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Orginal Article

Summarising the seismic risk reduction processes in standard residential buildings of Yerevan: why don't we have real results?

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Abstract: The article addresses issues of ensuring housing safety. The aim of this work is to summarise the tasks set by the state for seismic risk reduction in Yerevan and to identify their reflection in the process of increasing the seismic resistance of standard residential buildings. The work includes: summarising the seismic risks of the territory of the Republic of Armenia and Yerevan; discussing the current situation of housing development in Yerevan, types of buildings, and possible reconstruction options; analysing the tasks set within the framework of increasing the seismic resistance of residential buildings built during the Soviet era in Yerevan; raising questions about the shortcomings of state policy; and revealing the contradiction between the measures taken in management and the principle of “priority of preparedness over recovery”. It was substantiated that the lack of significant results in the process is due to failures in management, rather than technical, economic, or legal problems. The results can be useful for improving strategies of residential development safety, as well as for fostering a more conscious approach to the problem by the state and society.

Keywords: standard residential buildings of Yerevan, seismic risk reduction, reconstruction options, housing policy management

1. Introduction

The amount of new residential construction worldwide is insignificant compared to the existing stock. Therefore, ensuring the operating life durability of buildings is crucial [1–5]. Seismic safety is of significant importance here. Although positive results in reducing earthquake casualties are almost universally observed, unlike other disasters, the problem is far from solved, and risks associated with natural disasters are rapidly increasing [5].

It should also be noted that due to the small number of newly constructed buildings overall, the impact of improved building codes on environmental safety risks is minimal. Real changes are only evident decades later [5]. A large number of buildings were constructed before the introduction of modern seismic design codes, which are regularly updated [6].

The approach of demolishing buildings to construct new ones does not effectively resolve the issue either. Research indicates that this is neither economically nor environmentally feasible for urban development [7–9].

In the broader context, Balasanyan and others note that in developing countries, where seismic risk is high and increasing due to urbanization, the main unresolved issue in risk reduction is the absence of a state policy. They suggest that the strategy for the 21st century to reduce seismic risk should focus on the priority of preparedness over recovery [10, 11].

A clear reflection of these problems can be seen in the Republic of Armenia (RA), particularly in its capital, Yerevan. Following the catastrophic Spitak earthquake of 1988, the attitude towards seismic safety in RA changed significantly, with extensive work carried out in the northern regions for seismic risk reduction. However, the situation in other parts of the Republic, especially in Yerevan, where more than a third of the country’s population resides, is concerning. Buildings constructed in Yerevan before 1988 constitute the majority of existing development, with a design seismic resistance of 7-8 on the MSK-64 intensity scale. Yerevan is located in the third seismic zone (intensity 9 and above), suggesting that many buildings would collapse in a large earthquake [12].

State and local governments should proactively take action, not wait for the next disaster. There is ample technical knowledge for effective modernization to prevent many losses [6]. Spence raises the question of why, despite advances in scientific understanding and technology, the number of victims and losses does not decrease, and what actions society, specialists, and government should take [5]. This paper attempts to clarify how the reduction of seismic risk in Yerevan's residential buildings is progressing, what results have been achieved, and whether research is moving in the right direction.

The selection of literary sources was based on collating local and international studies on the topic. The generalisation of numerous issues led to the identification of specific directions for the selection of literary sources. These directions include: dynamics of risks associated with natural disasters [5]; features of housing stock structure and components of seismic risk assessment [1–5, 13–15]; design features of buildings in seismic regions, structural efficiency problems of various types of buildings and serial housing construction [2, 4, 10, 12, 14, 16–18]; bearing capacity resources of residential buildings [13, 19]; seismic assessment methods and data collection challenges [6, 9, 12–16, 20–24]; calculated levels of seismic resistance and damage risk assessment results [6, 11–14, 16]; options for increasing seismic resistance, methods, and their comparison [5, 7–10, 12, 17, 19–21, 25–29]; economic and financial issues of increasing seismic resistance [6]; housing policy and management issues, and the role of society and the state [5–7, 23, 30, 31]; data on the history of earthquakes in the Armenian Highlands and the modern dynamics of seismic activity [10–12, 27]; characteristics of Yerevan's earthquake zone [10, 27]; the general picture of existing residential development, classification, prerequisites for seismic risk occurrence [12, 27, 32–34]; quantitative assessments of seismic risk and vulnerability of buildings [10, 12, 27, 35]; results of building certification [11, 12]; use of seismic isolation in the RA, its features [25, 26, 36–38]; and state measures to prevent seismic risks [27]. While the selection of literature sources on seismic risk assessment, building design peculiarities, economic issues of increasing seismic resistance, housing policy, and management principles was based on experiences from various geographical and economic contexts, in the case of RA and particularly Yerevan, where such studies are limited, an attempt was made to summarise all available scientific publications.

Previous works have discussed the need for modernisation of residential development in Yerevan, classification of problems in standard residential buildings, strategies for ensuring structure durability, development of proposals for increasing buildings' seismic resistance, and the need for enhancing the state's role in these processes [10–12, 17, 20, 25, 27, 34, 36, 39, 40, 41]. However, their reflection in state housing policy and tangible results were not adequately addressed. Research in this area, with respect to Yerevan, has predominantly focused on finding technical and economic solutions, leading to the perception that the main problem lies therein. This paper argues that this is a significant gap in existing research. The aim is to summarise the tasks set by the state for seismic risk reduction in Yerevan and to examine their impact on the process of increasing the seismic resistance of standard residential buildings. The work primarily focuses on the key points of the “Report on Seismic Risk Assessment and its Reduction on the Territory of the Yerevan City” (RSRARTYC) developed by the National Survey for Seismic Protection (NSSP) of RA in 1996 [27] and the issues of its implementation over the years, particularly concerning standard design residential buildings constructed during the Soviet period.

2. Materials and methods

The work was developed based on published materials, archival and active documents (scientific articles, reports, legal acts, regulations, specialist proposals, projects), and original research data, using scientific methods of generalisation and analysis.

In the first part of the work, the seismic risks of the territory of the RA and Yerevan were summarised: seismic activity of the region; characteristics of earthquake zones in Yerevan; analysis of the results of assessment of seismic resistance and the buildings' destruction risk were presented. It has been established that the magnitude of the expected seismic impact in Yerevan significantly exceeds the design capabilities of buildings.

The second part discussed the current situation of Yerevan's residential development, types of buildings, and possible reconstruction options: structural classification of residential buildings built during the Soviet era in Yerevan, their quantitative data, types, characteristics, prerequisites for the seismic risk occurrence and the share of vulnerability; a depiction of the city's seismic risk in the event of a repetition of the earthquake scenario of 1679; seismic assessment methods for buildings and the existing database; comparison of traditional and alternative reconstruction methods; existing proposals were presented.

In the third part, the following were analysed: the implementation of tasks assigned in the field of increasing the seismic resistance of residential buildings built in Yerevan during the Soviet years; legal mechanisms and tasks of state policy for ensuring seismic resistance; principles of countering seismic risks in the legal acts in force in RA; strategy for reducing the seismic risk of structures' destruction in Yerevan; issues of residential buildings strengthening. The target date for the processes and responsible authorities were presented. The downgrading of the status of the state authorised body managing seismic protection policy in the RA was established, and the contradiction of the measures taken in the field of management with the principle of "priority of preparedness over recovery" was revealed. Several questions aimed at the shortcomings of the state policy in the field of increasing the seismic resistance of Yerevan's standard residential buildings were raised. It was substantiated that the lack of any significant results in the process is due to failures in management, rather than technical, economic, and legal problems. The results can be useful for improving strategies of residential development safety, as well as for fostering a more conscious approach to the problem by the state and society.

With the graphic material presented in the work, an attempt was made to clearly show the structural classification, types, characteristics, and vulnerabilities of residential buildings in Yerevan, built during the Soviet years.

3. Results

3.1. Seismic risks of the territory of RA and Yerevan

Seismic risk assessment studies provide clear data on the history of earthquakes in the Armenian Highlands. According to these studies, documentary information about significant earthquakes is available from the 5th century work of M. Khorenatsi. He mentioned a large hollow on the northern slope of Mount Ararat, formed as a result of an earthquake. Notable earthquakes occurred in Dvin, Tsakhkadzor, and Garni. The Parakar source of large earthquakes, adjacent to Yerevan's western borders, has been particularly active over the last century, experiencing seven large earthquakes in the 20th century [12, 27].

Data characterising the seismic activity of the Armenian Highlands and the Caucasus region in the 1970s-1990s indicate changes in seismic activity dynamics. If previously a large earthquake occurred approximately every 50 years, this interval has significantly shortened since 1976 [12, 27].

The seismic hazard of the RA territory is at an extremely high level, and, according to some experts, it has reached its historical peak [27]. Almost the entire territory of the RA lies within a seismically active zone.

The 1988 Spitak earthquake stands out as a significant event, being the largest earthquake in Armenia's instrumental observation history. Occurring 100 km from Yerevan, it resulted in approximately 25,000 fatalities, 20,000 serious injuries, and over 500,000 people displaced [27]. This earthquake demonstrated that the seismic resistance level of structures in the RA is significantly lower than potential hazards.

Since 1989, measures have been undertaken to reduce seismic risk in the earthquake-affected northern regions of Armenia. This has involved establishing a national construction regulatory framework for seismic resistance, reassessing seismic risk, taking inventory of earthquake-damaged structures, and strengthening them [12]. As noted by Spence, significant earthquakes typically lead to considerable strengthening programmes and improvements in building codes as public concern and risk awareness rise. However, in high-risk areas with no recent earthquake activity, these processes often remain neglected [5]. In this context, it's important to acknowledge that other regions of the RA have not received adequate attention. Furthermore, in Yerevan, considering its large population size and density, a major earthquake would pose a severe hazard. Historically, Yerevan has experienced significant earthquakes, and according to maps outlining the distribution of seismic risk, the highest hazard within the territory of the RA is concentrated in this region [10, 11].

The characteristics of Yerevan's seismic hazard zone are detailed in the RSRARTYC. Seismic zones in this report are identified based on the location of active faults and sources of historically significant earthquakes [10, 27]. The document includes engineering geological characteristics of Yerevan's territory, with a notable analysis of seismicity and earthquake chronology. This chronology, covering large earthquakes that caused destruction and human casualties, spans from 550 B.C. to 1993, and includes 223 earthquakes of varying intensities – up to 1932 based on macroseismic data, and thereafter, on instrumental data. The overall time range is divided into three parts according to the quality of the data obtained: 550 B.C.-1932, 1932-1962, and 1962-1993. From this division, the authors have identified certain patterns in the chronology of earthquakes. In the first range, it is projected that the next large earthquake, with a magnitude of 5.5, might occur in 2140, which would be 300 years after the largest Ararat earthquake in 1840, with a magnitude of 7.4. For the second and third ranges, where recurrent cycles of earthquakes with a magnitude of 5.0, approximately every 15 years, were identified, the next earthquake was expected in 2007, since the last earthquake of magnitude 5.0 occurred in 1992 in Martuni [27]. Interestingly, in 2007, an earthquake of magnitude 3.6 did occur in Gavar, located 30 km from Martuni.

The RSRARTYC also addresses issues of fault activity and seismotectonics in the Yerevan region. It identifies key faults, including the Garni, Araks, and Yerevan faults, and highlights the main sources of earthquakes that have historically caused significant damage to the city. These sources include the area 90 km to the south, which was the origin of the Ararat earthquake in 1840, the highly active source located 20 km to the southeast responsible for the Dvin earthquakes in 851-893, and the Parakar source adjacent to the western borders of Yerevan, associated with an earthquake of magnitude 4.7 on February 13, 2021 [27].

In the RSRARTYC, the Garni fault is considered to be the most hazardous active fault. Located 10 km east of Yerevan, it stretches 166 km and has an average horizontal displacement velocity of 3-5 mm/year. This fault is linked to the epicentres of significant earthquakes, and some experts believe its activation was a contributing factor to the 1988 Spitak earthquake. The earthquake of June 4, 1679, associated with the Garni fault, is particularly notable; it devastated Yerevan and numerous villages in the Ararat Valley, causing tens of thousands of casualties. According to historical records, this was one of the most destructive earthquakes in the history of Yerevan, which dates back to 782 B.C. [10, 27]. Experts attribute the extreme hazard of the active Garni fault to Yerevan to two main factors: the spatio-temporal migration of large earthquake sources from the southeast to the northwest and the decreasing interval between significant seismic events. They consider the possibility of a recurrence of the Garni earthquake series as a plausible scenario [27].

Summarising various data, it is reported that currently, the magnitude of potential earthquakes can reach up to M=7.1-7.5, as determined by instrumental measurements, historical records, and paleoseismic estimations. The average focal depth of these seismic sources is about 10 km. All these sources are situated on active faults, which have an average displacement velocity of 1 cm/year. Under unfavorable ground conditions, the duration of earthquakes could extend up to 1 minute. The average recurrence interval for large earthquakes, with magnitudes of M≥5.5, is estimated to be 30-40 years [10].

Turning to the development issues and demographic characteristics of Yerevan in the context of seismic risk, according to the report by the "Seismanakhagits" company, Yerevan's structures are primarily built to withstand seismic resistance levels of 7-8 on the MSK-64 intensity scale [12]. Analysis of the calculated seismic resistance of buildings and the risk assessment of destruction reveal that approximately 15% of the city's territory lies in an extreme hazard zone, with over 5,000 buildings located there. Additionally, 24% of the city's area consists of more than 34,000 low-rise individual houses, most of which were constructed without professional design, placing them in the most hazardous areas as well. Estimates suggest that in the event of an earthquake with a magnitude of 7.0 in Yerevan, around 80% of buildings could be destroyed, potentially resulting in up to 300,000 casualties [11]. For comparison, it's noted that if the 1934 earthquake scenario in Nepal were to recur, an estimated 14% of structures would sustain major damage, 7% would be completely destroyed, and the total economic damage could amount to around 13 billion EUR [16]. In Portugal, the estimated economic losses from seismic impact were calculated at 15.7% of the total building stock, with restoration costs exceeding 350 billion EUR [14]. In Turkey, about one-third of the building stock, comprising approximately 9 million buildings, has inadequate seismic resistance; modernisation of these buildings is expected to require 500 billion USD and at least 20 years [6]. In Italy, it's projected that around 36,000 dwellings will become uninhabitable within a year, with approximately 80,000 people becoming homeless. In the most at-risk areas, the damage per square meter over one year is about 9 EUR, potentially reaching 275 EUR over 50 years [13]. Overall, these data paint a concerning picture, particularly for Yerevan.

Therefore, it is clear that the increase in seismic activity in the region presents a significant hazard for Yerevan. It's important to remember that the capital of the RA, covering an area of 223 square kilometers, has a population of about 1.1 million people, which constitutes more than one-third of the Republic's total population.

In conclusion, the discussion of seismic risks reveals that the expected seismic impact in Yerevan greatly exceeds the design capabilities of buildings. Research indicates that increased damage from natural disasters often results from inadequate construction controls. To mitigate this, effective regulation by the state is crucial [5]. Countries that adopt a policy of preventive modernization tend to experience less structural destruction than anticipated [6; 13]. This issue should have been a primary concern for the Government of the RA. The program for seismic risk reduction in Yerevan, adopted by Government Resolution No. 392 on June 7, 1999, aimed at comprehensive seismic risk reduction in Yerevan, is a crucial step towards ensuring national safety in the RA. However, before delving into government programs, it's important to understand the types of residential buildings and developments present in Yerevan and their current condition.

3.2. The current situation of residential development in Yerevan, types of buildings, and possible reconstruction options

The existing residential development in Yerevan, primarily established in the last century and especially during the Soviet period, is categorized into distinct stages corresponding to various objectives [12, 32-34]. The classification of the structure of residential buildings is presented in accordance with the evolution of the construction industry, the establishment of a regulatory framework for earthquake-resistant construction, and the characteristics of state policy in the housing sector. This classification is depicted in Fig. 1.

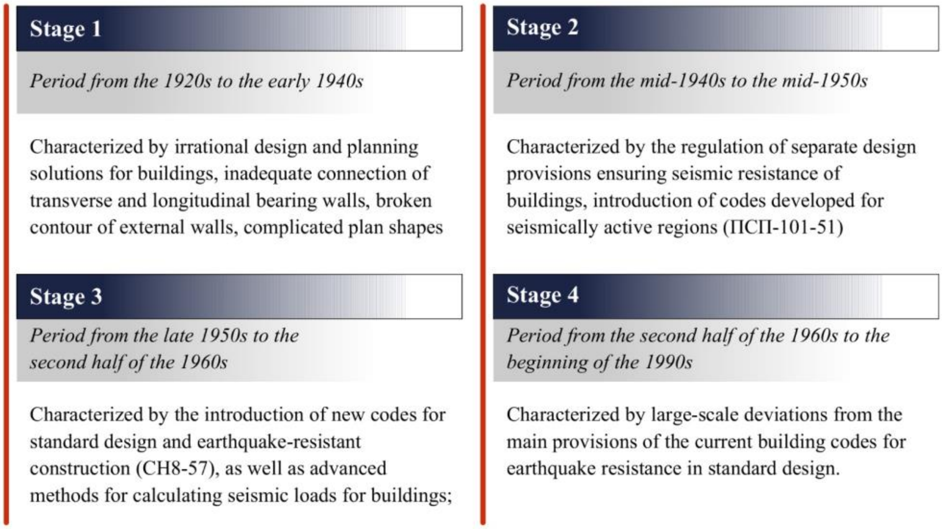

Fig. 1. Classification of Soviet-era residential buildings in Yerevan by structure. *Source:* [12]

Residential buildings constructed in Yerevan during these stages vary in terms of the number of floors, structural solutions, and seismic resistance. As of 2021, there are 4,982 residential buildings in Yerevan: 2,373 stone buildings (47.6%), 2,410 reinforced concrete (R/C) precast buildings (48.4%), and 199 R/C monolithic buildings (4%). Over 90% of these buildings were constructed during the Soviet era, before the Spitak earthquake. Data from 2008 indicate the distribution of building storeys as follows: 3-storey buildings make up 15.7%, 4-storey 23.5%, 5-storey 33.9%, 6-8 storey 2.9%, and buildings with 9 storeys or more 24.1% [41].

The RSRARTYC summarizes the general picture of Yerevan's residential development during the Soviet period as follows: low-rise stone houses; stone and complex buildings up to 5 storeys; large-panel buildings up to 9 storeys; frame-and-panel buildings up to 9 storeys; buildings constructed by the lift slab method up to 16 storeys; frame and braced-frame buildings up to 16 storeys [27].

For certification purposes, residential buildings in Yerevan have been classified according to their structural system as follows: stone (individual, standard of 1-451 and 1A-450 series), and R/C (large-panel, frame, frame-and-panel, braced-frame, constructed by lift slab method, monolithic) [12].

The characteristics of these types of buildings are shown in Fig. 2.

N	Name/ Construction time	Basic volumetric and planning characteristics	Structural system and main characteristics	Seismic resistance characteristics	Quantitative data
1	Individual stone buildings/ before 1958 	number of storeys: 3-6, mostly 4 (3 storeys before 1940); plan shape: complicated, sectional; plan sizes: individual in each case; storey height: 3.5 m or more	structural system: bearing stone walls; foundation: strip, concrete; base part of the walls: basalt, thickness 60-80 cm, with lime mortar; walls: tufa, thickness 50-70 cm, midis masonry, with lime mortar; ceilings: wooden; lintels and parting walls: wooden; staircases: precast R/C; roof: pitched, with wooden structures, covered with corrugated asbestos or flat metal sheets	Among the main disadvantages are: disproportionality of bearing walls in two directions, leading to asymmetry of stiffness, low stiffness of ceilings and large building height for masonry, low design class of mortar and low bearing properties of masonry	The number of buildings in Yerevan is 802. There is no data on the number of buildings damaged in the disaster zone during the 1988 earthquake
2	Standard stone buildings (1-451 series)/ from 1958 to early 1970s 	number of storeys: 4-5; plan shape: rectangular, sectional; plan sizes: 10.8X46.8 m in case of 3 sections, 10.8X62.4 m in case of 4 sections; storey height: 3.0 m	structural system: bearing stone walls; foundation: strip, concrete; base part of the walls: basalt, thickness 60 cm, with cement-sand mortar; walls: tufa, thickness 50 cm, midis masonry, with cement-sand mortar, with R/C cores at intersections and corner sections, with monolithic R/C bands at the ceiling level; ceilings: precast R/C panels; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness; staircases: precast R/C; roof: pitched, with wooden structures, covered with corrugated asbestos or flat metal sheets	Among the main disadvantages are: poor choice of structural system, incompleteness of constructive measures, large building height for masonry.	The number of 1-451 and 1A-450 series buildings in Yerevan is 1312 (1001+311). The number of buildings damaged in the disaster zone during the 1988 earthquake: 320 (39.6 %)
3	Standard stone buildings (1A-450 series)/ from early 1970s to 1988 	number of storeys: 4-5; plan shape: rectangular, sectional; plan sizes: 12.7X49.2 m in case of 3 sections, 12.7X67.3 m in case of 4 sections; storey height: 3.0 m	structural system: bearing stone walls; foundation: strip, concrete; base part of the walls: basalt, thickness 60 cm, with cement-sand mortar; walls: tufa, thickness 50 cm, midis masonry, with cement-sand mortar, with R/C cores at intersections and corner sections, with monolithic R/C bands at the ceiling level; ceilings: precast R/C panels; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness; staircases: precast R/C; roof: pitched, with wooden structures, covered with corrugated asbestos or flat metal sheets	Among the main disadvantages are: violation of the principle of symmetrical and equal distribution of stiffness (lack of longitudinal walls in the middle sections and transverse walls in the end sections), low stiffness of ceilings and large building height for masonry, low design class of mortar and low bearing properties of masonry	
4	Frame-and-panel buildings (111 series)/ 1975-1988 	number of storeys: 9, with a service floor; plan shape: rectangular, sectional; plan sizes: 18.0X18.0 m in case of 1 section, 12.0 m width of the ordinary section; storey height: 3.0 m	structural system: precast R/C frame; foundation: point, precast R/C, with a monolithic concrete band under external self-supporting walls; base part of the walls: regular shaped tufa masonry, with R/C cores, facing with basalt slabs on the outside; columns: precast R/C, section 40X40 cm; bearing beams: precast R/C, with T-shaped section 52X40 cm; external walls: precast R/C suspended panels, facing with tufa slabs on the outside; ceilings: precast R/C panels; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness; staircases: precast R/C; lift shaft: monolithic R/C; roof: single-pitched, with internal drainage	Among the main disadvantages are: unreliability of columns and beams connections, asymmetrical arrangement of shear walls, disproportionality of shear walls and columns connections, external panels sharing in the operation of the frame	The number of 111 series buildings in Yerevan is 412. The number of buildings damaged in the disaster zone during the 1988 earthquake: 127 (52.0 %, in Gyumri: 95 %)
5	Buildings constructed by lift slab method/ 1970-1988 	number of storeys: 12-16, with a service floor; plan shape: complicated, symmetrical in relation to certain geometric axes of the structure, mainly with 1 section; plan sizes: variable; storey height: 3.0 m	structural system: monolithic R/C bearing core, precast R/C columns and monolithic R/C ceilings, which rise to the required level using columns; foundation: monolithic R/C slab of 40-50 cm thickness, connected to mutually perpendicular foundation beams; base part of the walls: self-supporting, thickness 45 cm, tufa masonry, with cement-sand mortar and R/C cores; columns: precast R/C, section 50X50 cm; core and ceilings: monolithic R/C; external walls: precast R/C self-supporting panels of 30 cm thickness; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness and precast R/C ventilation blocks; staircases: precast R/C; lift shaft: monolithic R/C; roof: single-pitched, with internal drainage	Among the main disadvantages are: insufficient integrity of the seismic resistance system, insufficient joint work of the core and frame, lack of rigid connections between the core and ceilings, columns and ceilings, unreliability of evacuation solutions.	The number of buildings constructed by lift slab method in Yerevan is 95. The number of buildings damaged in the disaster zone during the 1988 earthquake: 2 (100 %)

6	Braced-frame buildings/ 1960-1988 	number of storeys: 9-16; plan shape: rectangular and square, sectional; plan sizes: 18.3X18.3 m in case of 1 section; storey height: 3.0 m	structural system: precast R/C mutually perpendicular frames and half-frames, connected with monolithic R/C; foundation: monolithic R/C slab of 40-50 cm thickness, connected to mutually perpendicular foundation beams; base part of the walls: self-supporting, thickness 45 cm, tufa masonry, with cement-sand mortar and R/C cores; frames: precast R/C, section 50X50 cm; external walls: precast R/C self-supporting panels of 30 cm thickness; ceilings: precast R/C panels; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness and precast R/C ventilation blocks; staircases: precast R/C; lift shaft: monolithic R/C; roof: single-pitched, with internal drainage	Professional opinions note that the structural solutions of braced-frame buildings comply with the current code requirements for earthquake-resistant construction in the RA.	The number of braced-frame buildings in Yerevan is 526. No such buildings were built in the disaster zone, so there is no data on buildings damaged by the 1988 earthquake
7	Large-panel buildings/ from 1970 to present 	number of storeys: 4-9; plan shape: rectangular and square, sectional; plan sizes: 18.0X18.0 m in case of 1 section, 10.85 m width of the ordinary section; storey height: 3.0 m	structural system: precast R/C mutually perpendicular walls; foundation: strip, monolithic R/C, on mutually perpendicular directions; walls: precast R/C panels of 3.0X3.0 m sizes and 30 cm thickness; ceilings: precast R/C panels; lintels: monolithic R/C; parting walls: pumice concrete slabs of 6 cm thickness; staircases: precast R/C; roof: flat, with internal drainage	In professional reports, the performance of buildings during an earthquake is assessed as satisfactory	The number of large-panel buildings in Yerevan is 1197. The number of buildings damaged in the disaster zone during the 1988 earthquake: 0
8	Monolithic R/C buildings/ from 1988 to present 	number of storeys: up to 20 or more; plan shape and sizes: variable; storey height: 3.3 m	structural system: monolithic R/C frame and wall systems; foundation: strip, monolithic R/C; external walls: lightweight concrete blocks, facing with natural stone or artificial materials; ceilings: mainly monolithic R/C; lintels: monolithic R/C; parting walls: lightweight concrete blocks; staircases: monolithic R/C; roof: flat or pitched, with external or internal drainage	In professional reports, the performance of buildings during an earthquake is assessed as satisfactory.	The number of monolithic R/C buildings in Yerevan is 199 (as of 2021). No such buildings were built in the disaster zone, so there is no data on buildings damaged by the 1988 earthquake

Fig. 2. Types and characteristics of Soviet-era residential buildings in Yerevan. *Source:* [12]

Issues with the construction of mass-produced standard residential buildings and the quality of materials used are observed in many countries, often due to excessively large production scales [2, 4]. Following the Spitak earthquake, the State Commission under the Council of Ministers of the USSR highlighted significant shortcomings in the design and construction of mass-produced buildings in Armenia. These included extremely low quality of concrete and mortars, poor construction and installation work, as well as violations of design and construction standards, all of which contributed to the low seismic resistance of buildings [12].

Now, let's attempt to understand the efforts undertaken to assess the seismic resistance of existing residential buildings in Yerevan. However, first, it's important to clarify how the seismic risk for these structures originated. Beginning in 1960, a building code was applied in the RA, which considered the region's seismicity. This code was further enhanced in 1969 and 1981, incorporating more stringent design and construction requirements [27]. When designing buildings in seismic regions, factors such as the intensity and recurrence of seismic impacts are considered [14, 16]. In Armenia, these were assessed based on seismic zonation and microzonation maps of the USSR. According to these maps, constructing buildings in areas with seismicity exceeding 9 on the MSK scale was prohibited. Given that about 85% of the housing stock was built post-1960s, theoretically, only a small fraction of the structures should present significant seismic risk. However, as mentioned in the RSRARTYC, to facilitate rapid and inexpensive construction, measures were taken in the latter half of the 1970s that artificially lowered the perceived seismic hazard in the RA. In 1976, the USSR State Construction Committee approved new seismic zoning maps. For instance, the Spitak earthquake zone was marked as one of the safest areas, with the hazard rate reduced by 3 intensity levels (to 7 instead of 10 on the 12-intensity MSK scale). As a result, seismic hazards were not adequately considered during the design phase [27].

Based on various quantitative estimates, a general picture of Yerevan's seismic risk was obtained by considering a hypothetical repetition of the 1679 earthquake. This assessment took into account the entire chronology of seismic events, ground conditions, types of structures, their reliability based on the experience of the Spitak earthquake, and the number of inhabitants [10, 27, 35]. As a result, braced-frame and large-panel buildings were identified as the most reliable, a conclusion that aligns with assessments made in other countries as well [18]. Stone buildings were deemed to possess a certain degree of reliability. However, frame, frame-and-panel buildings, and those constructed using the lift slab method were classified as less reliable structures [10].

The analysis of developed maps led to the following conclusions:

In comparison with the overall occupied territory, the highest level of destruction is anticipated in the south-eastern part of the city, specifically in the Erebuni administrative district. However, human losses in this area are expected to be lower since it mainly consists of low-rise individual development.

The most significant human losses are expected in the north-western part of the city, in the Ajapnyak administrative district. Although the zone of destruction here will not be very extensive, this area contains many multi-storey residential buildings [10, 27].

Furthermore, calculations by the RA Ministry of Emergency Situations revealed that residential buildings in Yerevan constructed before the Spitak earthquake exhibit varying degrees of seismic vulnerability. This vulnerability is influenced by factors such as the year of construction, structural peculiarities, and the extent of damage sustained during their operation. The degrees of seismic vulnerability of these buildings are illustrated in Fig. 3.

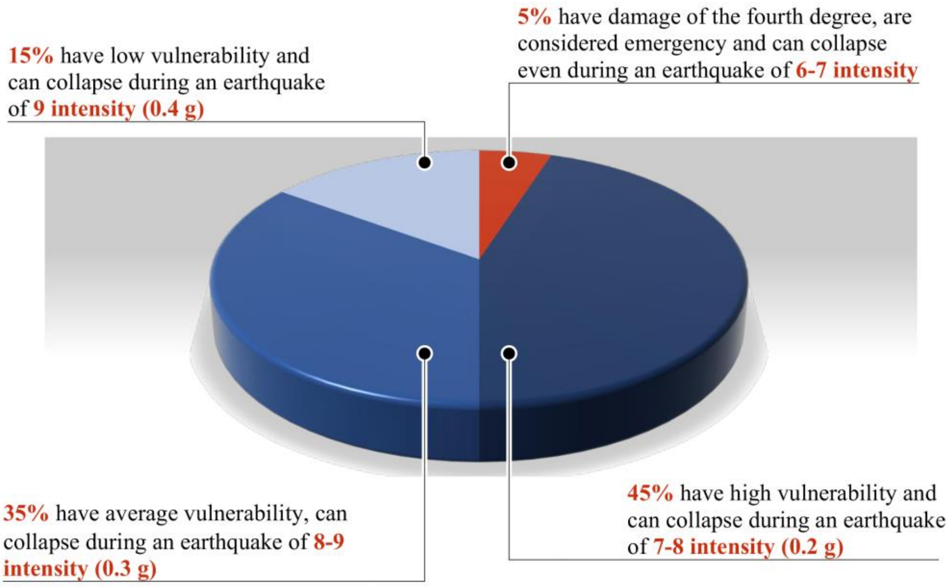

Fig. 3. Seismic vulnerability of Soviet-era residential buildings in Yerevan. *Source:* [12]

Based on experimental studies, earthquake analyses, international experience, and vibration tests of certain buildings, Armenia has developed a methodology for the seismic assessment of existing buildings [20]. The method involves several stages: 1) collection of general information and design documentation for the structure; 2) verification of the data's accuracy; 3) on-site inspection of the structure's technical condition and building materials; 4) assessment of the dynamic characteristics of the soil; 5) preparation of the building's design model; 6) determination of maximum potential accelerations in different parts of the building and assessment of the actual physical, mechanical, and dynamic characteristics of bearing structures; 7) calculation of the actual/required bearing capacity ratio of the building, based on the obtained data. This ratio must be at least 1 for the seismic resistance of the building to be considered adequate. Additionally, a method for calculating the actual bearing capacity is proposed for cases with incomplete information on bearing structures [20]. Note that assessing the physical deterioration of buildings is an extremely complex yet important task [9, 13, 14, 16], and in the works outlined in paragraphs 2 and 3 of the proposed method, recording changes caused by uncontrolled intervention by residents is essential. As in many cities around the world [16, 21–24], in Yerevan, such interventions also pose a significant risk. The accuracy of the data on buildings used in all calculations is critically important [13]. Data may differ significantly from reality, depending on the approach and feasibility of collection, and may contain uncertainties regarding the structural characteristics of the housing stock [13–15]. Using the aforementioned methodology, the seismic resistance of 20 buildings in the A1 and A2 microdistricts of the Malatia-Sebastia administrative district of Yerevan was evaluated, and a database was compiled. The assessment revealed that the seismic resistance of none of the buildings, according to the current seismic code, is guaranteed [11].

Another seismic risk assessment study was conducted in Yerevan in 2010, resulting from a collaboration between the "Seismanakhagits" company and the Japan International Cooperation Agency (JICA) [12]. Based on the city's first seismic risk map, Yerevan was divided into five large areas. These areas were further subdivided into sub-sites for the random selection of buildings to study. Consequently, certifications were compiled for 153 structures, including 103 residential buildings, providing an assessment of their technical condition [12]. However, the number of structures studied is relatively small. For comparison, it can be noted that in the DadO database in Italy, where data on the structural characteristics of buildings and damage from seismic impact are catalogued and compared, more than 320,000 buildings were registered in 2021 [13]. The continuous updating of this data is crucial, as it leads to regular refinement of planned actions [6].

In general, the seismic risk assessment of housing stock encompasses three main components: seismic hazard, the vulnerability of the considered assets at risk (types of buildings and their seismic resistance characteristics), and exposure (number of buildings, percentage of vulnerability, spatial distribution) [13, 14]. Accordingly, the exposure model for European seismic risk assessment consists of two main stages: identifying the predominant building classes and modelling the spatial distribution of the number of buildings, replacement cost, and number of occupants within each building class [15]. To effectively manage seismic risk, determining all the economic, social, and environmental consequences of a disaster is crucial. In this context, the proposed urban seismic risk assessment model is noteworthy, as it uses fuzzy sets to allow for the continuous integration of corrective and alternative measures [30].

However, with considerable reservation, it can be stated that some work in the field of seismic risk assessment has already been undertaken in Yerevan, and implementing the aforementioned considerations will aid in enhancing the efficiency of these efforts.

Next, let's explore what reconstruction options are available to enhance the seismic resistance of the structures mentioned earlier. Generally, mass reinforcement of existing buildings incurs enormous costs. In some countries, a transitional step involves a requirement that, in the case of reconstruction due to functional changes, the structure must also be strengthened [5]. However, this approach is often impractical for residential buildings with multiple owners, especially when functional changes are not anticipated. Additionally, traditional reconstruction methods, such as reinforced concrete jackets, additional shear walls, etc., are challenging to implement in the conditions of the RA. They demand significant financial resources and necessitate the relocation of residents. Consequently, the RSRARTYC is exploring alternative methods of building strengthening, including the implantation of an additional isolated upper floor (AIUF) and seismic isolation at the base [27].

The AIUF functions as a dynamic vibration damper. It involves a pendulum mechanism placed atop a building in the form of an extra floor, which oscillates in antiphase relative to the building, leading to a reduction in shear forces and horizontal displacement. The pendulum's mass is equivalent to that of the entire additional floor, and its spring consists of laminated rubber bearings (LRB), which connect this floor to the building. The additional floor is a rigid structure that, during an earthquake, rests on the LRB and experiences practically no deformations. The AIUF is implemented as a steel frame structure, with columns supported by LRB connected by steel trusses [27]. This method also enables an increase in usable area, which has been identified as the most appropriate option in various studies assessing the effectiveness of reconstructing residential buildings [8, 19, 28, 29]. Dynamic tests conducted on a 9-storey reinforced concrete (R/C) frame building have proven that the shear force on the 1st floor decreases by 1.7 times, and on the 9th floor by 2.1 times [10].

In the case of base isolation, the building's base is separated from the top using LRB. The damping properties of the LRB help to filter ground vibrations. This simplifies the building's vibration mode, making it more akin to that of a rigid body, and minimizes relative deformations within each floor's height, effectively preventing damage. The core concept involves installing reinforced concrete (R/C) beams at two levels along all bearing walls at the basement floor. During implementation, LRB are installed between these beams. The lower-level beams are connected to the building's foundations, and the upper-level beams to the upper part of the structure. Eventually, sections of the walls between the two beam levels are methodically removed, transferring the entire load of the building onto the LRB [10, 27].

An attempt to compare traditional and alternative methods of building reconstruction was based on data from the reconstruction of 25 buildings (5-storey with stone bearing walls and 9-storey with reinforced concrete (R/C) frames) in the Spitak earthquake zone [20]. According to this data, the average cost of strengthening a building with stone walls using traditional methods was 300,000 USD, and for a frame building, it was 150,000 USD. In these cases, providing temporary housing for residents was mandatory, leading to additional expenditure. However, for seismic isolation of buildings (one with stone walls and one with an R/C frame), carried out under the same program, there was no need to relocate residents. The cost of strengthening the stone building with base seismic isolation was 170,000 USD, while in the frame building where an AIUF was installed, it was 70,000 USD. Considering the elimination of the need for temporary housing, which is recognized as the most economically appropriate option in reconstruction processes [17, 21], these methods were approximately half the cost [20].

Comparison of reconstruction methods is also discussed in other studies [25, 26]. A notable example is the strengthening of a 9-storey large-panel residential building in Stepanakert. According to calculations, the effectiveness of base seismic isolation, compared to traditional methods, is estimated to be approximately five times greater. The cost for base seismic isolation was 185,000 USD compared to 1 million USD for traditional methods, and the time required was 6 months instead of 30 months [25].

Program proposals have been developed to enhance the seismic resistance of residential buildings using these technologies. The "Melkumyan Seismic Technologies"[1] company proposed a program aiming to neutralize the seismic risk of buildings constructed in the RA before 1994, through public-private collaboration. The proposal suggests applying seismic isolation technologies either at the base or on the top of the buildings, highlighting the already discussed advantages. The initial stage of the program expects state participation, such as funding pilot projects providing housing for socially unsecured families or war veterans. Subsequently, the plan is to attract businesspeople who, along with constructing and selling new areas, will improve the seismic resistance of buildings. The authors anticipate that the profits will significantly outweigh the costs. The proposal's effectiveness is characterized by several factors: no need for large financial investments and self-financing; avoidance of interruption in building operation; acquisition of additional usable areas without land procurement; no need for new utility construction for newly formed areas; addressing roof modernization issues; offering solutions to social problems; stimulating the construction industry; creating job opportunities; and fostering public-private sector cooperation. It is also emphasized that all required structures are produced within the RA. Importantly, the program raises the issue of managing the balance between public and private investments in organizing and financing government programs, as well as containing business objectives, which are crucial aspects [9, 22, 31].

Another proposal was put forward by the RA Ministry of Emergency Situations[2]. Like the previous case, this proposal views the increase in seismic resistance of Yerevan's buildings as a national security issue requiring urgent attention. In line with financial and practical expediency, the authors suggest the use of special seismic protection systems, such as AIUF. The proposal also identifies key implementation challenges that need addressing. One crucial aspect is the proposed amendment to the RA Law "On the Management of Residential Buildings," which would allow roofs not to be considered communal property and thus be freely provided to companies committed to strengthening the building. Additionally, the importance of government agencies developing projects for strengthening residential buildings is emphasised. It's worth noting that applying a standardization approach to these projects, as seen in the Russian Federation, could reduce costs by 30-40% compared to individual projects [21].

According to Melkumyan, seismic isolation in the RA is cost-effective due to the lower construction costs, particularly the reduced cost of locally produced LRB compared to other countries [36]. A number of buildings in the RA have been reconstructed using these technologies. The reconstruction of stone and large-panel buildings involved the

[1] "Melkumyan Seismic Technologies" Company. "Increasing the seismic resistance of existing buildings and structures in the Republic using innovative seismic isolation technologies in the conditions of high seismic risk without stopping their operation and without attracting state funds".

[2] Department of Structures Seismic Resistance under the Seismic Protection Territorial Survey (SPTS) State Non-Commercial Organization (SNCO) of the RA Ministry of Emergency Situations: "Strategic program for reducing the seismic risk of residential buildings in the city of Yerevan."

gradual formation of reinforced concrete (R/C) beams at two levels within the base floor, with LRB installed between them [25, 36, 38]. In frame buildings, LRB were placed under columns and shear walls, grouped into two or three isolators [37]. One advantage of this method is that strengthening the upper part of the building, often necessary in frame constructions, can be done concurrently with seismic isolation [26]. The LRB are expected to have a lifespan of several decades without requiring maintenance [25]. If we consider a time frame of 25-30 years, it may be prudent to make such investments while also planning for the future. During this period, the buildings might either be demolished and replaced with new ones, or the LRB could be substituted, providing another 25-30 years of service. However, it's important to consider the reserve bearing capacity of the buildings, acceptable limits of physical deterioration [13, 19], as well as the costs of monitoring and maintaining seismic isolation systems. Nonetheless, definitive answers to these questions should emerge from further research, where comparing the strengths and weaknesses of reconstruction options will help identify the most suitable solutions.

It should be noted that factual data on specific cases of increasing the seismic resistance of standard residential buildings in Yerevan is ambiguous. Although addressing this problem falls within the direct responsibilities of the Department of Housing Fund Management and Communal Infrastructure and the "Expertise Center for Urban Development Projects" JSC, both under the jurisdiction of the RA Urban Development Committee, our official inquiries reveal that they do not possess such information. Similarly, the Yerevan Mayor’s Office was unable to provide an answer to this question.

3.3. Analysis of the implementation of assigned tasks: why don't we have real results?

Addressing the management of processes, it's worth noting that in many countries, increasing seismic resistance is often planned to be funded by the owners, supplemented by government subsidies, tax incentives, and other forms of support, frequently on a voluntary basis. However, owners are generally reluctant to invest in building reinforcement, as it represents a substantial financial outlay without immediate, tangible returns, and is not easily capitalizable. This raises an intriguing question: if ensuring seismic resistance is challenging even with mandatory requirements, how can voluntary compliance be achieved [6]? The authors suggest that owners can be motivated through policy incentives and cite the example of Italy, where programs for seismic resistance and energy efficiency have been successfully integrated [6].

This policy should naturally be implemented by the state. Spence outlines several challenges associated with the government's role in reducing damage from natural disasters. These include the excessive complexity of modern seismic codes, the importance of training supervisors, the necessity of organizing financial assistance to enhance the effectiveness of building strengthening by owners, the efficient use of insurance resources to reduce risk, and raising public awareness. He particularly emphasises that codes should align with a country’s socio-economic conditions. Mechanically applying one country’s code to another may prove ineffective. Developing new regulations is a time-consuming process with various difficulties, and there are always stakeholders who may obstruct the passage of laws or avoid their implementation. Sometimes, the application of simpler rules, such as restrictions on the number of storeys or bans on construction in high-risk areas, can be more effective than complex technical requirements [5]. Furthermore, monitoring and periodically improving policies are crucial tasks in ensuring seismic resistance. Zhang and others highlight Japan as an example, where significant attention is paid to reducing the constant discrepancy between programs and actual results [6].

Now, let's try to understand how the RSRARTYC, a document prepared by an authorized government body, envisions the future of the RA's protection from seismic risks. In the document's fifth section, "Preparedness for Earthquakes," it is noted that Armenia's independence following the Spitak earthquake enabled the prioritisation of protecting the population from earthquakes as a national security task. Subsequently, in 1991, on the initiative of S. Balasanyan, the NSSP under the Government of the RA was established. This body was granted special governmental status and powers [27].

The primary responsibility of the NSSP was to conduct long-term, mid-term, and short-term operative assessments of the hazard on the territory of the RA, as well as to develop and implement both long-term and immediate measures to reduce seismic risk. To fulfil this objective, the NSSP's structure was designed to incorporate two essential principles: the collaborative operation of various centres united by a shared goal, structure, and working program, and the vertical subordination of all units to the NSSP President, who reported directly to the Prime Minister. It is noted that by 1996, the preparedness of both the state and society for earthquakes in the RA had significantly improved. The NSSP regularly updated the Prime Minister on the level of seismic hazard in the Republic and the measures taken to mitigate it [27]. In the same year, the draft RA Law "On Seismic Protection" was initiated, which was subsequently approved in 2002.

The seismic risk reduction strategy encompassed the organization of activities and the development of a national program. The key elements of this program included the assessment and reduction of seismic hazard and risk. The RSRARTYC highlights the progress made as of 1996 in the field of short-term seismic hazard assessment and the achievements in reducing seismic risk. Notably, it includes the development of new methods for reinforcing standard buildings, which were successfully tested in the Spitak earthquake zone [27].

Section 8 of the RSRARTYC outlines a strategy for reducing the seismic risk of building destruction in Yerevan. It proposes two options: demolition and construction of new buildings or strengthening of existing ones. Given the economic conditions in the RA, both mass construction of new buildings and reinforcement of existing structures using traditional methods are considered unrealistic. Consequently, a stage-by-stage strategy for building strengthening, developed by the NSSP, is presented. This strategy includes identifying high-risk development zones and prioritising vital importance objects and types of residential buildings that cover the largest population [27].

Following this strategy, it was recorded that:

- zones with the highest risk of destruction are predominantly occupied by individual stone houses, brick and stone structures, frame and frame-and-panel buildings, and buildings constructed using the lift slab method,
- the aforementioned buildings are classified as vital importance objects where a significant number of the population is exposed to fatal risks,
- effective and relatively inexpensive methods for the reconstruction of stone, frame, and frame-and-panel structures are known.

The total number of stone buildings (including complex structures) with a high risk of destruction is 840, and for frame buildings, the number is 303. Initially, 115 frame and 103 stone buildings need to be strengthened, which is estimated to require about 65 million USD[3] [27].

The conclusion of the RSRARTYC asserts that, given the similarities in building types, design standards, materials, and construction practices between Yerevan and the Spitak earthquake zone, combined with the fact that almost 40% of the Republic's population is concentrated in Yerevan, the magnitude of a potential disaster could be so extensive that no assistance would suffice to avert the threat of the RA ceasing to exist as a viable state [27].

Now, let’s delve into the legal acts formulated in the RA aimed at reducing seismic risk, and examine their relation to the seismic resistance of existing residential buildings. Government Resolution No. 392 acknowledges the previously discussed concerns regarding residential buildings. It also states that if a special state program does not significantly reduce the level of seismic risk in the capital, the consequences of a major earthquake – in terms of the number of victims and the extent of losses – could be so severe that effective assistance and destruction mitigation would become impossible. The primary objective of the program is to lower seismic risk in Yerevan to a level that ensures the safety of the population and the sustainable development of the city. This includes tasks such as prediction, assessment, and reduction of seismic hazards.

The strengthening of existing residential buildings is considered a key aspect within the broader context of seismic risk reduction. However, it's noteworthy that the Resolution somewhat understates the importance of building reinforcement. This aspect is mentioned in the 2nd and 3rd parts of the Resolution, where the focus is on creating detailed development maps, determining the design seismic resistance of structures, identifying their technical condition and degree of damage, and improving technologies for enhancing seismic resistance. Despite this, there is a lack of specificity regarding the actual process of strengthening the buildings. Importantly, the same section of the Resolution prioritizes preparedness over recovery in the seismic risk reduction strategy, implying that more emphasis should be placed on reducing the vulnerability of buildings.

Paragraph 7 of the 2nd part of the Resolution notes that the NSSP is responsible for implementing the program. It also clarifies that the program comprises short-term, mid-term, and long-term subprograms, with a timeline spanning 32 years as per the schedule outlined in part 11. Part 6 of the Resolution addresses the risks associated with the program, highlighting potential changes in Government policy regarding the priority of the seismic risk reduction program in the RA, as well as the risk of a lack of donors or the cessation of their funding.

In part 3 of the RA Government Resolution No. 136-N, dated February 9, 2012, which is titled “On amendments to Resolution No. 392”, the tasks addressed by the program are more explicitly defined. It now clearly includes the development and implementation of funded programs for standard residential buildings, aimed at increasing their seismic resistance. The resolution also highlights the importance of selecting, localising, and developing new, cost-effective, and efficient technologies for strengthening structures, as well as the need for using prefabricated structures. The enhancement of buildings' seismic resistance is further mentioned in part 4, which pertains to the expected outcomes of the program. The Government of the RA is designated as the program's client, with the Ministry of Emergency Situations acting as the implementer and coordinator.

[3] Data from the World Bank Reconstruction Program Project Office.

Notably, the implementation schedule provided on the Government's website appears to be empty.

In the RA Law "On Seismic Protection" (June 12, 2002), particularly in Article 16 (Basic Principles for Reducing the Vulnerability of Territories), among other functions, the strengthening of existing structures is highlighted. It is noteworthy that in the Law, the primary goal of seismic protection is the implementation of a unified state policy by the authorized body. According to Article 8 of the Law, the authorized body is not only responsible for developing state policy directions in the field of seismic protection but also for: responsibility for hazard assessment and risk reduction; coordination of work to reduce risk in the territory of the RA; approval of the prediction of a possible large earthquake, seismic zoning and risk maps, and risk expert assessment of the territories of special, important, and general-purpose facilities; organization of the population's preparedness to withstand a strong earthquake; coordination and monitoring of the implementation of state programs in the field of seismic protection; participation in rapid assessment of the vulnerability of structures to reduce risk; issuance of licenses for relevant work, etc. It is also important to note that according to Article 27, offenses committed in the field of seismic protection entail liability as established by the legislation of the RA.

Despite the questions that arise, which we will address further, it is notable that the resolution on the complex seismic risk reduction program in Yerevan has been in effect for 25 years, and the RA law on seismic protection for 22 years. The issue of strengthening existing residential buildings is included in these documents.

The presence of these legal acts indicates the state's concern for the future of existing residential buildings. In this context, let's examine what happened to the governmental body responsible for seismic protection policy in the RA – the National Survey for Seismic Protection (NSSP). According to the historical overview on the official website of the Seismic Protection Territorial Survey (SPTS), the de facto successor to the NSSP, the status of the NSSP began to decline for unknown reasons in 2002. It was incorporated into the Department of Emergency Situations under the Government of the RA, losing its direct subordination to the Prime Minister. In 2005, it became part of the RA Ministry of Territorial Administration, and in 2008, it was included in the RA Ministry of Emergency Situations. In the following years, these two ministries merged (2014) and then separated again (2016), with the NSSP remaining within them as an agency. Following another restructure in 2017, it was reorganised into the SPTS State Non-Commercial Organization (SNCO).

How can we interpret the downgrading of this critical state institution from "national" to "territorial" and from "service" to "agency"? Is it due to a lack of understanding of national security issues, a deliberate choice to overlook them, or simply the latest in a series of short-sighted steps in a self-contained chain of "reforms"? Answering this question is challenging, but logically, an institution endowed with such powers, goals, and objectives by law should have maintained its status at least until its problems were fully resolved. Only then, following the fulfilment of certain functions, could it have been reorganized. But which of these goals has been achieved? Let us reconsider the principle of "priority of preparedness over recovery" highlighted in the complex program for seismic risk reduction in Yerevan. Isn't the seismic resistance of existing buildings one of the most crucial components of preparedness? And how many buildings in Yerevan fail to meet this criterion?

Let's try to summarise the issues we've discussed. What questions arise from this discussion?

1) On what grounds was the status of the NSSP, responsible for implementing state seismic protection policy in the RA, reduced, and can we consider the tasks in this area as partially solved? Can a unified state policy be effectively maintained amidst periodic reorganisations and consistent downgrading of the authorized body?
2) What specific measures have been taken to ensure the seismic resistance of existing residential buildings following the RA Government Resolution No. 392 of 1999, which established a comprehensive program for seismic risk reduction in Yerevan?
3) Is there a strategic program in place to guarantee the operating life of the 1,516 residential buildings at the highest risk in Yerevan, as mentioned in section 8 of RSRARTYC?
4) Is the database maintained by government bodies on the actual condition of seismic resistance of over 4,600 residential buildings constructed in Yerevan before the Spitak earthquake adequate for assessing seismic risk?
5) How many residential buildings have documented cases of uncontrolled structural interventions by residents, and what actions have been taken to prevent such occurrences to stop the cycle of weakening buildings?
6) What is the practical implication of the principle “priority of preparedness over recovery”? Wouldn’t ensuring that buildings are not vulnerable in the first place significantly reduce the tasks associated with prompt response, which currently receive greater emphasis in legal acts?
7) What is meant by “changes in Government policy regarding the priority of the seismic risk reduction program in the RA” in the context of program risks? Is it possible to alter the RA Government's stance on this issue before the program’s full implementation?
8) How do we define “donor”? Could changes in the policies of bodies other than the Government jeopardise national security solutions? Is it appropriate for the risk of implementing a government resolution to depend on donors, and does the extent of donor involvement in government programs carry its own risks?
9) Will the comprehensive program for seismic risk reduction in Yerevan be fully implemented by the target year of 2031, or is this not a priority?
10) Is there a detailed comparative analysis of building strengthening methods proposed by experts? Do we have estimates of the actual time and investment required for each option? Have the proposals for AIUF and base isolation undergone comprehensive analysis to determine their suitability, and are there definitive conclusions or a general consensus on this matter?
11) What is the level of public awareness? Are the residents of over 4,600 residential buildings aware that their homes are at serious seismic risk?
12) Has any organization or individual ever been held accountable for failing to fulfill their responsibilities in the field of seismic protection in the RA?

The content of these questions is highly varied, and not just in nature. The intended audience also differs. However, it's clear that if the state has formed legal acts, and there are specialists with proposals backed by certain economic justifications, yet inaction persists, then the problem lies within the realm of management. It is the management system that should act as the unifying link, combining regulatory functions into a cohesive chain of actions with clear logic. Without this, no innovative solution will ever succeed. In fact, housing policy is often one of the best indicators of the models, structure, and strategy of a state and society [7, 23].

The role of society is equally crucial. Spence argues that public awareness is as important as regulations and their enhancement. Progress in seismic protection largely depends on fostering a "safety culture" within society. The general public must be aware of the risks they face, take steps to protect themselves, and support the initiatives undertaken by the state [5].

4. Conclusions

This study aimed to summarise the tasks set by the state for reducing seismic risk in Yerevan and to examine how these are reflected in the process of increasing seismic resistance of standard residential buildings. This was achieved by analysing key provisions of various documents and legal acts on seismic risk reduction in the RA and their implementation.

The presentation of the seismic risk in the territory of the RA underscored the urgency of reconstructing existing residential developments.

A thorough examination of the 1996 document from the RA NSSP, “Report on Seismic Risk Assessment and its Reduction on the Territory of the Yerevan City,” confirmed that the authorised state body had, 28 years ago, clearly identified existing problems and devised a strategy for their resolution. These were reflected in Government Resolutions and RA Laws.

The discussion on the current situation of residential development in Yerevan, the types of buildings, and potential reconstruction options revealed that in the field of reconstructing existing buildings, there are various professional solutions under consideration, which also take into account the economic aspect of implementation.

Despite the aforementioned factors, this study reveals that no significant progress has been made in reducing seismic risk in Yerevan's residential development. The scope of research previously conducted in this area is limited and has mainly focused on identifying problems and refining strategies for their resolution, developing engineering solutions, and providing economic justifications. It may appear that the absence of economically efficient technical innovations is the primary obstacle to solving the problem. However, our analysis suggests otherwise. The main issue is not a lack of governmental decisions, professional solutions, or financial resources, but rather ineffective management and a lack of seriousness towards environmental safety. Consequently, future research in this area should primarily focus on identifying management issues and developing effective models to address them. Addressing management problems is crucial before the effectiveness of engineering, economic, and legal solutions can be accurately evaluated. The first crucial step should be the restoration of the appropriate authorized body. The reduction in powers of a body yet to complete its tasks is a primary cause of the current situation. While not delving into the structural issues of the Government, it is clear that this body should, as before, report directly to the head of the Government, rather than being subordinate to any ministry or service.

Regarding the existing project proposals, it is essential to subject them to detailed and comprehensive examination, both from technical and economic perspectives. This process will help clarify the real potential and feasibility of their implementation. Proposals that successfully undergo this scrutiny can then form the basis for developing a clear program for the reconstruction of existing standard residential buildings. Additionally, the viability of new construction, investment, and their insurance in various city areas should be separately studied from the perspective of seismic risk reduction policy. Future efforts should also prioritally consider ethical, social, and environmental impacts in seismic risk reduction processes, as these are direct components of broader safety concerns.

Moreover, we believe that directing the questions formulated in the final part of this work to governing bodies with the relevant authority and to the public will not only provide accurate information about the work already done and planned future programs but will also help draw clearer conclusions regarding issues in housing policy management.

We find that the outcomes of this study can be instrumental in enhancing strategies for ensuring residential development safety and in fostering a more informed approach to these issues by both the state and society.

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