

**SEISMIC PERFORMANCE ASSESSMENT OF AN INDIVIDUAL RESIDENTIAL BUILDING
USING SITE-SPECIFIC SYNTHETIC ACCELEROGRAMS**

<https://doi.org/10.5281/zenodo.19361963>

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Abstract: *In this article, the seismic stability of a two-story private residential building located in Tashkent city is analyzed. Within the scope of the study, the building's foundation soil dynamic characteristics were taken into account, and the structure was modeled in the LIRA-SAPR software using accelerograms for different soil categories and probability levels. The results help to develop recommendations on the deformation state, structural integrity, and seismic safety of the building under various seismic conditions.*

Keywords: *Earthquake, seismic safety, accelerogram, LIRA-SAPR, computational model, soil category, stress, seismic vulnerability, deformation.*

INTRODUCTION

Earthquakes are among the most dangerous natural hazards, as they can trigger secondary events. Ground shaking not only damages buildings and structures but also induces secondary anthropogenic hazards such as fires, floods, and landslides, causing significant impacts on a country's economic and ecological stability. The recovery process after such disasters can take many years. The destructive effects of earthquakes can be illustrated by the earthquake that occurred in Turkey on February 6, 2023, as well as by other devastating earthquakes observed worldwide to date.

The Republic of Uzbekistan is one of the seismically active regions, and the territory of Tashkent city is located in a zone with high seismic potential, where earthquakes with a magnitude of up to $M \leq 6.5$ may occur. According to historical and instrumental data, earthquakes with magnitudes of $M=6.5$, $M=6.0$, and $M=5.3$ and intensities of 7–9 on the seismic scale were recorded in 1868, 1886, 1924, and 1966 within the city area. Furthermore, in 1980, the Nazarbek earthquake with a magnitude of $M=5.5$ and a seismic intensity of 8 occurred. Strong earthquakes in Tashkent are primarily caused by the

continuous movement along the Karjantou tectonic fault, which crosses the city in the southwest direction. It is evident that the occurrence of strong earthquakes with intensities of 7, 8, and 9 has caused significant economic losses to the city.

Objective: To assess the seismic vulnerability and seismic risk of a two-story residential building with a mixed-frame structural system in Tashkent under different soil conditions and probability levels.

Tasks: To determine the seismic vulnerability of the building under various soil conditions and compare the results. Based on the calculation outcomes, to develop recommendations for improving the building's seismic resilience.

Research Object: A two-story residential building with a mixed-frame structural system (Figure 2).

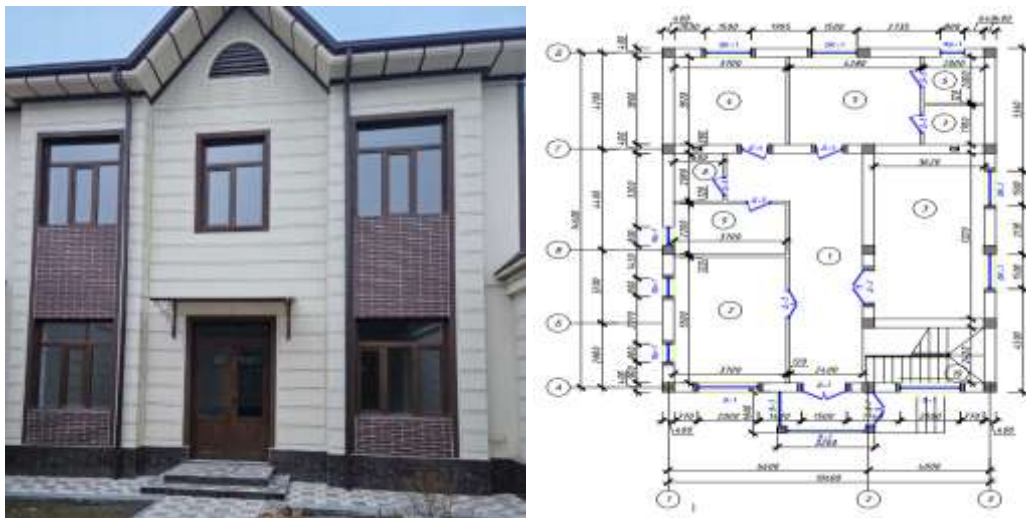


Figure 1. Front facade and floor plan of the building.

Structural characteristics of the building:

Foundation: Strip foundation with a thickness of 40 cm and a width of 120 cm, concrete grade B20.

Columns: 40 × 40 cm, concrete grade B20.

Beams: 40 × 40 cm, concrete grade B20.

Tie beams (ring beams): 20 × 40 cm, concrete grade B15.

Floor slabs: 22 cm thick precast hollow-core slabs.

Walls: 38 cm thick masonry walls made of M75 grade bricks.

Literature Review and Method

Ensuring seismic safety requires assessing the potential losses caused by strong earthquakes and implementing measures to reduce earthquake consequences. In order to protect the population and territories located in seismically active regions, particular attention is given to evaluating the economic losses caused by earthquakes, especially to assessing different levels of seismic risk. In Uzbekistan, research on the seismic resistance of buildings has been conducted by scientists such as V.A. Ismailov, Sh.I. Yodgorov, T.U. Artikov, R.S. Ibragimov, R.A. Niyazov, B.U. Aktamov, and others [1–3].

Globally, determining the stress–strain state of buildings under seismic loads is one of the important scientific research areas and has been studied by many researchers. Among dynamic analysis methods widely used in international practice are the Time History Analysis (THA) and the Response Spectrum Method (RSM).

The Time History Analysis (THA) method allows a more accurate assessment of structural response under seismic excitation using real or synthetic accelerograms (Chopra, 2012). This method enables a more precise description of the dynamic response of building structures over time. Meanwhile, the Response Spectrum Method (RSM) is a simpler and faster evaluation approach, which is based on calculating seismic forces using the spectral acceleration curve [4].

For the purpose of conducting numerical experiments, the considered structural systems were modeled as a spatial mixed-frame structural system in the LIRA-SAPR software, and the transition from the real structure to the computational model was performed (Figure 2).

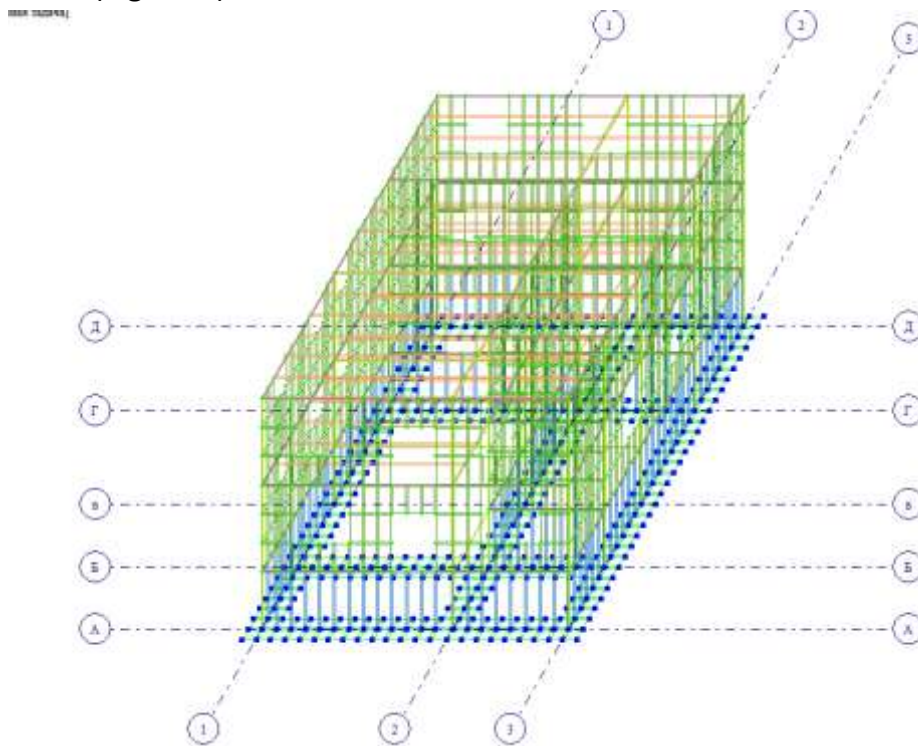


Figure 2. Analytical model of the building

In the software model, the foundation and its interaction with the soil were taken into account. The calculated ground motion accelerations should be determined depending on the importance category of the designed building (structure) and the recurrence interval of earthquakes. This is implemented by inputting accelerograms corresponding to the specified seismic intensity [5].

For the purpose of conducting numerical experiments, the loads acting on the building structures were assumed to be identical for all building types. The normative and design values of the loads were calculated in accordance with QMQ 2.01.07-96 – “Loads and Impacts” [6].

The loads in the building, as well as the self-weight of the slabs, were applied to the load-bearing beams (girders) considering their tributary areas. Depending on the duration of action, the loads were introduced into the program as several separate load cases. The load cases and their values are as follows.

Structures and foundations of buildings designed for seismic regions must be calculated considering seismic effects, using both basic and special load combinations. The basic load combinations are determined in accordance with the requirements of QMQ “Loads and Impacts”, while the special combinations are determined based on this document with consideration of seismic effects.

RESULTS

The displacements occurring in the structures as a result of seismic forces were analyzed using the graphical output results of the LIRA-SAPR software.

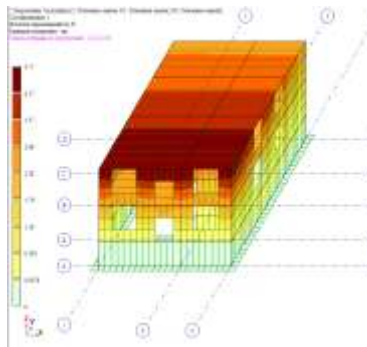


Figure 3. Displacement of the building along the X-axis under 90% probability in Type I soil conditions – 4.77 mm.

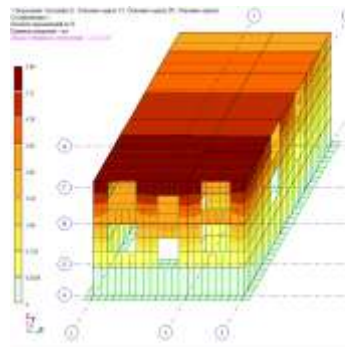


Figure 4. Displacement of the building along the X-axis in Type I soil conditions with 95% probability – 5.84 mm.

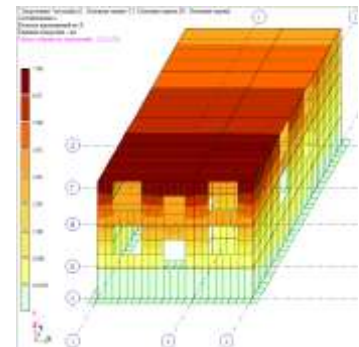


Figure 5. Displacement of the building along the X-axis in Type I soil conditions with a 98% probability – 7.86 mm.

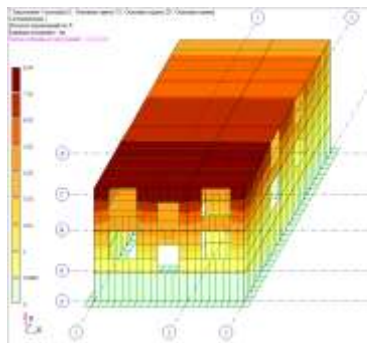


Figure 6. Displacement of the building along the X-axis in Type I soil conditions with a 99% probability level – 8.04 mm.

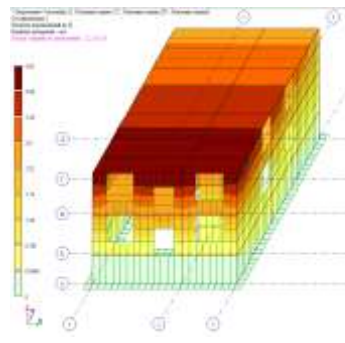


Figure 7. Displacement of the building along the X-axis in Type II soil conditions with a 90% probability level – 4.65 mm.

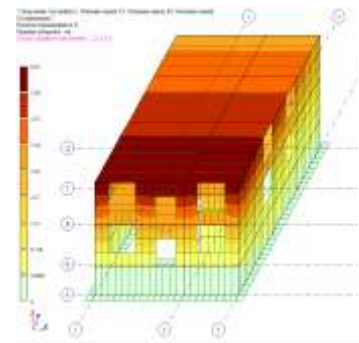


Figure 8. Displacement of the building along the X-axis in Type II soil conditions with a 95% probability level – 6.05 mm.

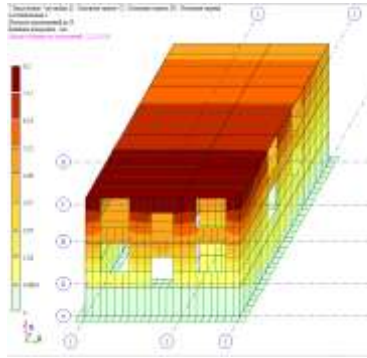


Figure 9. Displacement of the building along the X-axis in Type II soil conditions with a 98% probability level – 8.2 mm.

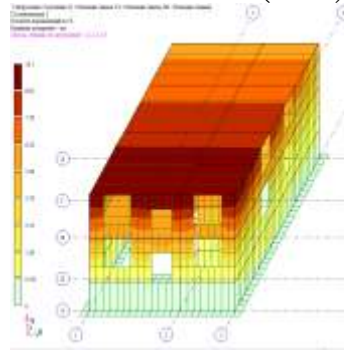


Figure 10. Displacement of the building along the X-axis in Type II soil conditions with a 99% probability level – 10.1 mm.

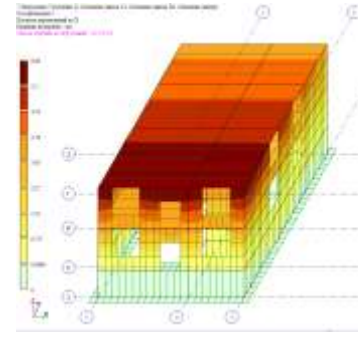


Figure 11. Displacement of the building along the X-axis in Type III soil conditions with a 90% probability level – 6.06 mm.

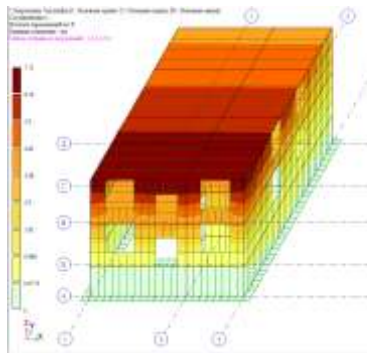


Figure 12. Displacement of the building along the X-axis in Type III soil conditions with a 95% probability level – 7.73 mm.

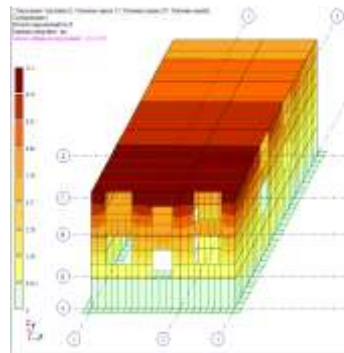


Figure 13. Displacement of the building along the X-axis in Type III soil conditions with a 98% probability level – 11.1 mm.

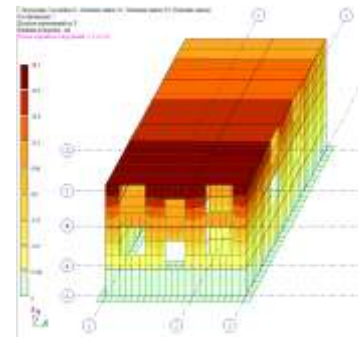


Figure 14. Displacement of the building along the X-axis in Type III soil conditions with a 99% probability level – 18.1 mm.

DISCUSSION

Under Type I soil conditions, the building demonstrates seismic stability, with deformations remaining within acceptable limits at 90% and 95% probability levels. However, at 98% and 99% probability levels, both deformations and stresses increase significantly. The required reinforcement for beams and columns also increases accordingly.

Under Type II soil conditions, structural stresses become considerably higher starting from the 95% probability level. At 98% and 99% probability levels, deformations reach critical values, and the likelihood of damage is high. Notably, at 99% probability, the required reinforcement for beams increases up to 18.6 cm^2 .

Under Type III soil conditions, the building experiences the largest deformations and the greatest increase in stresses. At 98% and 99% probability levels, the reinforcement of

columns and beams increases substantially. In such soil conditions, additional strengthening measures are required to ensure the building's seismic safety.

While the damage level remains minimal at 90% and 95% probability, the vulnerable areas of the structure become clearly identifiable at 98% and 99% probability levels. At 99% probability, the damage reaches four stages, indicating that significant reinforcement of structural elements is necessary [7].

CONCLUSION

The results of this study indicate that the seismic vulnerability of a two-story residential building with a mixed-frame structural system in Tashkent varies significantly depending on soil type and probability level. Specifically:

Under Type I soil conditions, the building exhibits relatively small displacements, and lower amounts of reinforcement are required.

Under Type II soil conditions, deformations increase and stresses rise substantially.

Under Type III soil conditions, the building experiences the largest deformations, and the need for reinforcement is highest.

To ensure the building's seismic safety, appropriate structural solutions must be implemented. Optimizing reinforcement and incorporating earthquake-resistant structural elements are essential for enhancing seismic resilience.

Funding. This research was supported by the Academy of Sciences of the Republic of Uzbekistan under the fundamental project "Development of a Scientific Basis for Assessing Various Levels of Seismic Risk in Seismically Active Areas and Reducing Earthquake-Related Losses" and by the Innovation Development Agency under project #AL8924073457, "Development of a Macroseismic Database Platform for Damage to Buildings and Structures in Epicentral Zones During Strong Earthquakes."

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