(3)

where \( \delta_f \) and \( \delta_{req} \) are the actual and required minimum width of evacuation exits, m.

\[ l_f \leq l_{req}, \]  

(4)

where \( l_f \) is the designed and \( l_{req} \) is the obligatory length of evacuation routes, m.

3. Audit for verification of smoke protection barriers and fire protection regulations

Smoke barriers in building are a complex of planning, expedient (rational) and specific engineering procedures [1, 3, 5, 45-48].

The composition of planning procedures includes: division of the object into sectors, isolation of possible routes for the movement of smoke along the territory of the structure of the object, namely: passages, openings, platforms on stairs, elevator shafts, chutes.

The composition of expedient (constructive) procedures includes:

- sealed covers for highly dispersed aerosols, including the smallest solid particles in suspension in the air;
- fences with a regulated limit of fire protection;
- security of entrance and technical passages by means of special doors made of materials that guarantee shielding from smoke and fire, especially in case of man-made fires;
- vestibule locks or bulkhead spaces between the rooms of the facility, preventing the spread of dust, smoke and fire;
- valves for protection against fire, first of all, remotely or automatically shutting off the ventilation device from the ingress of incomplete combustion components.

Special procedures include: devices for smoke removal directly from premises or from corridors of special devices in the form of hatches or smoke exhaust shafts with valves.

An object is considered to be guaranteed to be protected from smoke, provided: a complex of planning, expedient (rational) and specific engineering procedures and technical solutions is implemented comprehensively in accordance with the regulations for the protection of objects from fires. The basic limiting set of rules for auditing the smoke protection of objects is [45]. Additional requirements for the protection of objects from smoke are formulated in highly specialized regulatory documents that establish industry standards. The results of checking the smoke protection of the building are set out in table 2.

4. Technical solutions for escape routes and exits

1. Evacuation should be carried out: through smoke-free H2 type staircases.
2. The width of the staircases flights should be provided for:
   - in fire compartments when only office premises are placed in them - at the rate of 165 people per 1 m of the staircase flight width, but not less than 1.2 m;
• in fire compartments with trade, catering and sports premises - at the rate of 115 people per 1 m of width, but not less than 1.35 m;
• in the fire compartments of the parking lot at least 1 m.

**Table 2. Results of verification of compliance with smoke protection.**

| What is checked                                      | Accepted by the design                  | Required                                                                 | Result |
|------------------------------------------------------|-----------------------------------------|--------------------------------------------------------------------------|--------|
| The need for fire-fighting automatic system (FAS) equipment | The premises of the facility are equipped with FAS | Required                                                                | C      |
|                                                      | The car park is equipped with FAS       | Required in underground floors regardless of the number of storeys    | C      |
|                                                      | In the underground floors in the parking lot, smoke protection (SP) is provided | In the parking lot of cars operating under multi-storey buildings, it is necessary to design exhaust equipment for protection from smoke in order to eliminate incomplete combustion components from the stage of the fire. Regulation [45]: extraction (removal) of smoke is mandatory for buildings with a number of storeys less than 10; with passages not equipped with natural lighting, and oriented to the evacuation of 50 and more persons. | C      |
| The need for smoke exhaust systems                  | On the underground floors for corridors without natural light, equipped provided with SP |                                                                          |        |
| Air-supply systems                                   | Elevators descend into the basement, supply ventilation is provided | In front of the elevator on the underground floor and (or) the basement floor with a minus mark there are type 1 bulkheads with air pressure in case of fire. It is necessary to provide for air pressure in case of fire or device on all floors of type 1 vestibules with air pressure in case of fire. | C      |
|                                                      | The Parking lot is connected to other floors, and there is a supply ventilation system |                                                                          | C      |
| Way to remove smoke                                  | Exhaust systems with mechanical induction are provided in the building. | Exhaust systems with mechanical induction are provided in multi-storey buildings. | C      |

3. The width of the corridors should be:
• on floors with public premises not less than 1.2 m (estimated value);
• on technical floors at least 1 m.
4. For the organization of evacuation in the underground floors sections of service (technological) corridors can be used, provided that a constant free passage is organized with a width of at least 1 m,
taking into account the width of the opening doors inside the corridor and providing these sections with air pressure in case of fire.

5. Exits from evacuation staircases of the aboveground and underground parts of the building must be isolated.

Doors on escape routes should be opened in the direction of traffic flow to the exits of the building.

6. Escalators and travelators are not taken into account when calculating the parameters of escape routes. Open stairs can be considered in the calculation of escape routes, provided that they connect no more than two floors of the building.

5. Technical solutions for fire protection and communication systems

1. The fire compartments should be equipped with:

   Parking:
   • sprinkler fire extinguishing devices with a volume of at least 33.6 l/s;
   • own water supply, designed to prevent and extinguish a fire, with a volume of at least 10 l/s;
   • deluge barriers serving as a screen for the safety of fire-prevention gates of the ramps with a flow rate of at least 1 l/s for 60 minutes;
   • smoke exhaust systems at the rate of one smoke intake device per 900 m² of the area of the room;
   • smoke exhaust systems in the parking ramps;
   • systems for pressurizing air in staircases, lift shafts and vestibules.

   In the rest of the building's fire compartments:
   • sprinkler fire extinguishing systems with a flow rate of at least 9.6 l/s;
   • deluge curtains along the perimeter of the openings in the floor for the installation of escalators;
   • gas fire extinguishing systems in server rooms;
   • powder fire extinguishing system in diesel generator and transformer rooms;
   • internal fire-fighting water supply with a flow rate of at least 40 l/s;
   • smoke exhaust systems, respectively [45];
   • air pressurization systems in staircases, lift shafts and vestibules.

2. Provide a complex of automation equipment with active fire protection, representing a set of interconnected systems:

   • automatic fire alarm system (AFAS);
   • automated control of the internal fire-fighting water supply system;
   • automatic water fire extinguishing;
   • automatic gas fire extinguishing;
   • automatic powder fire extinguishing;
   • automated control of smoke protection.

3. Place the alerters:

   • on the ceiling of the elevator shaft;
   • on the wall of the lift shaft, in which exactly the openings leading to the lobby are equipped;
   • in pairs (with detectors) both belonging to the same tandem, are fixed to the same horizontal position;
   • the alerters are fixed at intervals of maximum height of 6 m;
   • at a maximum level of 300 mm from the top of the opening leading to the lobby in front of the lift.

6. Conclusion

1. As a result of checking the design documentation for compliance with fire safety requirements, it was found that the design documentation was developed with serious deviations, primarily in terms of organizing the people evacuation. The design envisaged staircases connecting all the underground and ground floors of the building, and from the underground floors there were no separate exits directly outside. To eliminate this and other violations appropriate engineering solutions were proposed.
2. Since the building does not fit into the current regulatory requirements, compensating measures have been developed first of all aimed at increasing the fire resistance of load-bearing structures, increasing the intensity of irrigation of the sprinkler fire extinguishing system, providing each fire compartment with lifts for transporting fire departments and providing the building with a 5-th type warning system.

3. During the development, verification calculations of smoke protection systems, which showed that the ventilation equipment had been selected correctly, were performed.

4. In the explanatory note a feasibility study was made for one of the proposed compensating measures, namely the determination of the effectiveness of the device of the enclosing staircases structures with a fire resistance limit of REI 180.

5. Checking the compliance of the multifunctional shopping and office center with fire-fighting requirements revealed the following violations of the requirements of norms and rules on fire safety. For example, one of them is the height of the building exceeds the maximum permissible height for public buildings of social purpose – 50 m.

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