DEVELOPING MID-RISE RESIDENTIAL BUILDINGS USING INDUSTRIAL CONSTRUCTION TECHNOLOGIES ADAPTED TO THE HOT AND ARID CLIMATE OF KHOREZM REGION

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Abstract: *This scientific article comprehensively investigates the issues of designing and constructing mid-rise multi-apartment residential buildings in the Khorezm region, considering its sharply continental, hot, and arid climate, using industrial construction technologies. The study analyzes the region's climatic characteristics, solar radiation intensity, wind patterns, and seasonal air temperature variations in terms of their impact on building structures. In addition, the energy efficiency, economic feasibility, and operational advantages of prefabricated and modular construction systems are substantiated. The findings have scientific and practical significance for creating a sustainable, energy-efficient, and climate-adapted housing stock in the Khorezm region.*

Keywords: *hot and arid climate, Khorezm region, industrial construction technologies, prefabricated technologies, mid-rise residential buildings, energy efficiency.*

INTRODUCTION

Today, the acceleration of urbanization processes, population growth, and increasing demand for housing require new approaches in the construction sector. Particularly in regions with complex climatic conditions, selecting construction technologies and developing design solutions has become a key scientific and practical issue. Among the territories of the Republic of Uzbekistan, Khorezm region stands out with its unique natural-climatic conditions. In this region, the extremely hot and dry summer season, high solar radiation, and low atmospheric precipitation directly affect the long-term durability and energy efficiency of construction objects.

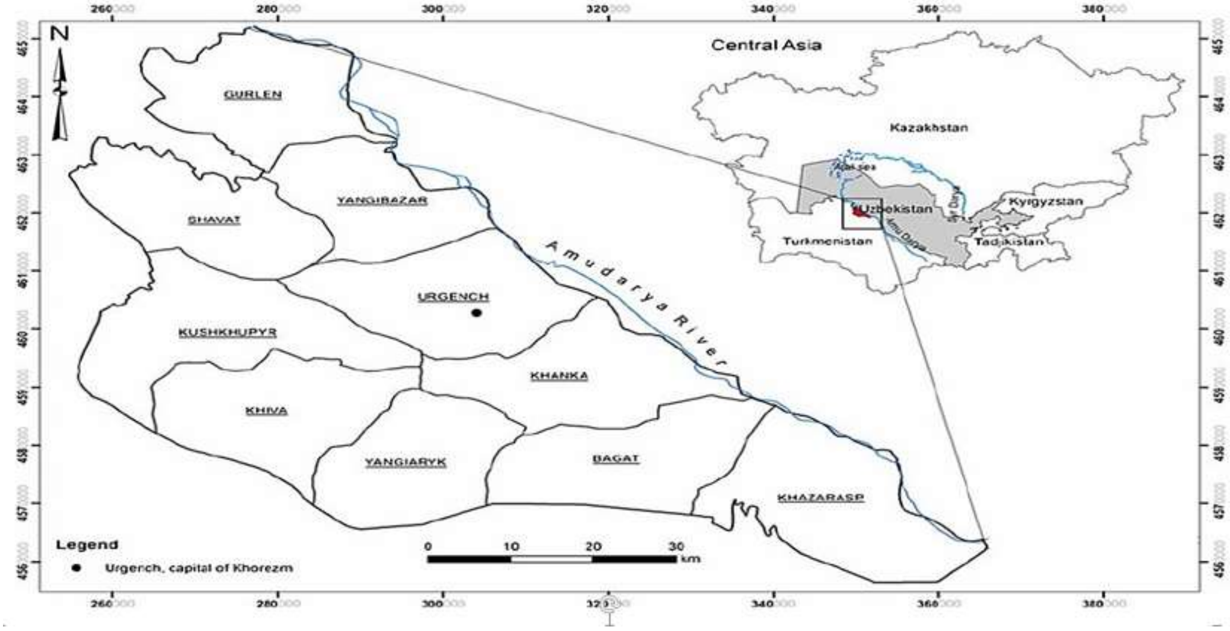
In recent years, housing construction in our country has been designated as one of the priority directions of state policy. In particular, mid-rise multi-apartment residential buildings are considered one of the most acceptable solutions from the viewpoint of rational use of land resources in city and district centers, optimization of engineering infrastructure, and improvement of living conditions for the population. However, erecting such buildings using traditional construction methods often requires significant time, financial costs, and high energy consumption.

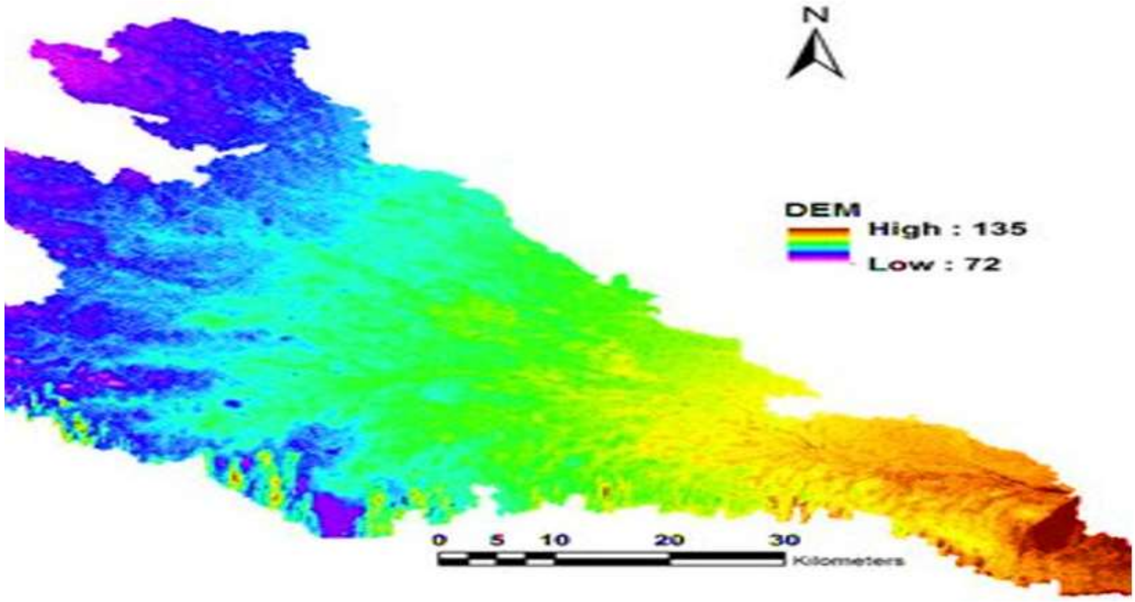
In this regard, the introduction of industrialized construction technologies is gaining urgent importance. Industrialized construction refers to technologies based on preparing construction elements in factory conditions, standardizing them, and quickly implementing assembly works. This approach allows improving construction quality, increasing labor productivity, and ensuring energy savings during operation.

The main objective of this scientific research is to develop optimal design solutions for mid-rise residential buildings using industrialized construction technologies adapted to the hot and dry climatic conditions of Khorezm region. During the study, the region's climatic factors, structural elements, energy efficiency indicators, and economic aspects are comprehensively analyzed.

Chapter I. Impact of Khorezm Region's Climatic Conditions on Construction Systems

Figure 1. Climate indicator map of Khorezm region.





Description of Khorezm region's natural-climatic conditions – Khorezm region is located in the northwest of the Republic of Uzbekistan and belongs to the sharply continental climate zone. The summer season in the region is long, with average air temperatures in July-August reaching +38…+42 °C. On some days, maximum temperatures exceed +45 °C. The winter season is relatively short and cold, with average January temperatures of -5…-7 °C. Annual atmospheric precipitation amounts to an average of 80–110 mm, with the majority falling in spring months. Relative air humidity drops to 20–30% in summer, causing high heat loads on building exteriors. Solar radiation levels are high, with 280–300 sunny days per year.

Figure 1. Climate indicator map of Khorezm region.

Xorazm shahri: Iyul oyining o'rtacha harorati (1980-2020) 32,91°C ni tashkil qiladi			
Sana	Yuqori harorat °C	Anomaliya	Intensivlik
1984-yil 23-25-iyul	38.28	5.37	Og'ir vaznli
	40.21	7.30	
	39.15	6.24	
1986-yil 14-17-iyul	38.28	5.37	Og'ir vaznli
	39.07	6.16	
	40.34	7.43	
	41.66	8.75	
1995-yil 14-17-iyul	39.60	6.69	Og'ir vaznli
	38.68	5.77	
	39.63	6.72	
	38.85	5.94	
2002-yil 15-18-iyul	38.07	5.16	Og'ir vaznli
	39.90	6.99	
	39.25	6.34	
	40.07	7.16	
2005-yil 5-7-iyul	38.63	5.72	Og'ir vaznli
	40.50	7.59	
	41.50	8.59	
2015-yil 13-16-iyul	39.82	6.71	Shimoliy HW
	39.97	7.065	
	39.52	6.61	
	40.27	7.36	
2018-yil 19-22-iyul	38.22	5.30	Og'ir vaznli
	39.57	6.66	
	40.87	7.96	

Figure 2. Annual average temperatures (°C) for the hottest cities in Khorezm region (1980–2020 comparison).

These climatic indicators cause the following problems in construction:

- Excessive overheating inside buildings.
- High demand for cooling systems.
- Rapid wear of exterior walls and roof structures.

Increased energy consumption.

Therefore, applying climate-adapted constructive solutions with passive protection features is crucial for residential buildings constructed in Khorezm region.

Requirements for construction structures in hot and dry climates – The main requirements for building constructive elements in hot and dry climates include:yuqori issiqlik qarshiligiga ega devor va tom tizimlari;

- Wall and roof systems with high thermal resistance.
- Exterior coatings that reflect solar rays.
- Planning solutions ensuring natural ventilation.
- Use of materials with high thermal inertia properties.

Studies show that properly selected constructive solutions can reduce indoor temperatures by 6–8 °C. This significantly reduces the need for mechanical cooling systems.

Chapter II. Theoretical Foundations of Industrial Construction Technologies in Hot and Dry Climates

Industrialized construction technologies are one of the widely used approaches in modern architecture and construction industry, enabling the erection of buildings quickly, qualitatively, and efficiently using standard elements. These technologies are based on prefabricated and modular systems. In prefabricated systems, main building structures are manufactured in factory conditions, while assembly is carried out at the construction site. This approach improves building quality, shortens construction ime, and reduces labor costs.

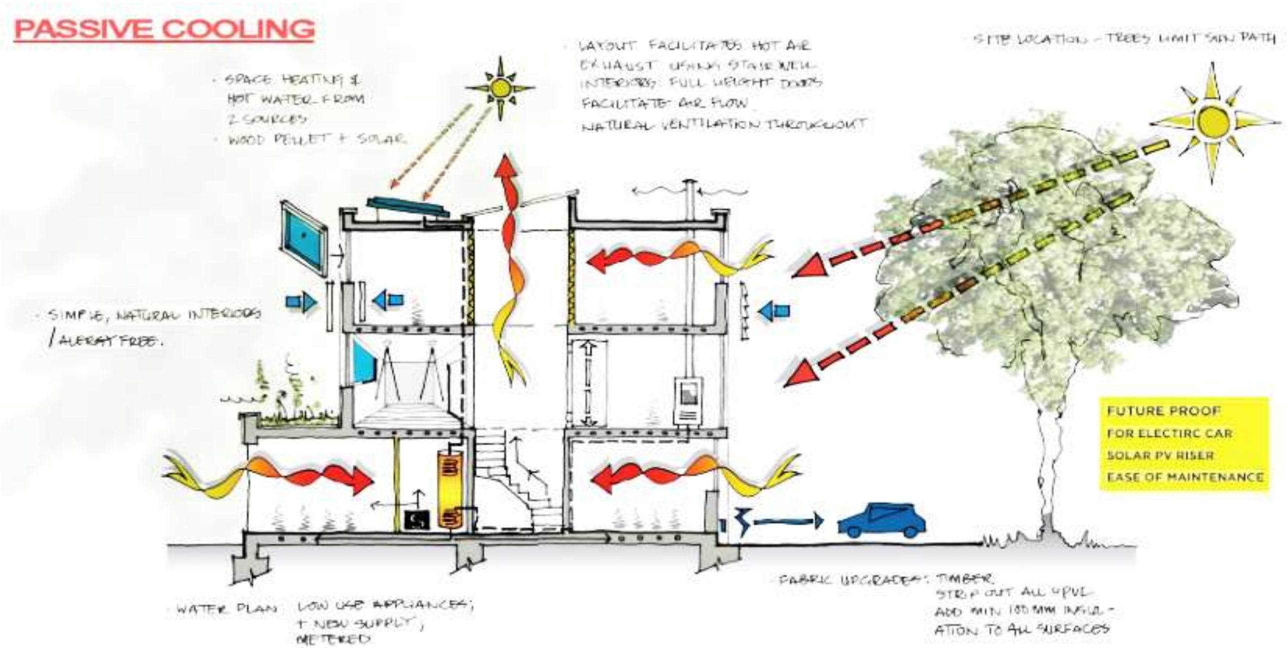


Figure 3. Principles of passive design strategies.

In hot and arid climates, such as those typical of Central Asian territories, buildings are exposed to high levels of solar radiation (often exceeding 5.5–6.0 kWh/m² per day annually), prolonged summer temperatures reaching 40–45°C, and significant diurnal temperature variations. Under these environmental conditions, thermal loads on building envelopes increase substantially, resulting in higher cooling energy demand. Research in building physics indicates that up to 60–70% of total heat gain in residential buildings in arid climates occurs through walls and roofs. Therefore, improving the thermal resistance of these components becomes a primary design objective. Prefabricated wall systems designed for hot climates typically achieve thermal transmittance (U-value) levels below 0.35 W/m²K when multilayer insulation systems are applied. Studies demonstrate that reducing the U-value of external walls from 1.5 W/m²K (typical of non-insulated masonry) to 0.3 W/m²K can decrease annual cooling energy consumption by approximately 25–35%. Factory-controlled production ensures uniform insulation thickness, minimizes thermal bridging, and improves airtightness, which directly enhances overall building energy performance. Roof assemblies, being the most exposed structural elements, contribute significantly to heat gain. The implementation of cool roof technologies — characterized by high solar reflectance (above 0.70) and high thermal emittance — can reduce roof surface temperatures by 20–30°C during peak summer periods. Consequently, indoor air temperatures may decrease by 2–4°C without additional mechanical cooling. When combined with photovoltaic integration, buildings can offset part of their electricity demand, contributing to near-zero energy building (NZEB) strategies increasingly promoted in international sustainability frameworks.

From a life-cycle perspective, industrialized construction methods also demonstrate economic efficiency. Life-cycle cost assessments indicate that although initial investment in prefabricated systems may be 5–10% higher than traditional construction, operational savings from reduced energy consumption can compensate for this difference within 6–8 years. Furthermore, controlled factory production improves structural accuracy, reduces on-site labor intensity by up to 40%, and enhances occupational safety.

Spatial planning strategies further strengthen climatic adaptability. Optimal building orientation along the east–west axis reduces direct solar gain on main façades, while shading devices such as horizontal louvers can reduce solar penetration by 60–80% during peak hours. Cross-ventilation designs increase natural airflow rates, reducing reliance on mechanical cooling systems and improving indoor air quality.

In summary, the integration of industrialized construction technologies with climate-responsive architectural design forms a scientifically grounded approach to sustainable mid-rise housing development in hot and arid regions. Quantitative performance improvements in energy efficiency, construction speed, and life-cycle cost confirm the feasibility and long-term benefits of such systems. Therefore, industrialized construction should be considered not merely as a technological alternative, but as a strategic framework for achieving resilient and energy-efficient housing solutions in extreme climatic environments.

A distinctive feature of industrialized construction in hot and dry climates is that structures and materials must withstand high heat loads. Exterior walls must have high thermal resistance, roofs and windows must be protected from solar rays, and interiors must be equipped with air exchange and natural ventilation paths.

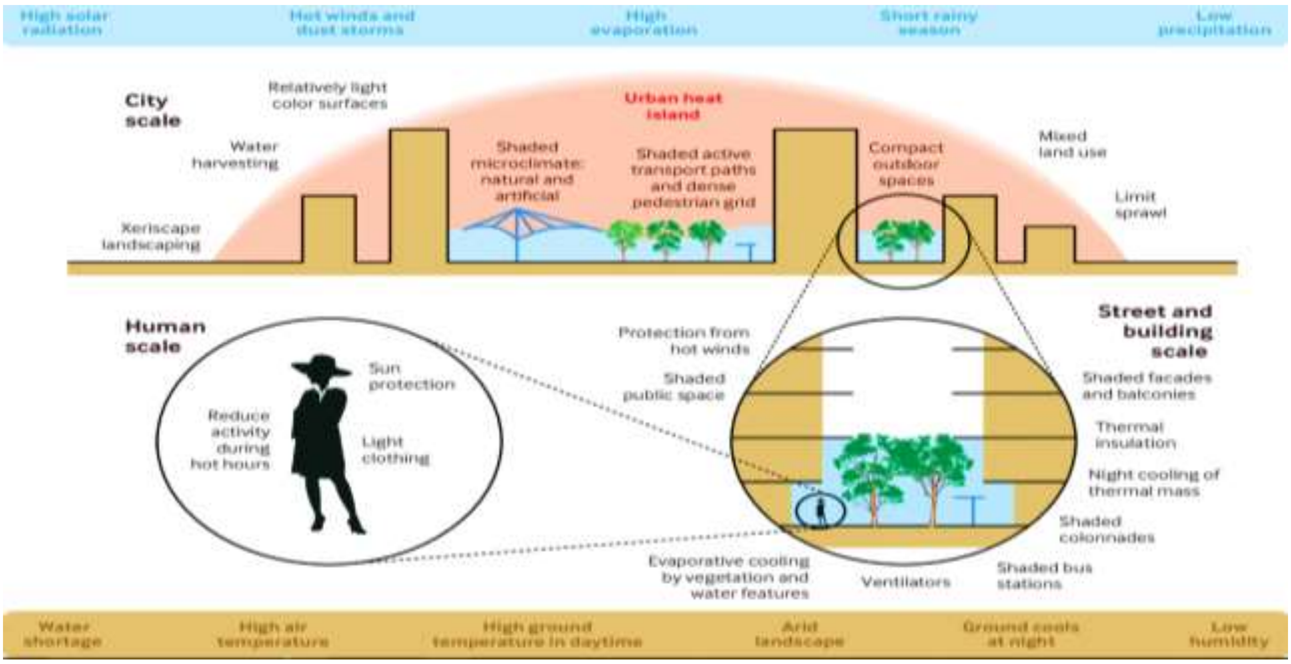


Figure 4. Building design in hot and dry climates.

The biggest challenge in hot and dry climate architecture is minimizing energy consumption as much as possible, and in this regard, ancient buildings can serve as a solution. Traditional houses in hot regions were built to allow natural temperature regulation. Small windows, lattice screens or "mashrabiya," inner courtyards, and wind towers – all these ancient construction techniques are effective in blocking solar rays and increasing air flow. Such climate-adapted architectural practices remain highly relevant today and can be very effective in minimizing energy consumption.

In hot and dry climates like the Near East, creating a healthy environment can be particularly challenging due to weather limiting outdoor interactions, physical activities, and active transport.

Some key challenges include:

- Green spaces facing issues related to water scarcity, prolonged hot summers, and high evaporation.
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Technology plays a key role in implementing passive design strategies for sustainable building design. Examples of technology use in enhancing passive design strategies in Masdar City:

1. Smart building management:

Buildings in Masdar City are equipped with smart systems that adjust lighting and temperature based on external conditions.

2. Automated shading devices:

Shading devices automatically adjust based on sun position, reducing heat gain and improving energy efficiency.

3. Use of advanced insulation materials:

Figure 5. Main passive design strategies for hot and dry climates.

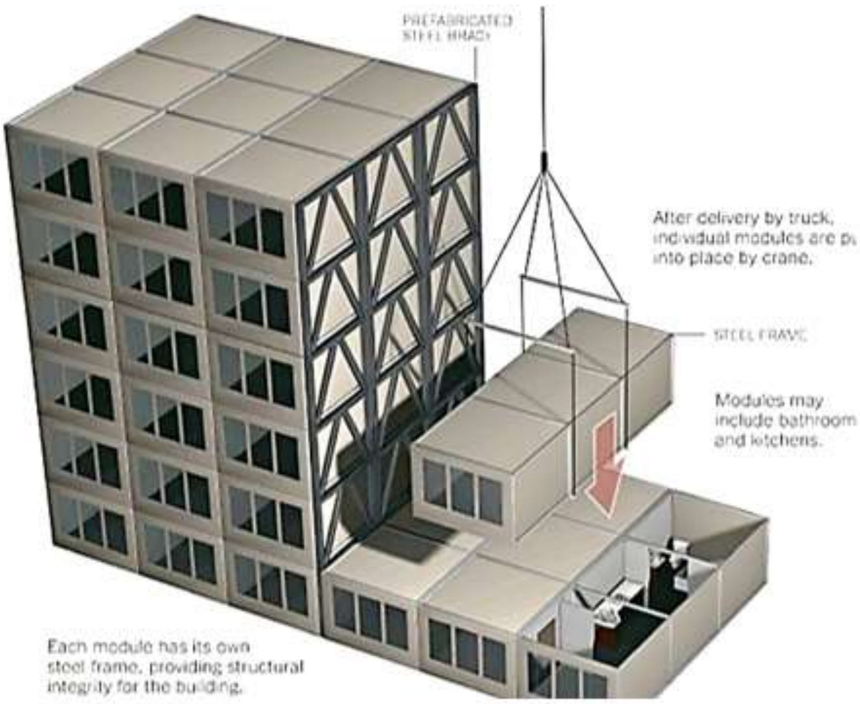
Buildings are designed using advanced insulation that minimizes heat transfer and reduces air conditioning needs.

Prefabricated systems are enriched with various modules adapted to regional climate features.

Prefabricated systems are enriched with various modules adapted to regional climate features. For example, exterior wall panels consist of mineral wool or EPS layers with high thermal resistance, while interior finishes meet acoustic and thermal requirements. Roof modules are equipped with thermal insulation and sun-protective coatings; integrated solar panels on roofs serve as additional energy sources.

Interior walls are easily installed via modular systems, providing acoustic and thermal insulation. Waterproofing is applied in basements and lower floors to reduce moisture and damage risks.

Theoretical studies indicate that industrialized systems significantly improve building energy efficiency. High insulation of exterior walls and roofs reduces cooling and heating energy by 35–45% annually. Prefabricated and modular systems shorten construction time by 40–60% compared to traditional methods, ensure efficient labor resource use, and substantially reduce waste.



Industrialized construction technologies also enable the use of climate-adapted eco-materials and passive energy efficiency elements. This holds significant importance for creating sustainable housing stock, maintaining stable indoor microclimate, and reducing construction costs in the region.

Thus, in Khorezm region's conditions, industrialized construction technologies using prefabricated and modular systems enable increasing energy efficiency, construction quality, and labor productivity in mid-rise residential projects. This approach is effective for creating climate-adapted designs and providing comfortable living conditions for the local population.

Chapter III. Design-Planning and Constructive Solutions for Mid-Rise Residential Buildings

In designing mid-rise residential buildings, regional climatic conditions, energy efficiency, and rational use of construction resources are primarily considered. In Khorezm region's hot and dry climate, buildings must maintain stable indoor temperatures and reduce external heat loads. Therefore, industrialized, prefabricated, and modular systems are applied in developing mid-rise residential projects. Optimal constructive solutions for exterior walls, roofs, and interior walls were developed during design. Exterior walls consist of three layers: outer coating, insulation, and

Figure 6. Industrial construction technologies (Prefabricated method).

reinforced concrete core. The outer coating has high solar reflection properties, ensuring atmospheric durability. Insulation layer thickness is 100–150 mm, increasing wall thermal resistance and maintaining indoor temperatures at +24…+28 °C. The reinforced concrete core provides structural strength, while interior finishes meet acoustic and aesthetic requirements.

Roof structures are also aimed at enhancing energy efficiency. Thermal insulation layers and reflective coatings reduce heat incidence on the building. Roofs allow integration of solar panels as additional energy sources for residences. Interior walls are designed with acoustic and thermal insulation; waterproofing is applied in basements and lower floors.

In planning solutions, orientation of apartments and common areas plays a key role. Kitchens and living rooms face south and west facades, while bedrooms are oriented toward shaded or northern sides. Indoor air exchange is ensured via natural ventilation paths, vents, and window systems. Buildings are equipped with stairs and fire-resistant materials compliant with emergency safety standards.

Simulation results for energy efficiency assessment show that prefabricated and modular systems reduce annual cooling energy by 40%, maintaining indoor temperatures in the specified range. Factory production of prefabricated panels shortens construction time by 50–60% and lowers labor costs. Passive design principles and high-quality insulation materials significantly reduce energy consumption during operation.

These solutions are recommended as effective and climate-adapted for mid-rise residences in Khorezm region. Industrialized and modular systems improve construction quality, reduce time and financial costs, ensure energy efficiency, create stable microclimates, and provide comfortable living conditions for the population.

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