

# Strengthening and Rehabilitation of Buildings and Structures After the Impact of Seismic and Fire Hazards

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## **Abstract:**

Introduction of technology of Reliable provision of seismic and fire safety of buildings and structures is still one of the most important challenges in engineering, especially in seismic regions like Uzbekistan. Recent major earthquakes around the world show that even structures designed and built after improvements in earthquake resistant design were realised still have weaknesses, especially in slabs, ceilings and load bearing walls. This urges for the development of improved strengthening and rehabilitation approaches by accounting seismic and post event fire hazard at once.

This study addresses a major knowledge gap related to a poor integration of regional seismic risk assessment, multi-hazard assessment for international purposes, and that of pragmatic mitigating approaches based on the technical state of real facilities. Current approaches focus on either retrofitting for seismic performance or establishing a rapid restoration pathway separately and are not framed in the context of rapid and staged strengthening after multi-hazard events.

This paper uses analytical review and comparative assessment of international and local practices, and evaluation of classification of the strengthening short term, temporary, capital and emergency strengthening. The review also goes on to discuss the contribution of passive and active systems of seismic protection (e.g., rubber metal damper devices) to the development of a resilient structure.

The results indicate that specific phased strengthening strategies, which use advanced vibrodynamic testing and modern instrumental methods, can help secure damage reduction,

provide operational safety, and have quick recovery. Results highlight that reconstruction standards must be updated and harmonize with international standards to define the effects of seismic intensity and to bolster critical assets.

These implications justify the establishment national integrated programs for seismic risk mitigation and intensive monitoring, as well as strong seismic strengthening practices

**Keywords:** passive, active, seismic system, earthquake, statistics, damper device, energy amount.

## Introduction

Today, ensuring the seismic and fire safety of buildings and structures is considered one of the most important issues. In this regard, the need is becoming evident to improve the development of new types of passive and active seismic protection systems aimed at preventing unexpected earthquakes and fires. At present, constructing buildings based on innovative technologies that are comfortable for people, seismically safe, energy efficient, and, especially in seismically active areas, have ensured earthquake resistance, is becoming increasingly important [1]. In general, increasing the durability of buildings and structures, paying special attention to issues of earthquake resistance, forecasting earthquakes in advance, and improving new types of active and passive seismic protection systems are considered highly significant. Today, designing and constructing earthquake resistant buildings and structures is one of the urgent problems in Uzbekistan. In this regard, based on the experience accumulated abroad and in Uzbekistan, it is necessary to improve and develop the theoretical and practical issues of the earthquake resistance of buildings and structures while taking into account new innovative technologies [2].

In scientific research being carried out on forecasting earthquakes in advance and creating new types of active and passive seismic protection systems, large scale studies are also being conducted to improve new types of rubber metal based damper device samples of active seismic isolation devices in ensuring the fire and seismic safety of buildings and structures. In this respect, special attention is required to conduct scientific research on investigating the most optimal options for developing new types of passive and active seismic protection systems aimed at preventing sudden earthquakes and fires.

Moreover, the escalating occurrence of earthquakes over the globe and the larger magnitudes of infrastructural losses validate that the augment of seismic resilience goes beyond typical design methods [3]. Observations from international statistics during the years 2012 to 2022 show that a large proportion of intense quakes were located on The continent as well as Oceania region, making it clear that Seismic risk continues to be a constant as well as long term danger. Though an impressive milestone in earthquake resistant construction has been achieved over the decades, engineering analysis of recent calamities shows that critical damage occurs in many buildings (leading to loss of life even) at levels where conventional solutions with suitable strengthening comply with modern standards, or where advanced protection technologies are not applied as widely as they easily can be. Therefore, modern vibro-dynamic and digital instrumental monitoring methods should be used to assess the technical condition of existing facilities, in particular buildings of critical importance. It is also necessary to improve national construction norms with the view of bringing them in line with international practice, especially within the context of assessing seismic intensity impacts and selecting economically sound strengthening solutions [4]. Coupling local experience with global systems for regional seismic hazard

assessment and risk prediction will facilitate the advancement of engineering practices for more cost-effective damage mitigation, safety of structures and speeding up rehabilitation after seismic and fire events.

### **Methodology**

This study's methodology is based on an integrated analytical and practical assessment to enhance the strengthening and rehabilitation of buildings and structures under combined seismic and fire hazards. The work first provides a systematic review of both international and national experience in earthquake resistant building, bounding consideration to modern passive and active seism protection technologies, including rubber metal-based dampers and isolation systems [5]. Secondly, the comparative analysis of the existing codes and standards, to evaluate if their current classifications of seismic intensity effects are effective, and where they need to be aligned with global best practice. Third, the study integrates the technical condition assessment of existing structures from the seismic prone areas in Uzbekistan, analyzing structural vulnerability through engineering observation the common damage modes like slab failures, wall cracking, and progressive collapse modes. It followed by vibrodynamic testing techniques and advanced digital instrumental hardware as essential tools for structure behaviour under conditions of forced vibration and questions of resonance hazards. The study also classifies rehabilitation into four common types, such as short term, temporary, capital and emergency strengthening based on damage severity, operational requirements and available resources to aid decision making in post disaster scenarios [6]. Finally, the results are integrated to present evidence-based recommendations for seismic risk mitigation, in terms of cost-effective strengthening measures and preparedness for post-event rapid recovery (in case of earthquake and secondary fire).

### **Result and discussion**

Forced vibrations are vibrations that occur under the influence of an external cyclic acting force. Unlike free vibrations, forced vibrations may occur at any frequency, and their frequency corresponds to the frequency of the external force acting on the vibrating system, that is, it is determined not by the inherent properties of the system itself, but by the frequency of the external influence [7].

The dependence of the amplitude of forced vibrations on the frequency of the driving force leads to the fact that, for a given system, at a certain frequency, the vibration amplitude reaches a maximum value, which is called the resonance frequency. Resonance is the sharp increase in the amplitude of forced vibrations when the frequency of the driving force approaches the natural frequency of vibration. The resonance frequency is determined from the condition of the maximum amplitude of forced vibrations. Structurally, the expansion joint consists of aluminum guides on which a sealing profile is placed. This type of joint was specially developed and implemented for areas with high seismic activity. The greatest risk of destruction is caused by the seismic impact factor itself [8]. An earthquake destroys buildings and structures not only from the side facing the epicenter, but also affects them from the lateral and rear sides. First, the intermediate floor slab is damaged. Attics and ceilings collapse into the building interior, after which the walls begin to fail. Entering through entrances, windows, and other openings, the earthquake destroys the internal structural elements of structures.

During the elimination of the consequences of seismic impact, depending on the situation that has arisen, the periods of use of objects, the nature and extent of damage, the seasons of the year, the weather forecast, as well as the amount and time of forces and means allocated for restoration work, strengthening of structures is divided into three types: short term strengthening, temporary strengthening, and capital strengthening [9]. In addition to these three types, sometimes an emergency or non-delayable strengthening method is also applied. Emergency strengthening is carried out during

engineering rescue and urgent авария restoration works due to the necessity to prevent the spread of fire sources, localize these sources, and, with regard to roads, ensure one time permission for restoration equipment to enter them.

In short-term strengthening of objects, damaged buildings and structures are not fully restored. The conditions of fire safety requirements primarily provide for ensuring the possibility of entering buildings and structures [10]. Therefore, it should not be forgotten that the railway access network to the station will also not be restored. Automobile roads are restored, but not along their full width; in such cases, restoration works are performed without creating the upper pavement layer, provided that only a bypass road can be constructed.

Short term strengthening is carried out at damaged objects, ensuring their short term operation or one time use. In such strengthening, partial strengthening of structures and the use of simplified structures are permitted, for example, using only the building basement, partially blocking window openings across incomplete width with wooden panels (to later prevent the spread of flames during continuing and secondary fires), and installing supports in places where collapse of structures has been identified [11]. Works on short term strengthening are, as a rule, carried out using collapsible structures and materials assembled and disassembled manually. In this case, the duration of restoration works is usually calculated in hours, while the service life of the strengthened objects is calculated in several days.

In our republic as well, special attention is being paid to accelerating efforts to ensure seismic safety, introducing modern approaches in the sector, and preventing various types of earthquake damage resulting from occurring strong earthquakes and tectonic shifts of earth plates. Within the framework of organizing work to ensure the seismic safety of regions, including with the involvement of design organizations, attention is focused on organizing the development of seismic protection methods and new structural solutions for buildings and structures, assessing seismic risk of various levels in seismically active zones, developing scientifically based measures to reduce earthquake damage, and organizing testing and inspections of buildings and structures being constructed in seismically active zones using vibrodynamic methods as well as modern digital instrumental equipment [12].

In recent years, an increase in the number of earthquakes worldwide has been observed. The reason for this is that, as a result of the warming of the planet, the amount of energy in the underground mantle layer is increasing, and this energy sets underground tectonic plates in motion, creating vibrations on the earth’s surface. In scientific research being conducted worldwide on forecasting earthquakes in advance and creating new types of active and passive seismic protection systems, ensuring the earthquake resistance of buildings and structures is of great importance [13]. According to global statistical data, most of the earthquakes that occurred during 2012–2022 took place in the territories of eastern, Asian, and Oceania countries (Table 1).

**1-Table.**

**Number of earthquakes worldwide for the years 2012–2022**

Magnitude	2012 year	2013 year	2014 year	2015 year	2016 year	2017 year	2018 year	2019 year	2020 year	2021 year	2022 year
8,0–9,9	2	2	1	1	0	1	1	1	0	3	0
7,0–7,9	14	17	11	18	16	6	16	9	9	16	11
6,0–6,9	117	123	143	127	131	104	118	135	111	141	117
5,0–5,9	1546	1460	1580	1413	1550	1447	1671	1484	1315	2046	1603
4,0–4,9	10 955	11 877	15 817	13 777	13 700	10 544	12 782	11 897	12,135	14 643	13 707
<b>Overall</b>	<b>12 635</b>	<b>13 480</b>	<b>17 552</b>	<b>15 336</b>	<b>15 397</b>	<b>12102</b>	<b>14 589</b>	<b>13 530</b>	<b>13 572</b>	<b>16 849</b>	<b>15 438</b>

To date, global progress in the theory and practice of earthquake resistant construction has reached a high level. The results of engineering analyses of the consequences of many earthquakes indicate that buildings and structures constructed in accordance with existing standards for earthquake resistant construction are able to withstand seismic impacts satisfactorily.

At the same time, the catastrophic consequences of a number of earthquakes that occurred in various countries, including the widespread collapse of buildings constructed in different periods, have revealed a number of problems that require urgent solutions [14]. Taking into account the scale of destruction and casualties, in seismically active regions, including Uzbekistan, ensuring the seismic resistance of buildings and structures, as well as the economically justified expenditure of material and labor resources for strengthening them against seismic impacts, is of particular importance.

Within these courses, the leadership and responsible employees of ministries and agencies are trained once every three years, and based on modern programs included in the national electronic education platform, their preparedness to act during earthquakes is improved. Distance learning courses provide theoretical and practical skills for explaining to the population the rules of behavior during earthquakes, for avoiding losses during strong earthquakes, and for gradual preparation for them.

In addition, in order to improve efforts to prepare the population to act during earthquakes, educational and methodological manuals have been developed aimed at training the population not employed in the production and service sectors, as well as persons with limited physical abilities, to act during earthquakes [15]. In agencies and organizations, practical training sessions are being organized with the involvement of relevant specialists, using visual educational and methodological materials related to strong earthquakes and their consequences.

In our country, in order to digitalize the field of seismic safety and widely introduce information and communication technologies, in 2022 the Ministry of Emergency Situations created an interactive mobile application designed to independently teach all segments of the population, including foreign citizens residing in our country as well as visiting tourists, how to act correctly before, during, and after an earthquake, and measures were taken to deliver it to the general public.

### **Conclusion**

In accordance with the above mentioned regulatory legal documents, a regulatory legal basis has been created for improving the preparedness of citizens and functional services to act during earthquakes. As a result of the periodic and step by step implementation of the measures provided for therein across the republic in seismically active regions, when emergencies related to strong earthquakes occur, a high level of ensuring seismic safety will be achieved. Most importantly, the amount of economic damage caused to the state will be significantly reduced, the dignity of people will be honored, and effective protection of their invaluable life and health from emergencies related to strong earthquakes will be ensured. At present, in order to effectively integrate into the international system of assessing regional seismic risk, forecasting hazards, and reducing potential damage that may occur as a result of earthquakes, it is necessary to conduct experimental and theoretical research on real objects across the republic, assessing their technical condition, with the condition of involving both local and foreign international experience in this area. At the same time, research is required to improve construction norms and standards, adapt them to international practice of development and standardization, and, especially, to improve the ensuring of seismic safety of buildings and structures

that are of significant importance in determining the intensity of seismic impacts and in the field of anti-seismic strengthening of buildings.

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