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**TEXNIKA FANLARI DOKTORI, PROFESSOR  
MIRAXMEDOV MAXAMADJON MIRAXMEDOVICH  
TAVALLUDINING 80 YILLIGIGA BAG'ISHLANGAN  
“SAMARALI QURILISH MATERIALLARI, KONSTRUKSIYALARI VA  
TEKNOLOGIYALARI”  
MAVZUSIDAGI XALQARO ILMIY-AMALIY KONFERENSIYASI  
ILMIY ISHLARI TO'PLAMI**

Toshkent davlat transport universiteti RAASN akademigi, O'zbekistonda xizmat ko'rsatgan yoshlar murabbiyi, texnika fanlari doktori, professor Miraxmedov Maxamadjon Miraxmedovich tavalludining 80 yilligiga bag'ishlangan, ilmiy ishlar to'plami nashr etilishi ko'zda tutilgan «Samarali qurilish materiallari, konstruksiyalari va texnologiyalari» mavzusidagi Xalqaro ilmiy-amaliy konferensiyani o'tkazishni rejalashtirmoqda.

M.M. Miraxmedov kompozitsion qurilish materiallarining polistruktura nazariyasini rivojlantirishga salmoqli hissa qo'shgan. Uning qurilish materialshunosligi sohasidagi ilmiy hissi e'tirofi sifatida 1995-yilda Rossiya arxitektura va qurilish fanlari akademiyasining (RAASN) xorijiy a'zosi etib saylangan. M.M. Miraxmedov 6 ta monografiya, 200 dan ortiq ilmiy maqolalar va 25 ta ixtiroga mualliflik guvohnomalari muallifidir.

Ushbu konferensiyaning asosiy maqsadi - qurilish materialshunosligi, bino va inshootlarni loyihalash va qurilish sohasidagi ilmiy tadqiqotlar natijalarini, shuningdek, muhandislik ta'limini takomillashtirish yo'llarini muhokama qilishdan iborat.



Konferensiya ishida ishtirok etish uchun oliy o'quv yurtlari va ilmiy tadqiqot institutlari olimlari, O'zbekiston Respublikasi va xorijiy davlatlarning ishlab chiqarish vakillari, ilmiy tadqiqotlarda salmoqli natijalarga ega bo'lgan mutaxassislar taklif etiladi.

**“Samarali qurilish materiallari, konstruksiyalari va texnologiyalari”** mavzusidagi xalqaro ilmiy-amaliy konferensiyaning asosiy yo'nalishlari quyidagilardan iborat:

1. Resurs va energiya tejovchi qurilish materiallari va texnologiyalari.
2. Atrof-muhitning transport infratuzilmasiga ta'siri va uni himoya qilish usullari.
3. Bino va inshootlarning qurilish konstruksiyalari: hisoblash va loyihalashning zamonaviy usullari.
4. Arxitektura, shaharsozlik va shahar muhitini rivojlantirish.
5. Qurilishni tashkil etishning innovatsion usullari va qurilish jarayonlari texnologiyalari.
6. Transport obyektlarini loyihalash va qurishda raqamli texnologiyalar hamda sun'iy intellekt.
7. Temir yo'l transporti infratuzilmasi obyektlarini loyihalash, qurish va ekspluatatsiya qilish.
8. Zamonaviy muhandislik ta'limi tizimini takomillashtirish.

Mazkur konferensiya ilmiy hamjamiyatning turli vakillarini bir joyga jamlab, qurilish materialshunosligi sohasidagi zamonaviy muammolar va istiqbollarni muhokama qilish uchun qulay platforma vazifasini bajardi.

# Passive Cooling Strategies in Residential Architecture of Hot-Dry Uzbek Cities: A Design-Screening Model

E. Urazxanova<sup>1</sup><sup>a</sup>, K. Markabaeva<sup>1</sup><sup>b</sup>

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**Abstract:** The article analyzes passive cooling strategies for residential architecture in hot-dry urban environments of Uzbekistan, with attention to the climatic conditions of Karakalpakstan and the lower Amu Darya region. The research evaluates orientation, compactness, shading, natural ventilation, courtyard design, envelope thermal resistance and reflective roof surfaces. A comparative design-screening model is proposed for four residential block variants. The results show that the highest cooling-load reduction is achieved through a combined passive package: east-west orientation control, external shading, ventilated roofs, improved wall insulation, night ventilation and shaded courtyards. The proposed approach supports energy-efficient housing design and can be used in early-stage architectural planning.

**Keywords:** Passive Cooling, Residential Architecture, Hot-Dry Climate, Nukus, Courtyard Housing, Shading, Energy Efficiency, Urban Heat Island, Sustainable Design

## 1. INTRODUCTION

Residential buildings in hot-dry cities face a dual challenge: they must protect occupants from high summer temperatures while keeping energy demand affordable. In the cities of Karakalpakstan, climatic stress is intensified by low humidity, strong solar radiation, dusty winds and the limited cooling capacity of urban vegetation. Therefore, architectural solutions should reduce heat gains before mechanical cooling is required.

Passive cooling is not a single technique but a coordinated design logic. It includes orientation, shading, compact planning, thermal mass, ventilation, roof protection, courtyard microclimate and envelope performance. The relevance of this topic is increasing as climate projections and urban heat-island effects indicate higher exposure of urban populations to extreme heat [1], [2].

The aim of this article is to develop a practical design-screening model for evaluating passive cooling strategies in residential architecture. The model is intended for preliminary architectural decisions and can be adapted to local building codes and available materials.

## 2. RESEARCH METHODOLOGY

The study uses a comparative design-screening method. Four residential block variants were formed: V0 - conventional block without systematic passive measures; V1 - orientation and shading improvement; V2 - improved envelope with ventilated roof; V3 - integrated passive package, including optimized orientation, external shading, insulated envelope, night ventilation and a shaded courtyard. The cooling-

load reduction index was estimated using normalized architectural parameters rather than full dynamic simulation.


$$CLI = 0.30O + 0.25S + 0.20E + 0.15V + 0.10C \quad (1)$$

where CLI is the passive cooling index, O is the orientation score, S is the shading score, E is the envelope performance score, V is the ventilation score and C is the courtyard microclimate score. Each component is normalized from 0 to 100. The model is designed for early-stage design comparison before detailed energy modeling.

**Table 1**  
Residential design variants used in the comparative assessment

Variant	Main design features	CLI	Cooling load reduction
V0 Conventional	Weak shading, ordinary roof, random orientation	28	0%
V1 Shading/orientation	Long facades controlled, external shading	49	14%
V2 Improved envelope	Insulated walls, ventilated roof, low WWR	63	24%
V3 Passive package	V1+V2, night ventilation, shaded courtyard	78	36%

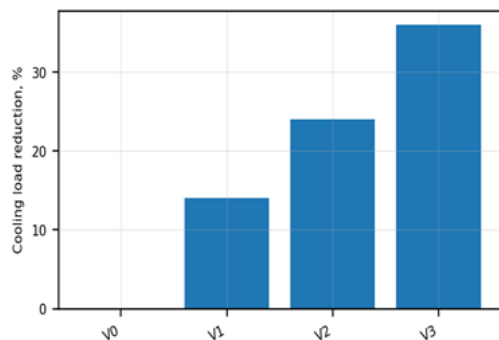
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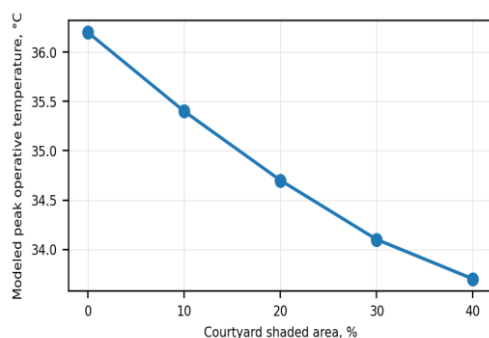
### 3. RESULTS AND DISCUSSION

The results show that single measures provide measurable benefits, but the strongest effect is obtained when measures are combined. Orientation reduces direct solar exposure on long facades; shading protects windows and walls; roof ventilation limits heat transfer from the most exposed surface; and the courtyard creates a semi-private shaded microclimate that improves thermal comfort.



**Fig. 1. Modeled cooling-load reduction by residential design variant**

Figure 1 demonstrates that the integrated passive package can reduce cooling demand by more than one third compared with a conventional design. This result is consistent with the general principle of bioclimatic architecture: energy performance depends on the interaction of building form, envelope and microclimate.



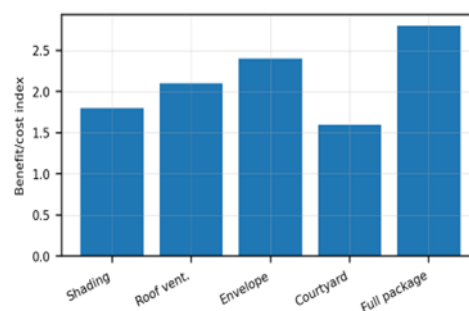
**Fig. 2. Effect of shaded courtyard area on modeled peak operative temperature**

**Table 2**  
Passive architectural measures and their design implications

Measure	Design recommendation	Architectural effect
Orientation	Limit east/west glazing; use narrow east-west exposure	Lower solar heat gain
External shading	Deep reveals, screens, pergolas, balconies	Window protection

Ventilated roof	Air gap and reflective upper layer	Reduced roof heat flow
Wall envelope	Lightweight insulation or insulated masonry blocks	Stable indoor temperature
Courtyard	Trees, pergolas, permeable surfaces	Cool semi-open space

The relationship between courtyard shading and indoor comfort is important for hot-dry cities because courtyard housing is compatible with local spatial traditions. However, courtyards should not be designed as closed heat traps. They need controlled proportions, nighttime air exchange, shaded surfaces and vegetation selected for low water demand.



**Fig. 3. Comparative benefit/cost index of passive cooling measures**

**Table 3**  
Recommended envelope targets for preliminary design

Component	Recommended solution	Target indicator
External wall	Insulated lightweight masonry or composite block	U-value < 0.55 W/(m <sup>2</sup> ·K)
Roof	Ventilated and insulated roof build-up	U-value < 0.35 W/(m <sup>2</sup> ·K)
Windows	Low solar-gain glass with external shade	WWR 20-30%
Openings	Opposite vents and secure night ventilation	ACH increase at night
Urban plot	Trees and shaded pedestrian edge	Shade > 40% of main path

#### Application in residential design practice

The proposed model can be applied at three levels. At the urban level, the orientation of streets and residential blocks should reduce prolonged solar exposure of east and west facades. At the block level, semi-open courtyards and shaded pedestrian passages should be arranged to support air movement rather than block it. At the building level, the envelope should be designed as a protective thermal filter



consisting of shaded windows, insulated walls, ventilated roofs and controllable openings.

A major advantage of passive cooling is that it can be implemented using local construction practices. Deep window reveals, balconies, perforated screens, verandas and courtyard galleries are compatible with regional architectural traditions. When these elements are combined with modern insulation and rational glazing, they create a bridge between cultural identity and energy efficiency.

The economic effect of passive measures is strongest when they are introduced during the design stage. Retrofitting external shading or roof ventilation is possible, but it is more expensive and less integrated. Therefore, municipal architectural guidelines should include a passive-cooling checklist for new residential districts.

**Table 4**  
**Passive-cooling checklist for preliminary architectural review**

Criterion	Recommended check	Risk if ignored
Orientation	Long axis near east-west; minimize west glazing	High afternoon heat gain
Window shading	External shade for south/west windows	Overheating and glare
Roof protection	Ventilated or highly insulated roof	Strong ceiling heat flow
Courtyard comfort	Shade, vegetation, night flushing	Courtyard becomes heat trap
Natural ventilation	Cross-ventilation and secure night openings	Dependence on mechanical cooling

The limitations of the model should also be noted. The calculated indices are comparative and should be verified through thermal simulation, field measurements and post-occupancy evaluation. Nevertheless, the model is useful because it transforms general climate-responsive principles into a measurable decision-making tool for architects and planners.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

The study confirms that passive cooling should be treated as a system of mutually reinforcing measures. In hot-dry cities of Uzbekistan, the largest effect is achieved by combining orientation, external shading, roof ventilation, improved envelope insulation, controlled openings and shaded courtyards.

For architectural practice, the following recommendations are proposed: (1) introduce passive-

cooling checklists at the concept design stage; (2) regulate window-to-wall ratio and external shading for residential facades; (3) encourage ventilated roofs and reflective roof surfaces; (4) integrate courtyard microclimate into residential planning; (5) connect building-level cooling strategies with district-level green corridors.

The scientific contribution of the article is the formulation of an integrated passive-cooling index for early design comparison. The practical contribution is a compact checklist that can be used in residential design review, educational studios and pilot housing projects in hot-dry regions.

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