JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 5, ISSUE 05
MONTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

UDC: 624.042.7:699.841:728.1

CALCULATION OF EARTHQUAKE LOADS AND CONSTRUCTIVE SOLUTIONS IN DESIGNING STABLE RESIDENTIAL BUILDINGS IN EARTHQUAKE AREAS

Author: **ASKAROVA MUHLISA BAKHROMJON KIZI**

UMIRAQOVA SARVINOZ DILZIYODBEK KIZI

Organization: ANDIJAN STATE TECHNICAL INSTITUTE

Abstract. The article studies engineering solutions aimed at calculating earthquake loads, selecting a structural scheme and increasing seismic safety in the design of stable residential buildings in seismic areas. The study analyzed the spectral approach, structural regularity, inter-storey displacement, center of gravity and center of mass imbalance, foundation-soil interaction and energy-absorbing structural elements based on the principles of QMQ 2.01.03-19 “Construction in seismic areas”, SHNQ 2.01.07-21 “Loads and actions” and Eurocode 8. As a result, a step-by-step calculation algorithm for residential buildings, criteria for evaluating structural decisions and practical recommendations were developed.

Keywords: seismic zone, residential building, earthquake load, spectral calculation, structural regularity, seismic stability, interstory displacement, reinforced concrete frame.

ENTRANCE

A large part of the territory of Uzbekistan is located under the influence of active tectonic zones, and the seismic safety of residential buildings is one of the most important problems of urban planning and construction practice. Especially since multi-storey and medium-rise residential buildings are permanent living environments for the population, their reliability under earthquake influence is determined not only by structural strength, but also by the criteria of human life safety, economic stability and operational continuity.

Earthquake loads, unlike ordinary static loads, are time-varying, inertial, repetitive, and probabilistic. Therefore, when designing a residential building, it is not enough to simply check the strength of the element sections; it is also necessary to design the building systematically in terms of plan and elevation, ensure the continuity of load-bearing elements, limit inter-storey displacements, prevent local brittle failure, and provide the structure with a sufficient plastic reserve.

The relevance of the article is that in practical projects, the calculation of earthquake loads is often carried out only based on the results of software complexes. However, the correct structure of the calculation model, soil conditions, mass distribution by floors, eccentricity between the center of gravity and the center of mass, diaphragm performance and the actual behavior of structural nodes are the main factors determining the final seismic reliability of the project.

The purpose of the study is to systematize the regulatory and engineering foundations for calculating earthquake loads for the design of stable residential buildings in seismic areas, determine the criteria for selecting a structural scheme, and develop a set of innovative structural solutions that increase seismic safety.

ANALYSIS OF LITERATURE AND NORMATIVE DOCUMENTS

The national regulatory framework for seismic design is determined by the requirements of QMQ 2.01.03-19 “Construction in seismic areas”. This document establishes the main requirements for the seismicity of the area, structural systems of buildings, design impacts and structural measures. It is important to use the requirements of SHNQ 2.01.07-21 when determining loads and impacts, and SHNQ 2.08.01-19 when determining functional and volumetric-planning requirements for residential buildings.

In international practice, Eurocode 8 promotes a performance-based approach to seismic design. It considers the limit states of the structure, the design spectrum, the plasticity classes, the behavior coefficient and the structural detailing rules as interrelated. This approach allows for the assessment of not only the earthquake resistance of the building, but also its post-earthquake functional state.

An analysis of scientific literature shows that the most dangerous factors in residential buildings are irregularity in the plan, the formation of soft floors, discontinuous placement of walls and columns in height, excessive mass of heavy coating and finishing layers, uneven foundation settlements, and insufficient plasticity in structural nodes. Therefore, seismic calculation and structural solution should not be considered as separate processes, but as a single integrated design stage.

RESEARCH METHODOLOGY

The research methodology is based on normative-computational analysis, comparison of structural schemes, spectral calculation model and generalization of engineering assessment criteria. In this case, a residential building is considered as a multi-mass spatial system; an equivalent dynamic model is formed with mass, stiffness and damping properties for each floor.

The computational approach to assessing the impact of an earthquake is carried out in the following sequence: the seismicity of the area and the soil category are determined; the building function and reliability level are determined; a load-bearing structural scheme is selected; the seismic mass is calculated from permanent and temporary loads on the floors; the periods and forms of vibration are determined; horizontal seismic forces are found by the spectral method; floor shear forces, overturning moments, floor displacements, and the stress-strain state of structural elements are checked.

The computational model paid special attention to the following engineering conditions: 1) avoiding sudden changes in mass and stiffness across floors; 2) maintaining the continuity of vertical load-bearing elements; 3) ensuring that diaphragms function as rigid disks that transmit horizontal loads; 4) selecting the foundation system in accordance with the seismic properties of the soil; 5) forming a mechanism of controlled plastic deformation in structural nodes, rather than brittle failure.

General algorithm for calculating earthquake loads

A simplified basic representation of the horizontal earthquake force acting on a residential building can be estimated by the following expression:

V = S_d(T_1) W / R

where: V is the calculated seismic shear force at the foundation level; S_d(T_1) is the calculated spectral acceleration of the building at the fundamental vibration period; W is the calculated seismic weight of the building; R is the reduction coefficient expressing the plasticity and energy dissipation capacity of the structural system. In practical design, this expression is specified by the seismic coefficients given in national standards, soil conditions, building significance, and structural system characteristics.

The earthquake force distributed across floors is determined based on the following general ratio:

F_i = V (W_i h_i) / S(W_j h_j)

where: F_i — horizontal earthquake force distributed to the i-th floor; W_i — seismic weight of the i-th floor; h_i — height of the i-th floor above the foundation level . This formula shows that the inertial effect also increases with increasing floor height.

Table 1. Key parameters in earthquake load calculations and their impact on design decisions

Parameter	Engineering content	Control criterion in the project
Seismicity of the area	Determines the intensity of an earthquake and the calculated seismic hazard level	The normative seismic score and recurrence probability for the building location are determined
Soil category	Affects the amplification or attenuation of earthquake waves	The soil group is determined based on engineering and geological research.
Seismic mass	The main factor shaping inertial forces	The proportion of permanent loads and corresponding temporary loads is taken into account
Oscillation period	Determines the spectral acceleration value	The height of the building is calculated depending on the structural scheme and the density.
Constructive system	Determines energy absorption, plasticity, and failure mechanism	Frame, wall, frame-wall or mixed system is selected
Floor displacement	Shows operational damage and secondary effects	Compared with normative limit values

RESULTS AND DISCUSSION

The analysis showed that structural regularity is a decisive factor in the design of stable residential buildings in seismic areas. In buildings with a symmetrical or close-to-symmetrical plan, the distribution of horizontal loads is relatively stable. On the contrary, in L-, T-, U-shaped or sharply protruding plans, torsional vibrations increase, and excessive stresses occur in the edge elements.

Reinforced concrete frame systems are widely used in residential buildings, but they work effectively in seismic areas only with proper detailing. If there is insufficient transverse reinforcement at the column-beam junctions, plastic hinges are formed in uncontrolled zones. Therefore, the strong column - relatively weak beam principle, dense bracing in the junction zone, anchorage of reinforcement and standard preservation of the concrete cover should be considered as the main structural requirements.

The frame-wall system is one of the optimal solutions for increasing seismic stability. In this case, the reinforced concrete diaphragm and cores absorb most of the horizontal shear forces, while the frame participates in absorbing vertical loads and local horizontal impacts. Designing the elevator and stair blocks as a spatial rigidity core reduces the torsional vibrations of the building.

The soft floor effect occurs in residential buildings, especially when the ground floor is left open for commercial or parking purposes. In this case, the lateral stiffness of the ground floor is significantly reduced compared to the upper floors, and the earthquake energy is mainly concentrated on this floor. To overcome the problem, it is advisable to use additional diaphragms, moment-resistant frames, connecting elements or local energy-absorbing devices on the ground floor.

The concept of a sustainable residential building is not limited to earthquake resistance. It also includes criteria for safe evacuation of residents, relative performance of engineering networks, repairability, and reduction of economic losses. Therefore, the use of innovative methods in constructive solutions, such as damping, base insulation, lightweight wall materials, and expansion joints, is relevant.

Table 2. Comparative analysis of structural systems for residential buildings

Constructive system	Advantage	Limitation	Recommendation for seismic area
Reinforced concrete frame	High planning freedom, easy to adjust room sizes	Detailing at nodes is demanding, there is a risk of soft floors	The principle of strong columns is applied under the condition of tight coupling and control of floor stiffness.
Frame-wall system	High spatial density, reduced inter-storey displacements	the diaphragm position is incorrect, the torques will increase	Optimal for multi-storey residential buildings, cores are placed symmetrically
Load-bearing wall system	Virginity is great, effective in simple plans	Limited planning flexibility, significant impact of holes	Used in low and medium-rise buildings with a regular wall layout
Steel frame	Relatively light weight, quick assembly	Requires fire resistance and corrosion protection	Effective in combination with dampers and binders

Base isolation system	Reduces earthquake energy at the foundation level	High price and service control	It is used on a case-by-case basis in critical facilities and residential complexes in high-risk areas.

Developing constructive solutions

When developing structural solutions for residential buildings in seismic areas, the first step is to simplify the building's plan. Very long buildings are divided into independent blocks by means of deformation-seismic joints. The joints should be continuous along the entire height of the building and be selected at a distance that does not allow neighboring blocks to collapse during an earthquake.

The second solution is to ensure the continuity of vertical load-bearing elements. Columns, walls and diaphragms should continue from the foundation to the upper floors without sharp breaks. If the location of the element changes due to architectural requirements, the transition zone is designed with a separate calculation and reinforced reinforcement.

The third solution is mass reduction. Using lightweight aerated concrete, expanded clay concrete, gypsum-based panels, or lightweight composite layers instead of heavy brick barriers reduces seismic mass and inertial forces. In this case, the barrier walls should be flexibly connected to the frame, they should not add unnecessary additional stiffness to the frame, and there should be no risk of collapse.

A fourth solution is to use energy-dissipating elements. Viscous dampers, metal-plastic dampers, or frictional couplings absorb some of the earthquake energy outside the structural elements. As a result, the plastic deformation requirement in column and beam sections is reduced, increasing the likelihood that the building will remain in a repairable condition after an earthquake.

The fifth solution is a comprehensive assessment of the foundation and soil system. Under the influence of an earthquake, soil liquefaction, uneven settlement, lateral displacement, and deformation of the foundations relative to each other provide additional stresses to the superstructure of the building. Therefore, the type of foundation should be selected not only according to its vertical load-bearing capacity, but also according to its seismic deformation compatibility.

Table 3. Structural measures that increase seismic stability

Problem	**Constructive solution**	**Expected result**
Rotational vibration	Bringing the centers of mass and stiffness closer together, symmetrically placing the diaphragms	Excess voltage is reduced on edge elements
Soft floor	Use of additional frames, diaphragms or dampers on the first floor	The risk of interfloor displacement and local failure is reduced
Brittle knot disorder	Tightly clamp the knot zones, strengthen the anchorage	Controlled plastic deformation forms

Excess seismic mass	Use of lightweight barrier and finishing materials	Inertial forces are reduced
Neighboring blocks hitting	Leaving sufficient seismic seams	Interblock shocks are prevented during an earthquake
Foundation deformation	Choosing soil reinforcement, pile foundation or solid slab	Uneven subsidence and additional internal forces are limited

PROPOSED COMPUTATIONAL AND DESIGN MODEL

The model proposed in the article is aimed at evaluating seismic calculations in conjunction with structural decisions. In the first stage of the model, a seismic hazard passport for the building is created: the seismicity of the area, soil category, building floor, structural system, seismic mass and operational significance coefficients are entered. In the second stage, a spatial calculation model is created and the mass-density distribution by floors is checked. In the third stage, the results of the spectral calculation determine the longitudinal shear forces, displacements and element stresses.

In the fourth stage, the structural regularity index is evaluated. This includes analyzing the sharp decrease in the height of the void, the change in the floor mass, the eccentricity in the plan, and the continuity of the vertical elements. If the index is below the required level, the structural scheme is revised: a diaphragm is added, the column section is changed, a seam is introduced, or heavy elements are lightened.

In the fifth stage, seismic safety indicators are evaluated in an integrated manner. In this case, strength, deformation, plasticity, foundation stability, safety of secondary elements and preservation of evacuation routes are taken as separate criteria. The proposed approach allows the designer to identify not only the calculation result, but also the dangerous points of the constructive decision.

Table 4. Stages of the computational and design model

Stage	Work to be done	Result
Stage 1	Determining the seismicity of the area, soil conditions, and building function	Seismic risk passport is being formed
Stage 2	Building spatial model and seismic mass input	The initial model for the dynamic calculation is obtained
Stage 3	Determination of floor forces and displacements through spectral calculation	Calculated internal forces and deformations are found
Stage 4	Checking for constructive regularity and soft floor risk	Weak zones in the constructive scheme are identified
Stage 5	Optimization of constructive solutions	Diaphragm, joint, reinforcement and foundation

		solutions are specified
Stage 6	Final assessment of operational and safety criteria	A sustainable and repairable project solution is formed

SCIENTIFIC NOVELTY AND PRACTICAL SIGNIFICANCE

The scientific novelty of the research is the unification of the process of calculating earthquake loads and selecting structural solutions in the design of residential buildings in seismic areas into a single algorithmic system. The proposed approach evaluates the seismic load not as a separate calculation quantity, but as a complex effect associated with the shape of the building, the structural system, the mass of the material, the foundation-soil conditions and operational stability.

The practical significance is that the algorithm presented in the article can be used in design organizations at the stages of preliminary feasibility studies, selection of structural schemes, and engineering control of software calculation results. Especially in medium- and multi-storey residential buildings, it increases the possibility of early detection of the risks of soft floors, torsional vibrations, heavy retaining walls, and incorrectly positioned diaphragms.

CONCLUSION

1. Seismic safety in the design of stable residential buildings in seismic areas depends on the interaction of the structural scheme, soil conditions, building mass, and load distribution across floors.

2. The spectral approach to calculating earthquake loads is effective for modern design because it takes into account the building's vibration period, seismic mass, and the energy dissipation capacity of the structural system.

3. In residential buildings, ensuring regularity in plan and elevation, continuous placement of vertical load-bearing elements, prevention of the formation of soft floors, and detailing of structural nodes in accordance with plasticity are the main requirements.

4. Frame-wall systems, symmetrical stiffness cores, seismic joints, lightweight barrier materials, dampers, and foundation isolation are considered effective structural solutions in increasing seismic stability.

5. The proposed computational and design model connects the results of seismic calculations with design decisions, allowing for the identification and optimization of vulnerable areas of the project at an early stage.

REFERENCES USED

1. QMQ 2.01.03-19. Construction in seismic areas. Ministry of Construction of the Republic of Uzbekistan. Tashkent, 2019.
2. SHNQ 2.01.07-21. Loads and impacts. Ministry of Construction and Housing and Communal Services of the Republic of Uzbekistan.
3. SHNQ 2.08.01-19. Residential buildings. Construction standards of the Republic of Uzbekistan.
4. QMQ 2.03.01-96. Concrete and reinforced concrete structures. Design standards.

5. Eurocode 8: EN 1998-1:2004. Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings. European Committee for Standardization, Brussels, 2004.
6. Chopra AK Dynamics of Structures: Theory and Applications to Earthquake Engineering. 5th ed. Pearson, 2017.
7. Naeim F. The Seismic Design Handbook. 2nd ed. Springer, 2001.
8. Paulay T., Priestley MJN Seismic Design of Reinforced Concrete and Masonry Buildings. Wiley, 1992.
9. Taranath BS Reinforced Concrete Design of Tall Buildings. CRC Press, 2010.
10. Fardis MN Seismic Design, Assessment and Retrofitting of Concrete Buildings. Springer, 2009.
11. FEMA P- 1050. NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. Federal Emergency Management Agency, 2015.
12. ASCE/SEI 7-22. Minimum Design Loads and Associated Criteria for Buildings and Other Structures. American Society of Civil Engineers, 2022.
13. TR Rashidov, RR Kadirov, etc. Issues of seismic strength of structures. Tashkent: Fan, various years.
14. Decree of the President of the Republic of Uzbekistan No. PF-144. Measures to improve the seismic safety system, 30.05.2022.
15. JRC European Commission. Eurocode 8: Seismic Design of Buildings—Worked Examples. Luxembourg: Publications Office of the European Union, 2012.
16. MBAskarova, BOMirzayev "Building and Structure Constructions", Textbook, 2024.
17. MBAskarova, BOMirzayev and DDKhasanov, "Reinforced concrete stone structures", Textbook, 2025.
18. MBAskarova, BOMirzayev and Abdurasulova SH.SH (student) "Introduction to the field", Textbook, 2025.
19. MBAskarova "Building and Structure Constructions", Textbook. 2025.
20.MBAskarov, OZKamilova "Metrology, Standardization and Certification", Textbook, 2025.
21.MBAskarov "Fundamentals of Architectural Composition and Design", Textbook. 2024.
22.MBAskarov "Fundamentals of Architectural Composition and Design", Textbook. 2024.
23. MBAskarova, Kh. Fayziyev "Waterways and Ports", Textbook. 2024.
24.SMMahmudovich and MBAskarov, "Soil Mechanics, Grounds and Foundations", Textbook. 2024.
25. SMMahmudovich and MBAskarov "Soil mechanics, floors and foundations", Textbook. 2024.
26. MBAskarova, MXParpiyev "Construction estimate work", Textbook. 2024.