Western European Journal of Modern Experiments and Scientific Methods
Volume 3, Issue 12, December 2025
https://westerneuropeanstudies.com/index.php/1
ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

ENHANCING SEISMIC SAFETY THROUGH THE APPLICATION OF ADVANCED PARAMETRIC DESIGN SOLUTIONS

S.M.Mirzababayeva[1], Z.A.Abobakirova[1]
Fergana State Technical University, Associate Professors[1],
saxiba.mirzababayeva@fstu.uz_(ORCID 0000-0002-6183-4688)
zebuniso.abobakirova@fstu.uz, (ORCID 0000-0002-9552-897X)

Annotation. This article analyzes the modern challenges of the sustainable architecture concept, the possibilities of addressing them through the parametric design approach, and the ways to enhance the seismic stability of buildings. The study explores the impact of parametric design technologies on environmental, social, and technical efficiency, as well as the prospects for applying this approach in the seismically active regions of Uzbekistan. In the course of the research, the scientific works of several scholars working in this field were studied.
Key words: sustainable architecture, parametric design, seismic stability, innovation, environmental efficiency, Uzbekistan.
Аннотация. В данной статье анализируются современные проблемы концепции устойчивой архитектуры, возможности их решения посредством параметрического дизайна, а также пути повышения сейсмической устойчивости зданий. В исследовании раскрывается влияние технологий параметрического дизайна на экологическую, социальную и техническую эффективность, а также рассматриваются перспективы применения данного подхода в сейсмоактивных регионах Узбекистана. В процессе исследования были изучены научные труды ряда ученых, работающих в данном направлении.
Ключевые слова: устойчивая архитектура, параметрический дизайн, сейсмическая устойчивость, инновации, экологическая эффективность, Узбекистан.

Introduction

The twenty-first century has marked a new stage in the development of human civilization, characterized by globalization, rapid advances in science and technology, accelerated urbanization, and the growing impact of global climate change. These processes have imposed new and critical responsibilities on the construction industry. In particular, the destructive consequences of natural hazards—such as floods, strong winds, fires, and most notably earthquakes—pose a serious threat to human life due to structural damage and building collapse. Therefore, contemporary architecture must be based not only on aesthetic expression and functional efficiency, but also on fundamental principles such as seismic safety, structural resilience, and environmental sustainability.

Over the past decades, the concepts of sustainable architecture and seismic-resistant construction have gained increasing attention within the scientific and professional community. This approach considers the entire life cycle of a building—from design and construction to operation and eventual demolition—by evaluating environmental impact, energy consumption, and user safety at each stage. As a result, sustainable architectural solutions contribute not only

Western European Journal of Modern Experiments and Scientific Methods
Volume 3, Issue 12, December 2025
https://westerneuropeanstudies.com/index.php/1
ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

to efficient resource utilization, but also to the creation of built environments capable of withstanding natural disasters.
In recent years, parametric design has emerged as a widely adopted methodology in architectural and engineering practice. Parametric design represents a computational approach in which geometric, structural, and functional components of a project are controlled through interrelated parameters governed by digital algorithms. Changes in a single parameter—such as story height, material elasticity, or geometric curvature—automatically trigger corresponding modifications throughout the entire model. This capability enables efficient optimization, advanced simulation, and rapid analytical evaluation, making parametric design a powerful tool for enhancing seismic performance in modern building design [1-5].
The primary advantage of parametric design lies in its ability to digitally simulate and evaluate complex geometric forms, structurally efficient systems, and seismic-resistant elements within a virtual environment prior to construction. This approach allows designers and engineers to test how structures respond to natural forces and seismic actions under various scenarios. As a result, parametric design enhances not only architectural expression, but also the structural safety and reliability of buildings by enabling early-stage optimization and risk reduction.
International experience demonstrates that parametric design plays a significant role not only in architectural form-making, but also in improving engineering safety. Japan, for instance, is recognized as one of the leading countries in the practical implementation of advanced seismic isolation technologies. Landmark structures such as the Tokyo Skytree and the Osaka International Convention Center incorporate base isolation systems, energy dissipation devices, and parametric structural monitoring technologies. These solutions reduce the natural vibration frequency of buildings and partially absorb seismic energy, thereby minimizing structural damage during earthquakes.
In New Zealand, parametric design methodologies have been integrated into building regulations through the adoption of the performance-based design approach. Within this framework, each project undergoes comprehensive digital seismic response analysis before proceeding to the construction phase. This ensures that structural performance under earthquake loading is verified in advance, leading to safer and more resilient building outcomes.
In the United States and Europe, existing building stock is increasingly being optimized through *sustainable seismic retrofitting* programs. For example, within the framework of the **Resilient City Program** developed by the California Seismic Safety Commission, older buildings are re-evaluated using parametric modeling techniques and subsequently strengthened through energy-efficient retrofit solutions. In these processes, **Building Information Modeling (BIM)** and **parametric simulation technologies** play a central role by enabling integrated structural, seismic, and energy performance analysis.
The experience of Türkiye highlights the necessity of revising construction standards in seismically hazardous regions. Following the 1999 İzmit earthquake and the 2023 Kahramanmaraş earthquakes, the concept of *dual-resilient architecture*—structures capable of adapting to both seismic and climatic impacts—was introduced. However, empirical studies indicate that incomplete compliance with construction regulations in practice significantly increases seismic vulnerability, despite the existence of advanced design frameworks.
In the countries of the Commonwealth of Independent States, particularly in Russia and Kazakhstan, scientific schools focusing on digital analysis of seismic dynamics and structural

ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

geometry have been actively developing in recent years. Research conducted at institutions such as the **Moscow State University of Civil Engineering (MGSU)** and **Al-Farabi Kazakh National University** applies the **finite element method (FEM)** to assess the influence of local construction materials (including concrete, reinforced concrete, and aerated concrete) as well as site-specific geological conditions on structural seismic response.

As a country located within a seismically active zone, the Republic of Uzbekistan faces a substantial demand for advancements in this field. In recent years, a series of state-level reforms have been implemented to promote sustainable and seismic-safe construction practices. Research initiatives focusing on parametric design methodologies, adaptive structural systems, and energy-efficient technologies are being carried out at leading institutions such as the **Tashkent University of Architecture and Civil Engineering**, the **M.T. Urozbayev Institute of Seismology of Structures and Mechanics**, **Fergana State Technical University**, and several other scientific and research centers [6-15].

These studies primarily focus on enhancing the seismic resilience of **soft-story buildings**, which are recognized as one of the most vulnerable structural typologies in earthquake-prone regions. Through parametric modeling, the deformation behavior of such buildings, the formation of plastic hinge zones, and their energy dissipation capacities are systematically analyzed. These assessments are conducted using digital prototypes that explicitly incorporate local construction materials and region-specific building conditions, ensuring realistic and applicable results.

The parametric design approach contributes not only to improved seismic performance, but also to broader environmental efficiency objectives, including resource conservation, waste reduction, and the minimization of carbon emissions. By aligning with the principles of sustainable urban development, this methodology supports enhanced human well-being, improved indoor comfort, and greater social sustainability within the built environment.

From an economic perspective, parametric modeling enables the optimization of construction materials and energy consumption, resulting in potential reductions of approximately **15–25%**. In the context of Uzbekistan, such efficiency gains are particularly significant, given the reliance on local raw material resources and the need to strengthen long-term economic stability in the construction sector.

The implementation of parametric design technologies marks the beginning of a new phase in the development of sustainable and safe construction practices in Uzbekistan. Through this integrated approach, seismic safety, environmental performance, and economic efficiency are treated as interdependent components of a unified system. Consequently, a national model of seismic-resilient architecture is emerging—one that ensures both human safety and environmental protection.

Thus, the integration of seismic resilience with sustainable architectural principles is increasingly regarded not merely as a technical challenge, but as a **strategic direction for national development**. Ongoing scientific research in this field provides a solid theoretical and methodological foundation for the creation of future urban environments that are safe, environmentally sustainable, and innovation-driven.

Methodology

The conducted research is scientifically significant as it aims to develop innovative approaches for enhancing the seismic resilience of existing buildings while facilitating the practical implementation of sustainable architecture principles. Based on the application of parametric

Western European Journal of Modern Experiments and Scientific Methods
Volume 3, Issue 12, December 2025
https://westerneuropeanstudies.com/index.php/1
ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

design elements, the structural systems of buildings were subjected to comprehensive analysis, resulting in the development of adaptive and energy-efficient solutions capable of responding effectively to seismic actions. This methodology enables accurate simulation of structural deformation behavior, stress distribution, and the interaction between structural components, thereby providing a robust basis for improving seismic performance.

During the research process, key structural elements—including frames, supports, stiffening ribs, and connecting components—were parametrically modeled under various seismic scenarios. The results indicate that this approach significantly reduces dynamic loads generated during earthquakes, maintains structural deformations within acceptable limits, and enhances the overall energy dissipation capacity of the system. In addition, parametric modeling allows precise evaluation of factors influencing seismic safety, such as material properties, structural geometry, center of mass distribution, and foundation stability.

The scientific novelty of the study lies in the integrated use of parametric design elements not only as tools for engineering analysis, but also as an essential component of the sustainable architecture framework. In this approach, seismic safety, energy efficiency, and environmental balance are considered as interdependent elements of a unified system. Such integration enables the design of buildings that are not only earthquake-resistant, but also economically efficient during operation, environmentally responsible, and comfortable for users throughout their service life.

Results

The research outcomes demonstrate significant practical relevance. The application of parametric solutions for enhancing the seismic strength of buildings reduces the need for extensive post-earthquake rehabilitation and reconstruction, thereby lowering construction costs and promoting the rational use of natural resources. At the same time, the proposed approaches contribute to achieving a balanced relationship between safety, economic efficiency, and environmental sustainability within the urban built environment.

Overall, the scientific contribution of the study lies in the development of an integrated system that simultaneously improves seismic safety through parametric design tools and aligns with contemporary principles of sustainable architecture, incorporating climatic and energy-related considerations. The obtained results may be effectively applied in further scientific investigations and practical design activities, particularly in the seismic strengthening of existing buildings and the development of a new generation of environmentally sustainable structures.

In this study, advanced modeling techniques based on parametric design and seismic analysis were employed. Seismic performance evaluations were carried out using **modal analysis methods** in accordance with established analytical procedures [5-19].

As the case study, a **five-story educational building** was selected. The structural system of the building consists of a **reinforced concrete frame–monolithic structure**, with the integration of energy-efficient façade elements and parametrically defined architectural forms.

Preliminary analyses have yielded initial findings, and the research is currently ongoing. The key preliminary performance indicators obtained from the analysis are presented in the following table.

Parameter	**Parameter**	**Parameter**	**Parameter**

Western European Journal of Modern Experiments and Scientific Methods
Volume 3, Issue 12, December 2025
https://westerneuropeanstudies.com/index.php/1
ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

Deformation (cm)	4.5	3.2	-28.8
Seismic Force (kN)	920	770	-16.3
Energy Efficiency	1.0	1.35	+35

The data presented above demonstrate that the application of parametric design elements significantly improves both the seismic resilience and energy efficiency of buildings. According to the table, the **deformation** in the parametric model is reduced by **28.8%** compared to the conventional building. This improvement is attributed to the more effective distribution of internal stresses across structural elements and a reduction in plastic deformations, resulting in an overall increase in structural stability and enhanced resistance to strong seismic excitations.

Similarly, **seismic forces** were observed to decrease by **16.3%**, indicating that the mass distribution and structural geometry of the building have been optimized in the parametric model. Such improvements not only enhance the seismic safety of the structures but also contribute to their economic efficiency by reducing potential damage and the need for post-earthquake interventions.

One of the most significant outcomes is a **35% increase in energy efficiency**, which aligns with the core principles of sustainable architecture. The parametric model enables optimization of natural lighting, ventilation, and the structural energy balance, creating buildings that are not only seismically resilient, but also environmentally and economically sustainable. Consequently, parametric design proves to be an effective approach for achieving integrated performance in terms of safety, energy efficiency, and ecological responsibility.

Overall, the application of parametric design technologies in seismic-resilient architecture marks a new stage in the development of sustainable construction. This approach not only mitigates the risks associated with natural hazards but also ensures long-term resource efficiency, occupant comfort, and environmental sustainability throughout the building's life cycle.

The research findings indicate that parametric design serves not merely as a tool for architectural expression, but also plays a critical role in ensuring structural efficiency and sustainability. Through parametric modeling, seismic resilience can be quantitatively assessed, enabling the optimal placement of structural elements and balanced distribution of internal stresses. As a result, deformation levels under seismic loads are reduced, enhancing the overall structural durability of buildings [4-20].

Furthermore, parametric modeling facilitates the integration of architectural and engineering disciplines. The combined application of **Building Information Modeling (BIM)** and parametric design allows for the digitalization of construction processes, implementation of energy-efficient façade solutions, and optimization of material usage. This approach aligns with one of the primary goals of sustainable architecture: the creation of buildings that are environmentally responsible, economically efficient, and socially beneficial.

In conclusion, parametric design can be considered a scientifically grounded, innovative, and sustainable architectural solution for buildings constructed in regions with high seismic risk, providing a holistic framework for safety, efficiency, and environmental performance.

Muhokama: Parametrik dizayn texnologiyalari seysmik xavfi yuqori bo'lgan hududlarda binolarning barqarorligini ta'minlashning samarali vositasi hisoblanadi [5,28]. Shu bilan birga parametrik modellashtirish orqali konstruksiya elementlarini optimal joylashtirish natijasida binolarning energiya yutish qobiliyati va deformatsiyaga chidamlilik darajasi oshadi. Energiya

This article/work is licensed under CC Attribution-Non-Commercial 4.0

tejamkor fasad yechimlarini joriy etish orqali binolarning ekspluatatsiya xarajatlari sezilarli darajada kamayib, uzoq muddatli iqtisodiy barqarorlik ta'minlanadi. O'zbekistonda yangi qurilayotgan ta'lim, sog'liqni saqlash va ma'muriy binolarda parametrik dizayn elementlarini joriy etish nafaqat seysmik xavfsizlikni, balki qurilish sohasidagi raqamlashtirish va barqaror arxitektura tamoyillarini amalga oshirishni ta'minlaydi. Tadqiqot natijalari mamlakatimizda zamonaviy va ekologik barqaror arxitekturani rivojlantirishda ilmiy-amaliy asos bo'lib xizmat qilishi mumkin.

References [1]. Kh.S. Sagdiev, Z.R. Teshabayev, V.A. Galiaskarov, and A.S. Yuvmitov, "Centrifugal modeling of underground polymer pipes under temperature effect," Magazine of Civil Engineering, No. 6(98), 9801–9801 (2020).
[2]. Z.A. Abobakirova, S.M. Mirzababayeva, "Seismic safety issues of flexible-layered buildings," Scientific-Technical Journal (STJ FerSTU), 2025/10, Vol. 29, pp. 87–91.
[3]. Sh.A. Umarov, S.M. Mirzababayeva, Z.A. Abobakirova, "Modern methods of reducing seismic risk in buildings," Scientific-Technical Journal (STJ FerSTU), 2025/10, Vol. 29, pp. 91–94.
[4]. S.M. Mirzababayeva, Z.A. Abobakirova, "The role of parametric design elements as an innovative solution in seismic safety concept," Scientific-Technical Journal (STJ FerSTU), 2025/10, Vol. 29, pp. 127–130.
[5]. Z.A. Abobakirova, S.M. Mirzababayeva, "Ways to reduce environmental impact through construction waste recycling," Scientific-Technical Journal (STJ FerPI), 2025, Vol. 29, Special Issue No. 9, pp. 224–229.
[6]. S.M. Mirzababayeva, Z.A. Abobakirova, Sh.A. Umarov, "Active seismic protection devices to enhance the earthquake resistance of buildings and structures," Scientific-Technical Journal (STJ FerSTU), 2025, Vol. 29, No. 9, pp. 131–134.
[7]. Z. Abobakirova, S. Umarov, R. Raximov, "Enclosing structures of a porous structure with polymeric reagents," E3S Web of Conferences, Vol. 452, p. 06027 (2023, September).
[8]. S. Umarov, S. Mirzababayeva, Z. Abobakirova, N. Goncharova, S. Davlyatov, "Operation of reinforced concrete beams along an inclined section under one-sided heating," E3S Web of Conferences, 2024, Vol. 508, p. 05001.
[10]. Y. Karimov, I. Musaev, S. Mirzababayeva, Z. Abobakirova, S. Umarov, "Land use and land cover change dynamics of Uzbekistan: a review," E3S Web of Conferences, Vol. 421, p. 03007.
[11]. X. Akramov, S. Davlyatov, S. Umarov, Z. Abobakirova, "Method of experimental research of concrete beams with fiberglass reinforcement for bending," E3S Web of Conferences, Vol. 365, p. 02021 (2023).
[13]. S. Mirzababayeva, Z. Abobakirova, S. Umarov, "Crack resistance of bent concrete structures with fiberglass reinforcement," E3S Web of Conferences, 2023, Vol. 452, p. 06023.
[14]. Z. Abobakirova, S. Umarov, R. Raximov, "Enclosing structures of a porous structure with polymeric reagents," E3S Web of Conferences, 2023, Vol. 452, p. 06027.
[15]. AJD Mirzababyeva, S. Mirzaakbarovna, Z. Abobakirova, "The role of parametric design elements in sustainable architecture and seismic resilience," Architecture. Construction. Design. Architecture and Urban Planning. Design, Vol. 3, No. 3, pp. 972–976.
[16]. A.S. Yuvmitov, B.O. Egamberdiyev, Z.A. Abobakirova, "Dynamic characteristics of buildings with inertia dampers under seismic forces," Architecture and Construction Problems, Vol. 2, No. 2, pp. 294–301.

Western European Journal of Modern Experiments and Scientific Methods
Volume 3, Issue 12, December 2025
https://westerneuropeanstudies.com/index.php/1
ISSN (E): 2942-1896 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

[17]. N.I. Vatin, Z.A. Abobakirova, Sh.M. Davlyatov, Sh.A. Umarov, “The role of corrosion-resistant polymer additives in forming protective coatings,” Scientific-Technical Journal, Vol. 29, No. 4, pp. 61–70.
[18]. A. Ibrokhimov et al., “RETRACTED: Mathematical modeling of particle movement in laminar flow in a pipe,” BIO Web of Conferences, Vol. 84, 2024.
[19]. M. Madraximov et al., “Numerical simulation of laminar symmetric flow of viscous fluids,” AIP Conference Proceedings, Vol. 3119, No. 1, p. 040003 (2024).
[20]. S. Umarov et al., “Comparison of current and expired norms for the development of methods for checking and monitoring the seismic resistance of buildings,” E3S Web of Conferences, Vol. 474, p. 01020 (2024).
[21]. S.M. Mirzababayeva, M.M. Baxromov, “Foundation construction features in seismic regions,” Scientific-Technical Journal (STJ FerPI), 2024/12, Vol. 28, Special Issue No. 26, pp. 70–74.
[22]. S.M. Mirzababayeva, Z.A. Abobakirova, Sh.A. Umarov, J.D. Axmedov, “Utilizing the ‘adaptive floor’ effect in frame-structured buildings,” Architecture, Construction, Design, pp. 929–932 (2024).
[23]. S.M. Mirzababayeva, Z.A. Abobakirova, “Application of the ‘adaptive floor’ effect in frame-structured buildings,” In Proceedings of the International Scientific and Technical Conference on Innovations in Construction, Seismic Safety of Buildings and Structures, pp. 205–208. Namangan, Uzbekistan, November 27–28, 2024.
[24]. J.D. Axmedov, S.A. Umarov, Z.A. Abobakirova, S.M. Mirzabayeva, “Strength and ductility investigation of concrete beams reinforced with glass composite reinforcement,” Architecture. Construction. Design, 2024/10, No. 3, pp. 559–564.
[25]. Sh.A. Umarov, S.M. Mirzababayeva, Z.A. Abobakirova, “Recommendations for ensuring seismic stability of buildings in use,” Scientific-Technical Journal (STJ FerPI), 2024/10, Vol. 28, Special Issue No. 20, pp. 115–122.
[26]. Z. Abobakirova et al., “Methodology for checking the seismic strength of buildings based on existing norms,” BIO Web of Conferences, Vol. 105, 2024.
[27]. S. Umarov et al., “Operation of reinforced concrete beams along an inclined section under one-sided heating,” E3S Web of Conferences, Vol. 508, p. 05001 (2024).
[28]. N. Goncharova et al., “Improving the thermal properties of lightweight concrete exterior walls,” E3S Web of Conferences, Vol. 508, p. 05002 (2024).