Analysis of the accidents causes at different stages of the construction object life cycle

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Abstract. The article discusses the main causes of accidents of buildings and structures having occurred due to the errors made at various stages of their life cycle (design, construction, operation). A brief analysis of the accidents that occurred within the period from 2010 to 2017 in the Russian Federation is presented. The examples of accidents in construction due to underlying causes and the ways to prevent those accidents in future are considered.

Introduction

Currently, in many countries, the construction industry is equipped with new technologically advanced devices, mechanisms and technologies, and the modern software calculation systems are used. Despite this, the dynamics of emergency cases in industrial and civil buildings is not only non-decreasing, but sometimes increasing [1].

In recent years, the mass media have provided a lot of information about emergency situations, so one can analyze the causes of accidents with a fairly high degree of accuracy. Fig. 1 presents information about the victims and those who lost their lives as a result of accidents on the territory of the Russian Federation from 2010 to 2017 according to the EMERCOM of Russia.

![Figure 1. The number of registered dead and injured in accidents that occurred on the territory of the Russian Federation for the period from 2010 to 2017.](image-url)
Analysis of the main accidents causes
Analysis of the data showed that the number of the dead and the injured as a result of accidents for the period under review does not decrease, but on the contrary increases, which indicates the failure to take appropriate measures to prevent accidents in construction [2].

Accidents in construction can occur due to mistakes made at each stage of the life cycle of a building or structure: from design to operation.

The main accidents’ causes over the years are [3]:
1. Errors at the design stage.

Figure 2 shows the main errors at the design stage:

![Figure 2. The common mistakes made at the design stage](image)

Poorly conducted pre-design surveys
 Errors in the design and calculation of foundations
 Errors in the calculation of the structures work
 Insufficient stability at power side wind loads

In February 2010, the metal structures of the roof and walls of the unfinished sports complex of the Poltava Technical University named after Kondratyuk collapsed. Fortunately, there were no casualties. According to the project, the authors of which were the teachers of the architectural and construction faculty of the university, the gym was provided with the basketball and volleyball courts, as well as a futsal hall and four tennis courts. The capacity of the sports complex is 1500 people. As a result of the accident, the metal roof was destroyed on the area of 1200 m², the metal elements of the walls and the glazing were damaged. The results of the examination confirmed that at the design stage the loads on the metal structures of the coating were not fully taken into account, with the result that the roof and walls collapsed.

The human factor can be attributed to the causes of errors at the design stage, leading to accidents. For example, the incompetence of the designer and his lack of experience in the designed complex structures; insufficient geotechnical and geodetic surveys; the calculation verification neglection of structures produced in the specialized software systems.

The example of the accident occurred due to the human factor is the collapse of a residential building in Italy (1999), having led to the 67 peoples’ life loss. As a result of the work of the experts, it turned out that the cause of the tragedy was not only numerous construction errors, but also the construction of a house in the flooded soil without carrying out the appropriate protective measures.

Thus, we can conclude that in order to avoid errors at the design stage it is necessary [4]:
- to have complete information about the conducted pre-project surveys;
- to take into account the personal responsibility of the participants in the design process;
- to provide a strict and independent examination of the construction project;
- to use modern building materials and structures in the project.

Figure 3 shows the distribution of accidents by the stages of the life cycle of the object.
Figure 3. Diagram of the distribution of accidents by the stages of the object’s life cycle

Since 65% of accidents occur due to mistakes made at the “construction” stage (Figure 3), it is necessary to analyze them very carefully in order to minimize the number of accidents at this stage.

2. Accidents due to the errors during the construction phase.

Figure 4 shows the main errors at the design stage:

![Diagram of the main mistakes made at the construction stage](image)

- Deviations from the project
- Poor quality building materials
- Intention to reduce the cost of construction
- Poor winter concreting

Figure 4. The main mistakes made at the construction stage

In Saransk during the construction of a multi-storey building, the staircase collapsed from the 6th to the 2nd floors, as a result, three workers were killed on the 13th November, 2017 (Figure 5). The criminal case according to the part 3 of the article 216 of the criminal code (violation of safety rules in the conduct of construction work) was initiated upon the collapse. At the moment, the investigation is still being performed. However, the main version is the fact that on the lower floors the walls were erected using the level, and on the upper floors there was a deviation from the vertical. A “dome”, at which the flight of stairs could not be kept in the design position has been formed [5].

![Image of the collapse of the staircase in Saransk](image)

Figure 5. The collapse of the staircase in the city of Saransk

According to statistics, 20% of accidents at the construction stage occur due to the poor quality of the building materials use. The article 52 of the Town Planning Code and the articles 34 and 38 of the Technical Regulations on the Buildings and Structures Safety provide the mandatory entrance control of the quality of building materials. However, unfortunately, not all companies are ready to carry out such control objectively and significantly, and not formally, to fill in the notes in the journal input quality control.

In the city of Krasnodar, on the 31st July, 2013, the bottom of the pool basin as well as the bottling of water was pushed through and has been subsequently destructed. According to the official version, the cause of this incident was a design error. However, according to some data, the cause could be an
error during construction, namely, the use of cheaper and lower quality anchor bolts, instead of those that were provided for by the project [6].

To ensure that accidents do not occur due to errors at the construction stage, it is necessary to:
- to ensure the interrelation of the work of designers and builders;
- to implement technical supervision and quality control during installation of structures;
- to strictly follow the rules for mounting structures;
- to use only building materials and structures approved by the project;
- not to allow the replacement of materials of structures or their individual parts without the sanction of the design organization.

3. Accidents due to the errors at the operation stage [7].

Figure 6 shows the main errors at the design stage:

**Figure 6.** The main mistakes made during the operation phase

In St. Petersburg, on the 25th January, 2011 the roof of the O'KEY hypermarket collapsed (Figure 7). The project was based on thr standard snow loads - 100 kgs / m², the limit was - 140 kgs / m², but in fact the actual load reached about 180 kgs / m², which led to the collapse. The official version of the incident was the improper operation of the object: the snow on the roof from the beginning of the snowfall has not been removed, and a further attempt to clear the roof was unsuccessful. It caused the dynamic loads and subsequently a resonance due to the workers walking on the roof overloaded with snow, which led to its collapse.

**Figure 7.** Collapse of the roof of the hypermarket "O'KEY", St. Petersburg
Today, the problem of illegal redevelopment of residential apartments located on the 1st floor, for the public premises (shops, offices) is relevant. At the same time, the owners do not always get a permission from the Interdepartmental Commission or the housing inspection [8].

For example, on the 30th January, 2011 the whole entrance of a four-storey residential building in Yaroslavl collapsed. When redeveloping the apartment on the first floor as an office, according to the entrepreneur’s instructions, the two supporting structures were demolished. First, the cracks appeared in the residents’ apartments, and a little later, in the evening, the collapse of the span structures occurred (Figure 8). One elderly woman lost her life under the rubble.

Figure 8. The collapse of the entrance to the city of Yaroslavl as a result of illegal redevelopment.

However, practice shows that the cause of an accident is often errors not only at one stage of the object’s life cycle. The design errors, deviations from design decisions and gross violation of the regulatory requirements during the construction phase, and during the operation phase, gross violations of the rules for technical operation of buildings and structures are a standard chain of the problems leading to accidents.

The most famous example of this is Transvaal-Park [9], Moscow. On the 14th February, 2004 a reinforced concrete dome collapsed over the pool and water attractions. In the building of the complex, in terms of representing, a circle sector with an area of 4500m² and covered with a monolithic ribbed reinforced concrete sheath, more than 4000m² of the coating collapsed. The collapse was avalanche-like. The first column supporting the main contour of the shell along the axis was the first to lose stability, followed by the rest of the columns, which supported about half the length of the supporting contour. Simultaneously with the columns, the contour and the whole shell collapsed. The cracks were accompanied by vibration, which passed through both the shell and the entire building. The cracks were accompanied by scree to the aquapark premises, which carried along the whole mass of the roof. The collapse time was 30-40 seconds. Hundreds of people were under the rubble. As a result, 28 people lost their lives, more than a hundred were in hospitals with serious injuries. The reasons were the poor quality of construction and operation of the erected building, design errors.

Summary

Figure 9 presents information on accidents in industrial and civil buildings during the periods of their construction and operation in the territory of the Russian Federation according to the EMERCOM of Russia for the period from 2010 to 2017.
The analysis of these data showed that the dynamics of emergency cases of buildings and structures for residential, social and cultural purposes over the past seven years does not have a clear downward trend, which indicates the insufficiency of measures to prevent accidents. It is necessary to conduct a thorough analysis of the true causes of accidents in order to work out methods for eliminating and preventing errors at each stage of the life cycle of a construction object in order to reduce the number of casualties and increase the service life of the building.

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