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ARCHITECTURAL AND STRUCTURAL DESIGN OF A NEXT GENERATION STUDENT DORMITORY WITH PUBLIC SPACES IN HIGH-SEISMIC CONDITIONS

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ABSTRACT

Introduction. The rapid development of higher education and increasing demand for modern student accommodation have highlighted the importance of designing dormitories that provide not only residential functions but also educational, recreational, and social environments. In seismically active regions such as Almaty, Kazakhstan, student housing projects must simultaneously satisfy architectural, functional, and structural safety requirements. **Materials and Methods.** This study presents the architectural and structural design of a next-generation student dormitory with integrated public spaces located in Almaty. The proposed building has overall dimensions of 40.30 × 17.20 m and consists of a basement floor and five above-ground floors. The architectural concept incorporates residential units, coworking areas, study rooms, recreation spaces, and common facilities. A reinforced concrete frame-shear wall structural system was adopted considering the seismic conditions of the construction site. Numerical analysis was performed using the LIRA-SAPR software package based on the finite element method in accordance with the current building regulations of the Republic of Kazakhstan. **Results and Discussion.** The proposed design successfully integrates residential and public functions within a unified architectural structure. Public spaces occupy more than 370 mZ and contribute to the formation of a multifunctional educational environment. Structural analysis confirmed the adequacy of the selected reinforced concrete frame-shear wall system for construction in a 9-point seismic zone. Modal analysis demonstrated cumulative modal mass participation ratios of 79.83% along the X-axis, 92.13% along the Y-axis, and 74.03% along the Z-axis, indicating sufficient spatial stiffness and seismic resistance of the building. **Conclusions.** The developed architectural and structural solutions provide an effective combination of functional efficiency, social sustainability, and seismic safety. The proposed design approach can be recommended for student dormitories and similar educational facilities located in high-seismic regions.

KEYWORDS: student dormitory; public spaces; educational environment; architectural design; reinforced concrete structures; frame-shear wall system; seismic resistance; modal analysis; LIRA-SAPR.

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1 INTRODUCTION

The rapid expansion of higher education systems, increasing student mobility, and growing enrollment rates have significantly intensified the demand for modern student housing worldwide [1,2]. In recent decades, student dormitories have evolved from facilities intended solely for accommodation into multifunctional environments that support learning, social interaction, personal development, and well-being. Consequently, contemporary student residences are increasingly recognized as an essential component of educational infrastructure and campus development strategies [3].

The concept of student housing has undergone substantial transformation in leading universities across North America, Europe, and Asia. Modern dormitories are designed not only to provide comfortable living conditions but also to create environments that encourage academic collaboration, social engagement, and community building. Public spaces such as coworking areas, study rooms, lounges, recreation zones, and multifunctional halls have become key elements of student residential buildings [4,5]. Numerous studies indicate that the quality of shared spaces directly influences students' academic performance, psychological well-being, and social adaptation [6,7].

The integration of public spaces into student residences reflects contemporary approaches to educational architecture, emphasizing flexibility, inclusiveness, sustainability, and user-centered design [8]. Universities increasingly recognize that informal learning environments contribute significantly to knowledge exchange, interdisciplinary collaboration, and the formation of academic communities. Therefore, architectural and planning solutions for student housing should address not only residential functions but also educational and social needs [5,8].

In the Republic of Kazakhstan, the modernization of higher education infrastructure has become one of the priorities of national development programs. The growing number of students and the expansion of university campuses have increased the need for new dormitory facilities that comply with modern international standards. However, many existing student residences were designed according to traditional planning approaches that provide limited opportunities for social interaction, collaborative learning, and recreational activities. As a result, the development of next-generation student dormitories has become an important architectural and engineering challenge.

Particular attention should be paid to the city of Almaty, which is the largest educational center in Kazakhstan and accommodates a significant concentration of higher education institutions. At the same time, Almaty is located within a high-seismicity region, where the design of residential and public buildings must comply with strict seismic safety requirements. According to SP RK 2.03-30-2017, the city belongs to a 9-point seismic zone, requiring the implementation of reliable structural systems capable of ensuring safety, stability, and serviceability during seismic events [1]. Therefore, the design of student dormitories in Almaty requires a comprehensive approach that combines architectural functionality, social effectiveness, and structural reliability.

The analysis of international experience demonstrates that the most successful student housing projects integrate residential and public functions into a unified architectural system. Examples such as Simmons Hall at the Massachusetts Institute of Technology (MIT), student residences at Stanford University, and housing complexes at Delft University of Technology illustrate the effectiveness of combining accommodation facilities with educational, recreational, and communication spaces [10-12]. These projects emphasize flexibility, inclusiveness, and sustainability while creating environments that support both academic and social development.

Despite considerable progress in student housing design and seismic engineering,

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limited studies have investigated the combined influence of architectural planning solutions, public-space integration, and structural performance in student dormitories located in high-seismic regions. Most existing studies focus either on social and functional aspects of student housing or on structural safety and seismic resistance separately. Consequently, there remains a need for integrated architectural and structural approaches that simultaneously address educational, social, and seismic design requirements.

The aim of this study is to develop architectural and structural design solutions for a next-generation student dormitory with integrated public spaces under high-seismic conditions in Almaty, Kazakhstan. The research focuses on architectural planning concepts, functional zoning strategies, and structural systems capable of providing both social effectiveness and seismic resilience.

The study is based on the design of a five-storey student dormitory with a basement floor developed for the campus of the International Educational Corporation (KazGASA). The proposed building incorporates residential units, coworking spaces, recreational areas, and public facilities within a unified architectural structure while ensuring compliance with current seismic design regulations. The obtained results may contribute to the development of safe, functional, and sustainable student housing projects in Kazakhstan and other seismically active regions.

2 METHODS AND MATERIALS

2.1. Study Area and Project Characteristics

The study focuses on the development of a next-generation student dormitory designed for the campus of the International Educational Corporation (KazGASA) in Almaty, Kazakhstan. The selected site is located within an established educational environment and is characterized by favorable accessibility to academic buildings, transportation infrastructure, and public services.

Almaty is one of the largest educational centers in Central Asia and simultaneously belongs to a region with high seismic activity. According to the current seismic zoning regulations of the Republic of Kazakhstan, the design seismic intensity for the study area reaches 9 points, which imposes strict requirements on architectural planning and structural safety [1].

The proposed dormitory is intended to accommodate university students and provide not only residential functions but also educational, recreational, and social facilities. The project aims to create a balanced environment that promotes communication, collaborative learning, and personal development while ensuring structural reliability under seismic loading conditions.

The building consists of a basement floor and five above-ground floors. The overall dimensions of the building are 40.30 × 17.20 m, while the building footprint area is 801.1 mZ. The total site area is 0.24859 ha. The architectural concept incorporates residential units, coworking spaces, study rooms, recreation areas, and multifunctional public zones integrated into a unified functional structure.

Table 1. Main characteristics of the proposed student dormitory

№	Parameter	Value
1	Building type	Student dormitory
2	Number of floors	Basement + 5 floors
3	Building dimensions	40.30 × 17.20 m

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4	Building footprint area	801.1 mZ
5	Site area	0.24859 ha
6	Structural system	Reinforced concrete frame-shear wall system
7	Design seismicity	9 points
8	Software used	LIRA-SAPR, SCAD Office

The location of the project site within the educational campus is shown in Figure 1.

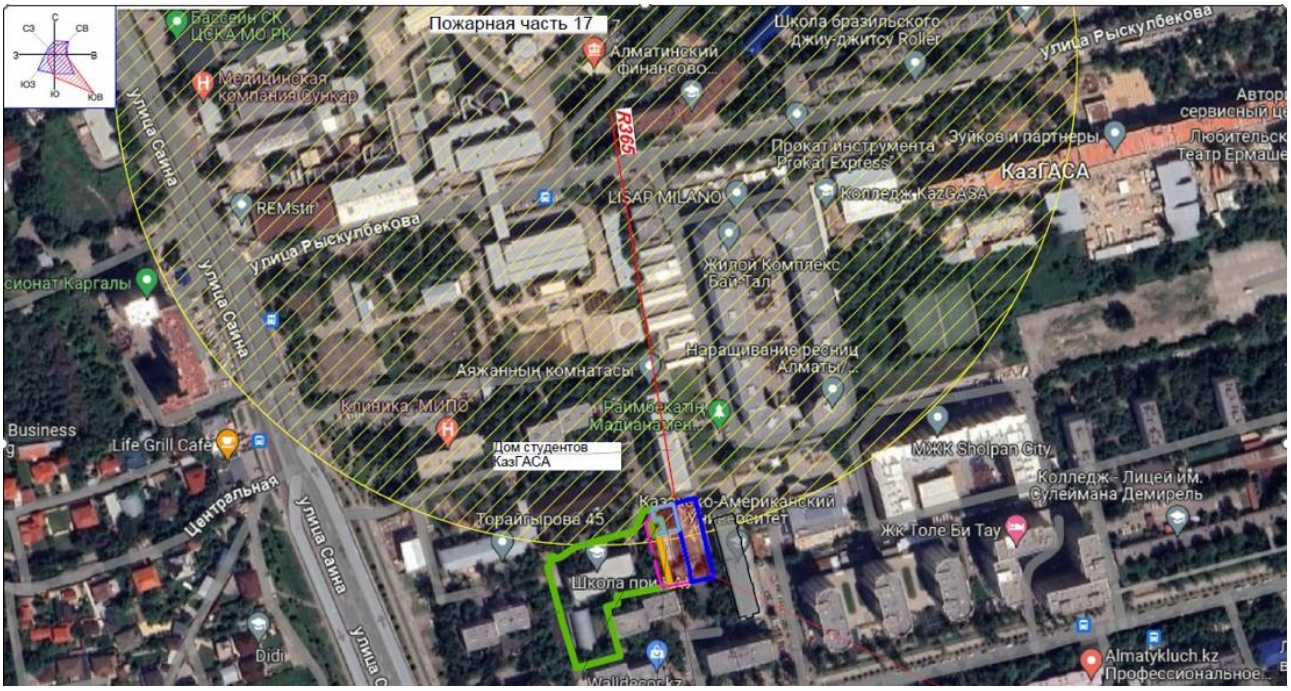


Fig. 1. Location of the proposed student dormitory within the KazGASA campus
Source: Developed by the author based on the situational plan of the master's project

2.2 Architectural Design Methodology

The architectural design methodology was based on contemporary approaches to student housing development, emphasizing multifunctionality, flexibility, social interaction, and accessibility [5-12].

The planning concept was developed according to three key principles:

1. Functional efficiency;
2. Integration of public spaces into residential areas;
3. Accessibility and inclusiveness.

Particular attention was paid to the organization of public spaces because modern studies indicate that informal learning environments significantly improve communication, academic collaboration, and social adaptation among students [6–8].

The proposed building incorporates several categories of public spaces, including coworking zones, study rooms, recreation areas, and multifunctional halls. These spaces are distributed throughout the building to ensure equal accessibility for residents.

Table 2. Functional composition of public spaces

№	Type of space	Function
1	Coworking areas	Individual and group study

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2	Study rooms	Academic activities
3	Recreation areas	Informal communication
4	Multifunctional spaces	Events and meetings
5	Common lounges	Social interaction

The functional organization of public spaces is presented in Figure 2.

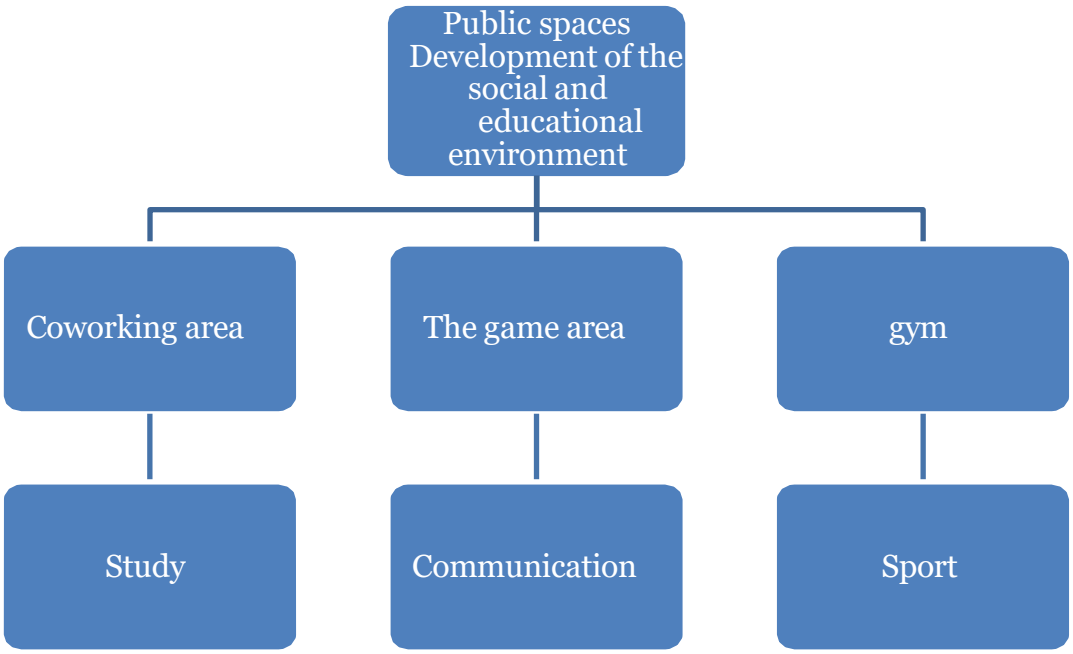


Fig. 2. Functional organization of public spaces within the dormitory
Source: Developed by the author based on the architectural planning solutions of the master's project.

2.4 Structural Design Methodology

The structural design of the proposed student dormitory was developed considering the high seismicity of the city of Almaty and the requirements of the current Kazakhstan building regulations, including SP RK 2.03-30-2017 *"Construction in Seismic Regions"* and SP RK EN 1992-1-1 *"Design of Reinforced Concrete Structures"* [1, 2].

Engineering-geological investigations conducted at the construction site revealed the presence of alluvial-proluvial deposits represented by fill soils, loams, and gravelly soils. These geological conditions were taken into account during the design of the foundation system and the selection of the structural scheme. The main engineering-geological characteristics of the site are presented in Table 3.

Table 3. Engineering-geological characteristics of the construction site

№	Soil layer	Soil type	Density (g/cm3)	Deformation modulus (MPa)
1	IGE-1	Fill soil	1.90	–
2	IGE-2	Loam	1.69	8.8
3	IGE-3	Gravel soil	2.28	78.0

Considering the geological conditions and the design seismic intensity of 9 points a

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reinforced concrete frame-shear wall structural system was selected as the primary load-bearing solution. This structural configuration was chosen due to its ability to provide adequate stiffness, stability, and seismic resistance for medium-rise residential buildings under dynamic loading conditions [13-20]. The adopted structural system consists of:

- monolithic reinforced concrete columns;
- reinforced concrete beams;
- monolithic reinforced concrete floor slabs;
- reinforced concrete shear walls acting as stiffness diaphragms;
- monolithic reinforced concrete foundations.

The frame-shear wall system ensures efficient transfer of both vertical and horizontal loads, improves the spatial rigidity of the structure, and enhances seismic performance. The final structural configuration was selected following a comparative evaluation of alternative structural schemes and their expected behavior under seismic actions.

The adopted structural system is illustrated in Figure 3.

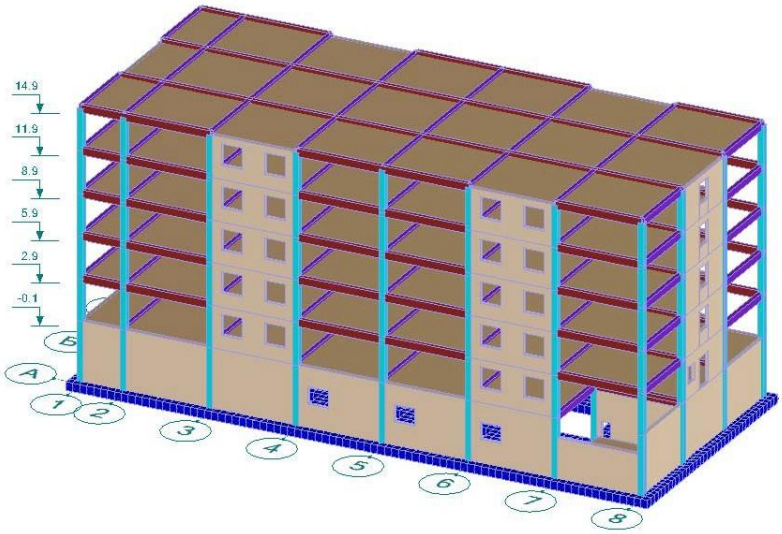


Fig 3. Structural system of the proposed dormitory
Source: Developed by the author based on the structural design documentation of the master's project.

2.5 Numerical Modeling Procedure

The structural behavior of the building was evaluated using the finite element method implemented in the LIRA-SAPR software environment [21].

A three-dimensional numerical model was developed to simulate the actual behavior of the building under permanent, variable, climatic, and seismic loads.

The following load combinations were considered:

- self-weight of structural elements;
- partition and finishing loads;
- live loads;
- snow loads;
- wind loads;
- seismic loads.

Table 4. Design loads considered in numerical analysis

№	Load type	Category
1	Self-weight	Permanent

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2	Finishing loads	Permanent
3	Live loads	Variable
4	Snow loads	Climatic
5	Wind loads	Climatic
6	Seismic loads	Special

The finite element model is shown in Figure 4.

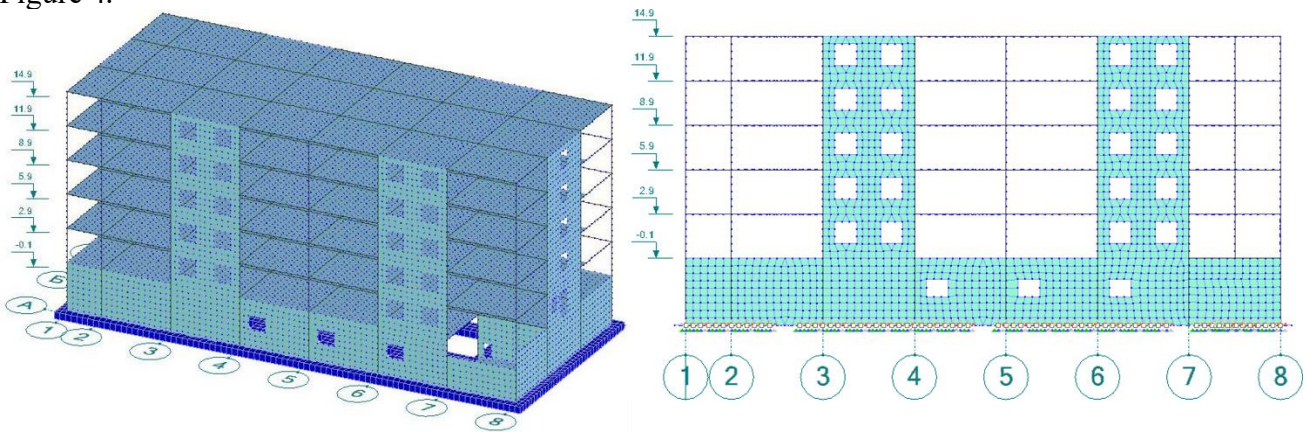


Fig. 4. Three-dimensional finite element model developed in LIRA-SAPR
Source: Developed by the author based on numerical simulations performed within the study

3 RESULTS AND DISCUSSION

3.1 Architectural and Planning Solutions

The proposed student dormitory was designed to provide a modern residential environment that combines accommodation, learning, recreation, and social interaction functions within a single architectural structure. The project is intended for students of the International Educational Corporation (KazGASA) and is located within the university campus in Almaty.

The building has a rectangular configuration with overall dimensions of 40.30 × 17.20 m and consists of a basement floor and five above-ground floors. The adopted architectural concept is based on the principles of functional zoning, accessibility, and efficient use of internal space.

The facade composition reflects a contemporary architectural approach through the combination of repetitive window modules, vertical rhythm, and accent elements integrated into the building envelope.

Table 5. Main architectural characteristics of the proposed dormitory

№	Parameter	Value
1	Building function	Student dormitory
2	Number of floors	Basement + 5 floors
3	Building dimensions	40.30 × 17.20 m
4	Building footprint area	801.1 mZ
5	Site area	0.24859 ha
6	Structural system	RC frame-shear wall system
7	Design seismicity	9 points

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8	Public spaces area	>370 mZ



Fig. 5. Main facade of the proposed student dormitory.
Source: Developed by the author based on the architectural design documentation of the master's project.

The architectural layout provides efficient circulation between residential and public areas while ensuring sufficient natural lighting and visual comfort for occupants.

To evaluate the architectural effectiveness of the proposed building, the main design characteristics are summarized in Table 5.

The proposed design incorporates residential rooms, study areas, recreation zones, and common facilities. Public spaces occupy more than 15% of the functional building area, corresponding to contemporary international recommendations for student housing design [5-8].

3.2 Structural System and Numerical Modeling

Considering the high seismicity of the construction site, special attention was paid to the selection of an efficient structural system capable of ensuring adequate stiffness and earthquake resistance.

The adopted structural solution consists of a monolithic reinforced concrete frame combined with reinforced concrete shear walls acting as stiffness diaphragms.

The effectiveness of reinforced concrete shear walls in improving lateral stiffness and seismic performance has been confirmed by recent studies focused on optimization of shear wall systems in multistorey buildings [18].

The structural layout of the building is presented in Figure 6.

The selected structural configuration provides:

- uniform distribution of vertical loads;
- efficient resistance to horizontal seismic actions;
- enhanced spatial stiffness;
- improved structural reliability under dynamic loading.

To evaluate structural performance, a finite element model was developed using the LIRA-SAPR software package.

The finite element model includes columns, beams, floor slabs, and shear walls. Permanent, live, climatic, and seismic loads were applied according to Kazakhstan building regulations [1, 2].

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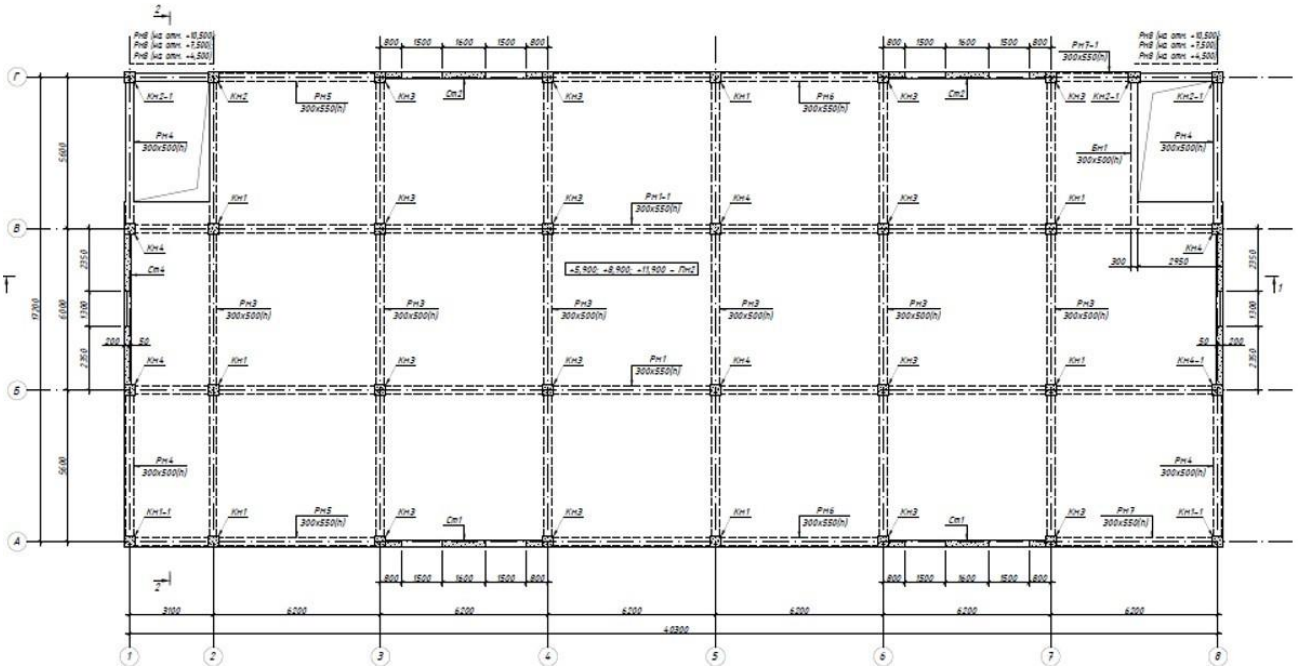


Fig. 6. Structural framing plan of the building.

Source: Developed by the author based on the structural design documentation of the master's project.

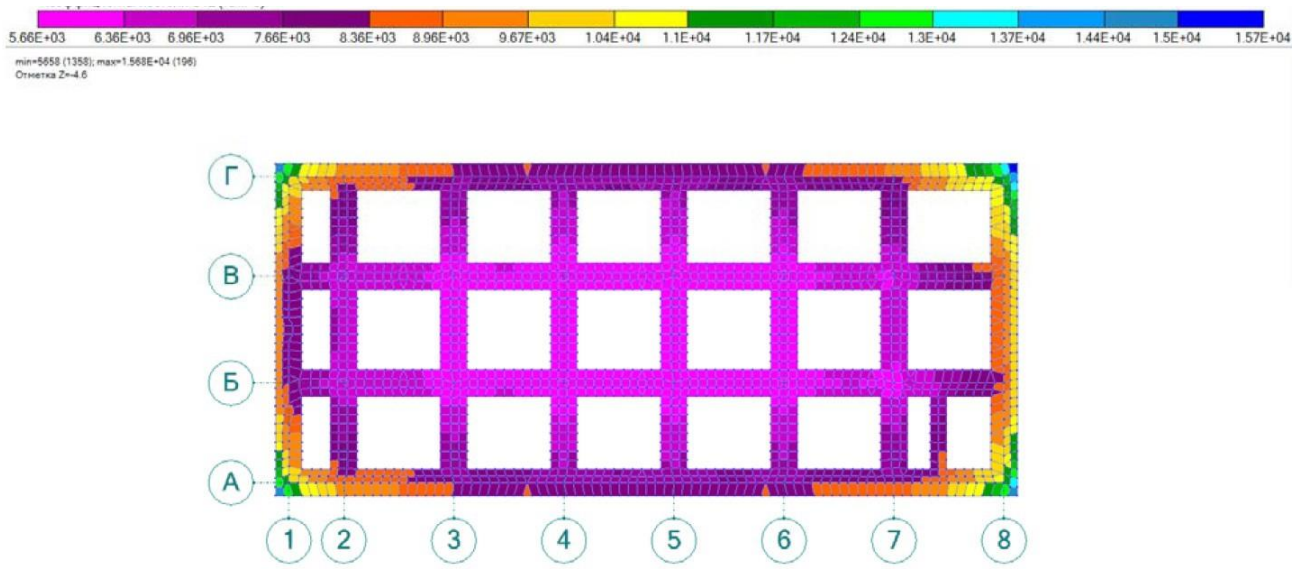


Fig. 7. Finite element model developed in LIRA-SAPR

3.3 Reinforced Concrete Design Assessment

The design of reinforced concrete members was performed in accordance with Eurocode-based Kazakhstan standards and current reinforced concrete design recommendations.

The stress-strain relationship adopted in the analysis is illustrated in Figure 8.

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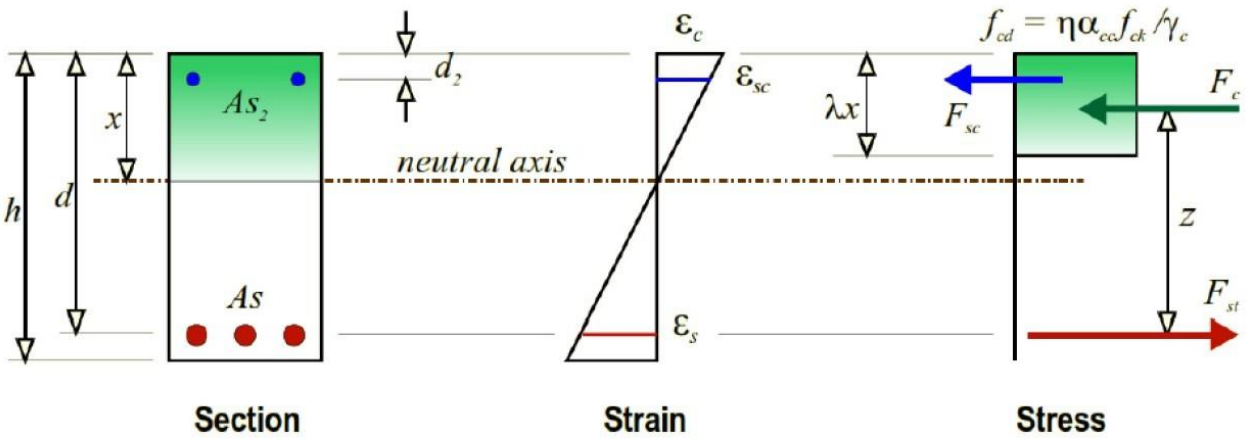


Fig. 8. Stress-strain distribution and internal force equilibrium in reinforced concrete sections.
Source: Adapted from Eurocode 2 [2].

The load-bearing capacity of reinforced concrete columns was additionally evaluated using axial force-bending moment interaction analysis.

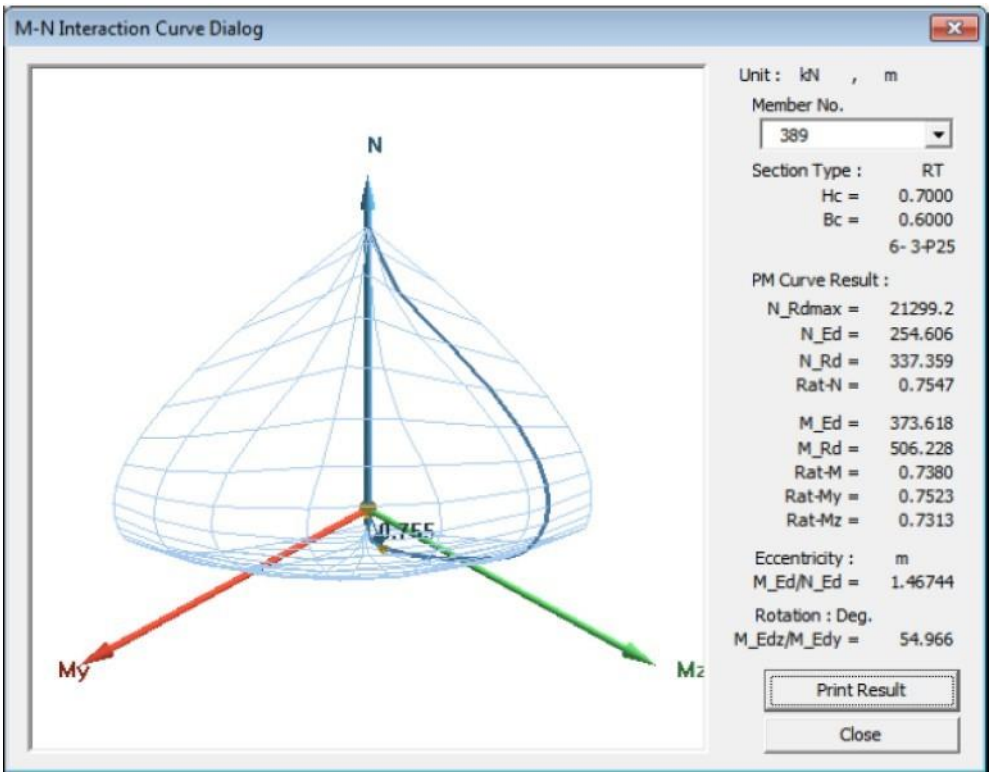


Fig. 9. Three-dimensional N-My-Mz interaction surface for a typical column section.
Source: Generated by the author using SCAD Office software.

The obtained interaction diagram demonstrates that the design load combinations remain within the safe load-bearing domain of the structural element, indicating sufficient strength reserves.

For interpretation of the failure mechanisms and stress redistribution, the corresponding interaction behavior is illustrated in Figure 10.

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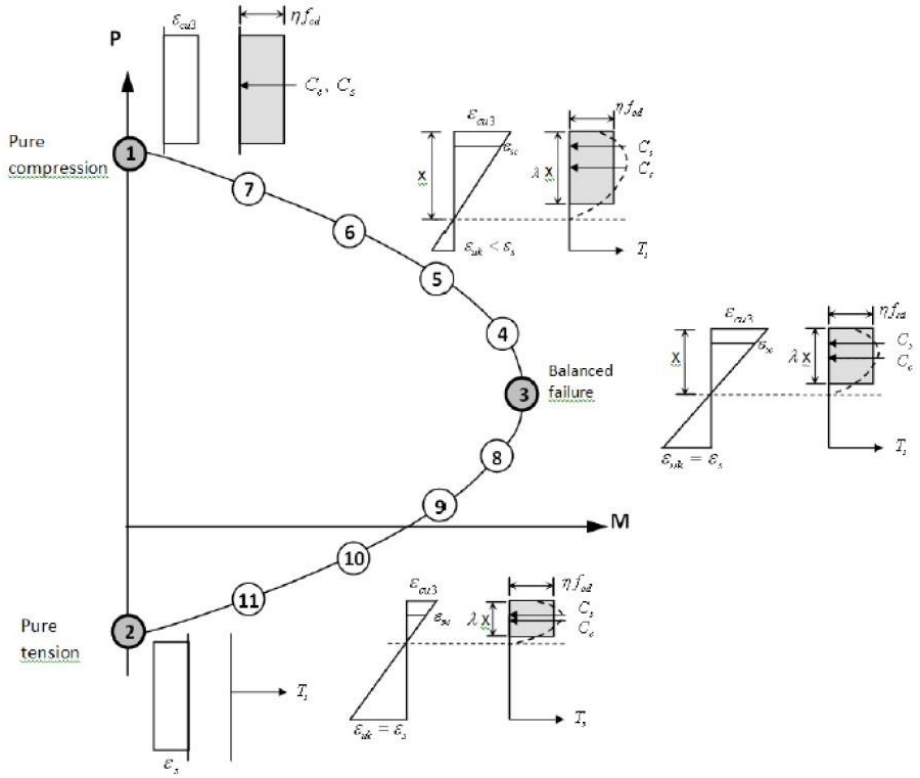


Fig. 10. Typical axial force-moment interaction curve for reinforced concrete elements.

Recent research demonstrates that modern reinforced concrete shear wall systems can significantly improve seismic energy dissipation and structural resilience under earthquake loading conditions [19].

3.4 Seismic Performance Evaluation

The seismic performance of the building was evaluated through modal analysis and dynamic response assessment.

The adopted frame-shear wall structural system ensures adequate resistance to seismic actions by combining the flexibility of reinforced concrete frames with the stiffness provided by vertical diaphragms. The adopted seismic design approach is consistent with international performance-based design recommendations and loading requirements presented in ASCE/SEI 7-22 [17].

The cumulative modal mass participation ratios obtained from the numerical analysis are presented in Table 6.

The results indicate compliance with recommended seismic design criteria. The highest modal participation was observed in the Y-direction (92.13%), while the X- and Z-directions achieved values of 79.83% and 74.03%, respectively.

These results confirm that the selected structural system provides sufficient spatial rigidity and seismic resistance for construction in a 9-point seismic zone.

The obtained results are consistent with contemporary approaches to structural performance assessment and damage-state evaluation of reinforced concrete wall systems subjected to seismic actions [20].

3.5 Architectural and Structural Integration

One of the key objectives of the project was to integrate public spaces into the residential environment without compromising structural safety.

The architectural section shown in Figure 11 illustrates the spatial organization of the building.

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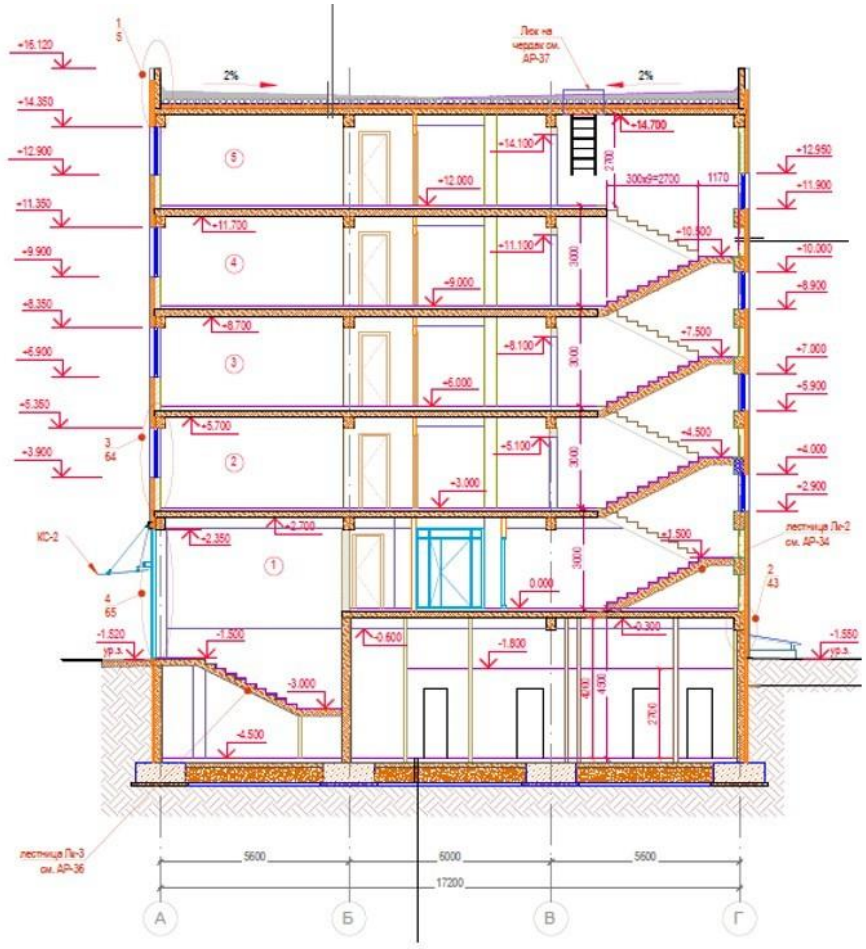


Fig. 11. Architectural section of the proposed student dormitory

The section demonstrates the rational arrangement of residential floors, circulation spaces, stair cores, and engineering systems. The adopted planning solution allows effective utilization of internal space while maintaining regularity of the structural system, which is considered an important requirement for earthquake-resistant design.

Overall, the proposed project successfully combines contemporary architectural approaches to student housing with structural solutions ensuring safety and reliability under high-seismic conditions. This integrated approach contributes to the creation of a comfortable, functional, and resilient educational environment.

The study is limited to numerical modeling and design evaluation. Experimental verification and post-occupancy assessment of the proposed dormitory were beyond the scope of this research and may be addressed in future studies.

4 CONCLUSION

Based on the conducted research, the following conclusions can be drawn:

1. A comprehensive architectural and structural design concept for a next-generation student dormitory with integrated public spaces was developed for the seismic conditions of Almaty, Kazakhstan.

2. The proposed architectural solution combines residential, educational, recreational, and social functions within a single building, creating a multifunctional environment that supports student learning, communication, and social interaction.

3. The building incorporates more than

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370 mZ of public spaces, including coworking areas, study rooms, and recreation zones. The integration of these spaces improves the functional and social effectiveness of the dormitory and corresponds to contemporary international approaches to student housing design.

4. Based on engineering-geological investigations and seismic design requirements, a reinforced concrete frame-shear wall structural system was selected. The adopted structural solution provides sufficient stiffness, stability, and load-bearing capacity for construction in a 9-point seismic zone.

5. Numerical analysis performed using the LIRA-SAPR software package confirmed the adequacy of the proposed structural system. The cumulative modal mass participation ratios reached 79.83% in the X-direction, 92.13% in the Y-direction, and 74.03% in the Z-direction, satisfying the recommended seismic design criteria.

6. The results demonstrate that the proposed project successfully integrates contemporary architectural planning principles with seismic-resistant structural design, providing a safe, functional, and sustainable student living environment.

The developed architectural and structural solutions can be recommended for the design of student dormitories and similar educational facilities in seismically active regions of Kazakhstan and other countries with comparable seismic conditions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ARTIFICIAL INTELLIGENCE STATEMENT

During the preparation of this manuscript, the authors used [tool name, version] solely for language editing and grammar checking. The authors reviewed and edited the output and take full responsibility for the scientific content, analyses, interpretations and conclusions of the article.

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Koishanbayev N.M. – providing project documentation; organization of internships and practical training in construction; analysis and collection of project-related information
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