



## Expert assessment of seismic safety of buildings and structures in Almaty

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### Abstract

The article presents the results of the research work "Certification of real estate objects of the city of Almaty for the purpose of their survey for earthquake resistance" carried out in 2017-2018 in the Republic of Kazakhstan. Almaty is located in the zone of high seismic risk. The main purpose of the work is to obtain up-to-date data on the seismic vulnerability of buildings and structures of existing buildings, primarily residential and social facilities, which is an urgent task not only for Almaty, but also for all settlements located in earthquake-prone regions of the Republic of Kazakhstan. According to the results of the work, up-to-date data were obtained and electronic passports were compiled for 10525 social and residential facilities. The results of the certification made it possible to identify earthquake-prone buildings, assign priority objects for their seismic reinforcement or demolition, determine the amount of costs for strengthening earthquake-prone buildings and demolishing dilapidated housing.

**Key words:** *earthquake, certification, survey, seismic safety, seismic reinforcement*

# 1 Introduction

The seismic areas of Kazakhstan occupy about 510 thousand km<sup>2</sup>, which is about 42 % of the total area of the republic. The largest cultural and industrial centers of the Republic of Kazakhstan, such as Almaty, Taraz, Shymkent and Oskemen, are located in areas of high seismic danger.

The city of Almaty (Verny, Alma-Ata) was founded in 1867 and is currently the largest administrative, economic and cultural center of the Republic of Kazakhstan. The city is located north of the Zailiysky Alatau ridge on the territory of the cones of the Bolshaya and Malaya Almatinka rivers and the adjacent sloping plain. Almaty seismogenic zone is bordered on the South by the TRANS-ili, in the South-East from the North-Kengashi, in the South-West with Kemin, which was located in the centers of the strongest earthquakes [1].

The city's territory is located in one of the most seismically active regions of Central Asia. Over the past 100 years there were three strongest earthquakes: Verny, 1887, 1889 Chilik and Kamenskoe 1911 Magnitude (M) of the last of them was close to 8,2 when the intensity at the epicenter of 10 to 11 points. In Verny, these earthquakes were accompanied by the destruction of buildings and the death of people [2].

The largest city of the republic – Almaty is located in the zone of possible earthquake foci and has a high population density. The territory of Almaty includes areas that are sufficiently favorable for construction (according to ground conditions), and located in zones of possible occurrence of faults on the earth's surface, with a slope steepness of more than 15 %, composed of loose water-saturated and subsident soils. According to the comprehensive map of seismic zoning, the area of the city Almaty is divided into zones with different intensity of predicted seismic impacts: zone I-8 points, zone II-9 points, zone III-10 points. Every year, on average, 15-20 earthquakes with an intensity of up to 3-4 points occur in Kazakhstan [3].

In the earthquake-prone regions of the Republic of Kazakhstan and in Almaty, at different times, work was carried out on the expert assessment of the state of the existing development.

## 2 General provisions

An enlarged expert assessment of the state of existing buildings in seismically dangerous areas of Kazakhstan, carried out in 1990, showed that, for example, residential buildings with a total area of 16.5 million m<sup>2</sup> (19 %) required seismic reinforcement; 10 million m<sup>2</sup> (12 %) - were subject to demolition. A sample survey of residential apartment buildings in the city of Almaty, carried out in 2008 in accordance with an Agreement with OYO International Corporation as part of the ongoing "Study on risk management related to seismic disasters in the city of Almaty, Republic of Kazakhstan", showed that at least 30 % of existing residential apartment buildings are not earthquake-resistant.

Approximately the same proportion of non-earthquake-resistant buildings in the group of objects related to the social sphere (schools, kindergartens, hospitals).

International experience shows that every devastating earthquake leads to a change in building codes in the direction of stricter requirements. Due to the observed tightening of the requirements of the standards, researchers and designers face problems related to the assessment of earthquake resistance and seismic safety of previously constructed objects [4].

### **3 The purpose of the work**

According to the Roadmap 2016-2018 "A set of measures to improve the efficiency of work to ensure the seismic safety of the Republic of Kazakhstan", the specialists of JSC "KazNIISA" carried out a research work Certification of buildings and structures of the existing development in Almaty.

The scientific work was carried out in 2017-2018 and consisted of two stages. At the first stage, in 2017, 7,027 objects are being surveyed. Of these, 6492 objects of housing and civil purposes and 535 social objects (preschool institutions, schools, hospitals and polyclinics) in the context of the administrative districts of the city of Almaty.

In 2018, a survey was conducted of 3,169 residential and civil facilities in Almaty, including 1,683 multi-apartment residential buildings, 1,486 civil and public buildings (administrative buildings, shopping centers, sports facilities, school and preschool buildings, sanatorium and resort buildings, recreation and tourism buildings, polyclinics). The main purpose of this work is to:

- create conditions for the sustainable functioning of the main social infrastructure facilities, life support systems and housing stock in Almaty;
- achieving an acceptable level of seismic safety of buildings and structures in Almaty;
- determination of the need to implement priority measures to account for seismic risk, prevent socio-economic losses, to ensure safety and improve the quality of life of the population, sustainable socio-economic development;
- reduction of possible economic, social and environmental damage from seismic impacts;
- creation of passports of survey on earthquake resistance of real estate objects in Almaty;
- creating a risk map with reference to the certification materials of the surveyed objects in Almaty.

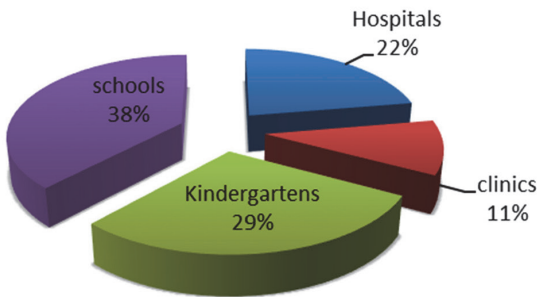
### **4 Tasks and stages of work**

To achieve this goal, the certification of real estate objects in Almaty included the following stages of work:

- visual inspection of buildings in Almaty in the context of administrative districts;

- creation of electronic passports of real estate objects in the GIS program with reference of objects to the local coordinate system of Almaty;
- identification of seismically vulnerable objects, in relation to which measures should first be developed to reduce the seismic risk of their further operation to an acceptable level;
- identification of the most earthquake-prone objects that require priority demolition or reinforcement;
- development of recommendations for further operation, seismic reinforcement or demolition of the object;
- assessment of the expected degree of damage to buildings and structures, depending on their design solutions, wear and seismic strength at maximum seismic impacts;
- assessment of economic and social damage from the consequences of possible earthquakes, assessment of the economic costs of seismic reinforcement by indicators of the degree of damage to buildings in possible calculated earthquakes.

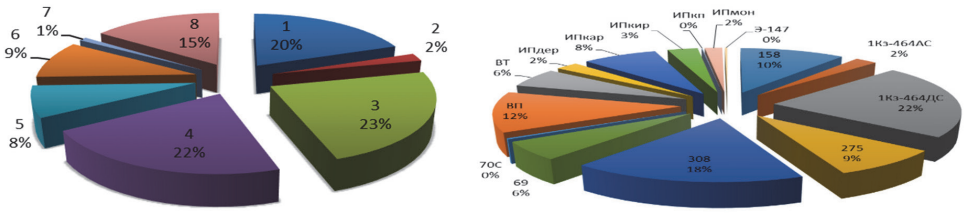
## 5 Results of the work



**Figure 1. structure of certification of municipal property objects by type of service**

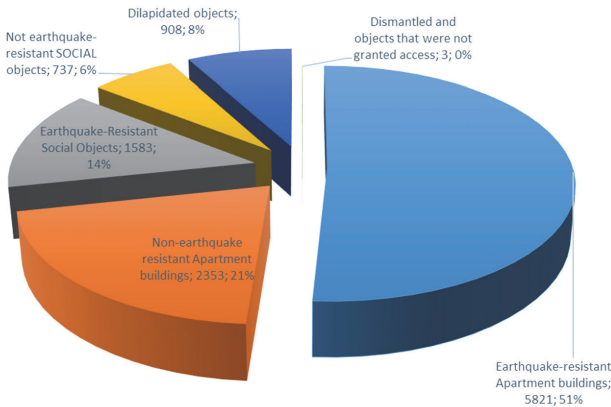
According to the results of the work carried out in 2017-2018 on the certification of real estate objects in Almaty, it was revealed:

2107 g. - of the total number of the surveyed buildings are earthquake resistant schools – 190 of 323 (58.9 per cent), kindergartens 129 of 246 (52,5 %), hospital – 76 of 191 (39,8 %), clinic – 69 of 89 (77,6 %), multifamily residential building – 4147 from 6490 (62,5 %). In terms of construction volume (total area), 73.6 % of schools, 62.1 % of kindergartens, 77.6 % of hospitals, 91.5 % of polyclinics, and 82.1 % of multi-family residential buildings are earthquake-resistant.



**Figure 2. The Structure of apartment buildings by administrative districts and by type series**

2018-earthquake-resistant: schools – 80 out of 96 (83.4 %), kindergartens – 84 out of 104 (80.8 %), medical and health facilities – 267 out of 365 (73.2 %), other buildings (multifunctional, administrative, shopping and entertainment centers, shops, sports, etc.) -778 out of 922 (84.4 %), multi – apartment residential buildings-1662 out of 1683 (98.8 %). By construction volume (total area), 81.5 % of kindergartens, 91.2 % of schools, other buildings (multifunctional, administrative, shopping and entertainment centers, shops, sports, etc.), and 99.6 % of multi-apartment residential buildings are earthquake-resistant.



**Figure 3. Structure of municipal property by type of service**

## 6 Conclusion

Based on the results of the certification, electronic passports of the surveyed buildings were created with an assessment of their seismic vulnerability.

The results of passportization made it possible to identify earthquake-prone buildings, assign priority objects for their seismic strengthening or demolition, and determine the amount of costs for strengthening earthquake-prone buildings and demolishing dilapidated housing [5].

According to the data of Passportization was revised to state program (for demolition of residential houses) and the old residential houses in Almaty are being demolished and in place of them to build new earthquake-resistant houses.

A spatial-territorial analysis of the data obtained with a seismic micro-zoning scheme was performed.

The classification of construction objects is based on the MSK-64 (K) seismic scale.

Based on the results of passportization, electronic passports of the surveyed buildings were created with an assessment of their seismic vulnerability.

An expert assessment of the economic costs of seismic reinforcement, economic damage and social losses from the consequences of possible earthquakes of different intensity is given.

Based on the results of certification, an electronic database on the seismic vulnerability of buildings and structures in Almaty was created, which will improve the reliability of life support systems, reduce damage to buildings and structures, and reduce the loss of population from destructive earthquakes.

An information model of urban development was created in the ArcGIS "ArcScene" program.

Based on the results of the research work, work will continue on creating an electronic map of the seismic risk of Almaty.

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