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Architectural Responses to Extreme Heat: Designing For 50°C Cities of Punjab, Pakistan

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ABSTRACT

This research employed a mixed-methods approach to investigate architectural responses to extreme heat in Punjab, Pakistan's hottest regions experiencing temperatures exceeding 50°C. The study selected three severely affected cities-Multan, Bahawalpur, and Rahim Yar Khan-through purposive sampling based on recorded peak temperatures, heat wave frequency, and urban vulnerability. Data collection involved structured surveys administered to 180 residents to assess thermal discomfort levels, existing cooling strategies, and heat-related health impacts during Punjab's brutal summer months. The researcher conducted systematic observations using thermal imaging cameras and data loggers to measure surface temperatures, indoor thermal conditions, and heat stress patterns across 120 residential buildings constructed with traditional brick and concrete during May-July peak heat period. Semi-structured interviews with 35 residents explored their coping mechanisms, traditional cooling practices like roof watering and use of thatched shelters, and daily adaptations during extreme heat events. Additionally, the study engaged 12 local masons (rajis), 8 traditional builders, and 6 meteorological experts through focus group discussions to understand vernacular construction wisdom and indigenous cooling systems specific to Punjab's hot-arid plains. Climatic data analysis involved examining temperature records, dust storm patterns, and monsoon cycles from Pakistan Meteorological Department stations across southern Punjab. The researcher analyzed historical Punjabi architecture including thick-walled havelis, underground basements (tahkhanas), and ventilation towers through documentation studies. Four contextually appropriate design prototypes incorporating passive cooling, reflective materials, and traditional shading devices were

developed and presented to communities through participatory workshops for validation and feedback.
Keywords: Architectural Responses, Extreme Heat, Hottest Regions, Multan, Bahawalpur, And Rahim Yar Khan, Heat Wave Frequency.

INTRODUCTION

Extreme heat conditions have been worsened due to climate change in the South Asian region and Pakistan has been recording steep temperature increases that have become very difficult to withstand especially in the city and survival of human beings (Arshad, Akram et al. 2025). The province of Punjab, and especially its southern parts, has become one of the most heat-prone in the world, with the temperatures of 50 o C or more being registered there during the summer time. Such excessive heat is not only endangering the very physical health of millions of citizens, but it is also confronting traditional forms of architecture which have been prevailing in the construction of urban areas in the past several decades. As the epicenter of this climate crisis, the cities of Multan, Bahawalpur and Rahim Yar Khan are the locations where residents experience extended periods of heat waves that disorient daily living, health, and available resources of cooling, which are already limited (Khalid, Hafeez et al. 2024). The architecture fraternity has a huge role to play in solving crisis by using the climate responsive design interventions where emphasis is made more on passive cooling measures instead of active cooling and thermal comfort (Akram, Ashraf et al. 2025).

Historically, the Punjab architecture proved to be highly adaptive to hot-arid weather conditions with ingenious architectural features such as thick-walled havelis, underground basement, referred to as tahkhanas, ventilation towers, and oriental building placement. These folkish remedies were based on centuries of practical experience and native knowledge regimes that knew the primary principles of mitigating heat without mechanical cooling devices (Nasim 2025). Modern urbanization has mostly discarded these age-old techniques to construct according to standardized construction techniques incorporating the use of brick and concrete which trap and retain too much heat that makes interiors uncomfortable and requires costly air conditioning systems to cool interiors. This loss of relationship between traditional wisdom and contemporary practice has worsened the thermal suffering, used more energy, and resilience of urban communities to extreme heat events (Akram, Mubin et al. 2025). The disappearance of vernacular architecture is not just an aesthetic issue but one that is fundamentally flawed in climate change adaptation and requires immediate research and recovery (Akram, Mubin et al. 2024).

The intensity and frequency of heat waves in south Punjab has become very high during the last twenty years where meteorological records have recorded the increasing span of extreme temperatures and shortening of recuperatory interval between heat waves. These altering climate conditions are accompanied by the high rates of urbanization that have turned the small, shaded traditional settlement areas to large concrete areas filled with very little vegetation and high levels of heat reflectivity (Arshad, Kazmi et al. 2022). The effects of the urban heat island only aggravate the overall respire of the region and create microclimates that are several degrees hotter than the surrounding rural environment (Mazhar 2024). Disproportionately affected vulnerable populations such as low-income families, older residents, and outdoor workers are at risk of heat stress because of the associated health complications such as dehydration and heat exhaustion, and potentially deadly heat stroke. This emergency needs to be addressed by the architectural profession in evidence-based construction solutions, the combination of passive cooling concepts, local building construction methods, and current building science to establish thermally comfortable spaces without overreliance on energy (Hyder, Awad et al. 2024).

This study examined architectural reaction to extreme heat situation in the hottest cities of Punjab, by through a thorough research in the available thermal environment as well as the traditional cooling techniques and vernacular construction wisdom. The research utilized both quantitative and qualitative inquiry through mixed-method using thermal measurements, questionnaires to residents, and qualitative research based on indigenous knowledge systems that are still maintained by local builders and communities. This study aimed at creating contextually relevant design prototypes that could inform future construction practices to be climate resilient by recording present-day heat stress conditions and examining past architectural responses. This ensured the involvement of local masons, tradition-based builders and meteorologists in terms of which solutions would be based on the regional realities and still apply scientific knowledge of thermal processes and passive cooling systems. Its final objective was not just scholarly research but practical action that would enhance the livelihoods of millions of residents living in the ever-unfriendly cities especially in summer.

Research Objectives

1. To determine the thermal performance of currently used residential buildings in Multan, Bahawalpur and Rahim Yar Khan in extreme heat conditions and the key heat stresses that influence the comfort of occupants.
2. To record and discuss the ancient architectural cooling methods and local construction methods adopted in the vernacular architecture of Punjab to be used in the present day.
3. To design and test contextually relevant prototypes of architectural design with passive cooling mechanisms, reflective surfaces, and conventional shading machines that would be used in high temperatures (50 C) environment.

Research Questions

1. What are the thermal performance and heat stress patterns of modern-day buildings within the residential neighborhoods in Multan, Bahawalpur as well as Rahim Yar Khan with regard to peak summer temperatures?
2. What role does the traditional Punjabi architectural features and local cooling uses play in terms of thermal comfort in hot arid climatic conditions?
3. Which architectural design interventions are ultimate in reducing the effects of extreme heat but are still culturally acceptable and economically viable to Punjab urban populations?

Significance of the Study

The study is essential in the provision of knowledge on how one of the most pressing climate change adaptations challenges to the cities of South Asia can be addressed due to extreme heat conditions. The results offer informed recommendations to architects, urban planners, and policymakers who want to enhance thermal comfort and mitigate the health hazards associated with heat in the vulnerable communities. The study creates useful design solutions applicable in the hot-arid areas of Punjab by filling the gap between the traditional architectural wisdom and the modern building science. Vernacular cooling strategies are documented in a manner that takes into consideration an important part of indigenous knowledge besides exemplifying how it can be used in relation to climate responsive buildings. The tested design models are replicable models of sustainable urban development that give priority on passive cooling, instead of energy consuming mechanical cooling.

LITERATURE REVIEW

The climate change studies around the globe have come up with conclusive evidences that extreme heat events are on the rise in terms of frequency, length, and intensity of extreme heat events in both tropical and subtropical area, but South Asia was particularly hard hit by extreme heat events as it affects urban populations (Batibeniz, Hauser et al. 2023). Scientific research records that urban heat islands enhance the warming of the regions by concentrating surfaces, reducing vegetation cover, and causing anthropogenic heat, produced by human activities and mechanical cooling systems. It is highlighted in the architectural and building science literature that the traditional modern construction materials, especially concrete and brick that lack sufficient thermal insulation, are a major contributor in the development of indoor thermal discomfort due to their tendency to absorb solar radiation during the day and release stored heat during the night (Newman and Noy 2023). The studies on passive cooling techniques have shown that the orientation of the building, natural ventilation, and thermal mass control as well as the use of solar shading are the core concepts of lowering the indoor temperatures without mechanical cooling. Research work done in hot arid environments such as Punjab has recognized certain building attributes such as high thermal mass walls with exterior insulation, reflective roof surfaces, wind catchers, and evaporative cooling systems as effective in reducing heat (Liu, Gao et al. 2023).

Studies of vernacular architecture has reported elaborate climatic responsive design solutions that have been evolved by traditional communities in various geographic areas, especially in hot-arid environments of the Middle East, North Africa and South Asia (Othman and Ashour 2024). Historical architecture study of Punjabi havelis has unveiled design smarts in characteristics like thick masonry walls which slow heat convection, central courts which facilitate air movement, underground basements which exploit the cooling capabilities of earth and projection balconies that offer excellent shading (Naeem and Kareem 2023). Empirical knowledge of material thermal characteristics, seasonal wind patterns, and microclimate-specifics that indigenous craftsmen, having no formal scientific education, were able to acquire, is the subject of ethnographic study of traditional building practices. Modern literature suggests that this folk wisdom embodies inestimable knowledge of climate adaptation that has been systematically marginalized by modern architecture using uniform building techniques and international building types. According to the literature, recovery and adaptation of traditional cooling methods present culturally suitable and affordable alternatives to energy-consuming mechanical cooling systems that currently dominate the development of modern urban centers (Waqar 2022).

A study on the climate challenges in Pakistan has revealed extreme heat to be a growing human health crisis impacting millions of urban residents and that the less affluent neighborhoods with inadequate housing infrastructures and cooling systems are more likely to become targets (Hasan 2022). Mortality related to heat waves in Pakistani cities have been documented in studies which show that poorly ventilated, thermally inefficient houses considerably heightens heat stress and health related complications (IRFAN and SARWAR).. Studies of occupant thermal adaptation behavior indicate that occupants have adopted a wide range of coping strategies such as roof watering, utilization of conventional cooling equipment, change of daily activity patterns, and temporary migration to cooler environments spanning the extent of the thermal discomfort and the longevity of existing indigenous cooling practices (Akram, Nadeem et al. 2025). Energy consumption literature points to unsustainable patterns of air conditioning use that puts pressure on the electrical infrastructure, causes more greenhouse gas emissions, and encumbers households with the financial aspect of providing cooling services to people that largely benefit wealthy populations (Khan, Khan et al. 2022).

The recent studies in architecture have presented some contemporary uses of the principles of passive cooling related to the new building envelope design and natural ventilation optimization and introducing the elements of the traditional construction with the new technologies of the modern construction (Khalid, Abdullah et al. 2025). Research on reflective and thermochromic surfaces indicates that there is a high prospect of minimizing the amount of solar radiation that is absorbed by doors and windows of buildings that experience exposure to severe radiation (Iqbal, Mubin et al. 2022). Studies on geometry of buildings and urban morphology point out that tight-knit building shapes, planned clustering, and conservation of conventional street designs can decrease the amount of heat exposure and improved natural ventilation through wall sizes in neighborhood levels. In developing country settings, participatory design research identifies the significance of community involvement in the legitimization of architectural interventions in making them culturally acceptable, practically feasible, and in accordance with the priorities and preferences of residents. It is increasingly accepted in the literature that climatic adaptation efforts must be holistic, entailing the combination of passive design of buildings on a building-scale, urban planning, policy frameworks underpinning sustainable construction and maintenance of indigenous knowledge systems built through generations of climatic experience (Naeem, Aziz et al. 2025).

RESEARCH METHODOLOGY

Research Design

To explore the architectural response to extreme heat in Punjab, Pakistan, the researchers have adopted mixed-methods research design to cover the study thoroughly. Quantitative and qualitative research techniques were used to study the thermal conditions and aboriginal cooling techniques.

Study Area and Sampling

The study sample size was determined using the purposive sampling technique in which the researchers selected three towns (Multan, Bahawalpur and Rahim Yar Khan) based on the highest temperature, frequency of heat waves and the vulnerability of the cities to heat waves. The analysis was on 120 residential buildings built using conventional brick and concrete.

Data Collection Methods

The researchers used various data gathering methods in the period of May-July when it was very hot. One hundred and eighty residents were selected by administration of structured surveys to evaluate the levels of thermal discomfort, current cooling measures and the health effects of heat. The systematic observations used thermal imaging cameras and data loggers, to measure surface temperatures, thermal conditions inside the buildings, and patterns of heat stress in a series of buildings of choice.

The semi-structured interviews were conducted with 35 residents and covered coping mechanisms, traditional cooling systems including roof watering and thatched shelters, the daily adjustments during the extreme heat events. The researchers carried out focus group interviews of 12 local masons (rajis), 8 traditional builders and 6 meteorological experts to obtain information on vernacular construction wisdom and indigenous cooling systems.

Secondary Data Analysis

The researchers examined climatic data such as temperature fluctuations, dust storms and monsoon patterns of Pakistani Meteorological Department stations. Documentation works reviewed historical Punjab architecture with havelis having thick-walled buildings, underground basements (tahkhanas) and ventilation towers.

Design Development and Validation

The researchers created four prototypes of designs with contextually relevant designs that embrace passive cooling designs, reflective surfaces and conventional shading systems. The communities were shown these prototypes in participatory workshops to seek validation and feedback of offered architectural solutions.

RESULTS AND DATA ANALYSIS

QUANTITAIVE ANALYSIS

Table 1: Thermal Comfort Assessment of Residents (N=180)

Thermal Comfort Level	Frequency	Percentage
Extremely Uncomfortable	98	54.4%
Very Uncomfortable	52	28.9%
Moderately Uncomfortable	23	12.8%
Slightly Uncomfortable	7	3.9%
Comfortable	0	0.0%

The thermal comfort assessment revealed that the overwhelming majority of residents experienced severe discomfort during peak summer months, with 54.4% reporting extreme thermal stress and 28.9% describing conditions as very uncomfortable. The complete absence of residents reporting comfortable conditions underscores the critical failure of existing housing to provide adequate thermal protection. Only 3.9% characterized their experience as slightly uncomfortable, indicating that nearly the entire surveyed population suffered significant heat-related distress. These findings demonstrate the urgent necessity for architectural interventions that can substantially improve indoor thermal environments and reduce occupant heat exposure.

Table 2: Indoor Temperature Measurements Across 120 Buildings

Temperature Range (°C)	Number of Buildings	Percentage
45-47	18	15.0%
47-49	35	29.2%
49-51	43	35.8%
51-53	19	15.8%
Above 53	5	4.2%

Indoor temperature measurements documented that 35.8% of surveyed buildings recorded internal temperatures between 49-51°C during peak afternoon hours, demonstrating that indoor conditions frequently equaled or exceeded outdoor ambient temperatures. Nearly 30% of buildings measured temperatures in the 47-49°C range, while 20% experienced even more extreme conditions exceeding 51°C. Only 15% of buildings-maintained temperatures in the relatively lower 45-47°C range, though even these conditions far exceed human thermal comfort thresholds. The data confirms that conventional brick and concrete construction without passive cooling features creates hazardous indoor environments that intensify rather than mitigate external heat stress.

Table 3: Existing Cooling Strategies Employed by Residents

Cooling Strategy	Users	Percentage
Roof Watering	142	78.9%
Electric Fans	168	93.3%
Air Conditioning (occasional)	23	12.8%
Thatched Shelters	67	37.2%
Underground Basements	31	17.2%
Window Shading	124	68.9%
Modified Activity Schedule	159	88.3%

The survey revealed that residents employed multiple adaptive strategies simultaneously to cope with extreme heat, with electric fans being the most universal intervention at 93.3% adoption despite limited effectiveness in temperatures exceeding 50°C. Traditional roof watering remained widely practiced by 78.9% of households, demonstrating the persistence of indigenous cooling knowledge. Modified activity schedules affected 88.3% of residents who adjusted daily routines to avoid peak heat hours. Only 12.8% had occasional access to air conditioning due to cost and electricity availability constraints. The continued use of thatched shelters (37.2%) and underground basements (17.2%) indicates recognition of traditional cooling strategies' effectiveness among portions of the population.

Table 4: Heat-Related Health Impacts Reported

Health Impact	Affected Residents	Percentage
Dehydration	156	86.7%
Heat Exhaustion	89	49.4%
Sleep Disruption	167	92.8%
Reduced Productivity	173	96.1%
Respiratory Issues	54	30.0%
Heat Stroke (self/family)	12	6.7%

Heat-related health impacts affected nearly all surveyed residents, with 96.1% reporting reduced productivity and 92.8% experiencing sleep disruption due to extreme nocturnal temperatures. Dehydration affected 86.7% of respondents, while nearly half reported heat exhaustion episodes during peak summer months. Respiratory issues affected 30% of residents, likely exacerbated by dust storms common in the region and inadequate ventilation in sealed buildings. Most concerning, 6.7% reported heat stroke incidents within their households, indicating life-threatening heat exposure. These findings establish clear public health imperatives for architectural interventions that can reduce indoor heat stress and protect vulnerable populations.

Table 5: Building Material Surface Temperatures

Material Type	Average Surface Temp (°C)	Range (°C)
Concrete Roof (unshaded)	68.4	64-73
Brick Wall (exposed)	61.2	57-66
Metal Roofing	71.8	68-76
Whitewashed Surface	52.3	48-56
Traditional Mud Plaster	49.7	46-54
Vegetated Roof	38.2	35-42

Thermal imaging measurements revealed dramatic temperature variations across building materials, with metal roofing reaching average surface temperatures of 71.8°C and concrete roofs recording 68.4°C during peak solar exposure. Exposed brick walls measured 61.2°C average temperatures, creating significant radiant heat transfer to building interiors. In contrast, traditional materials and treatments demonstrated substantially lower surface temperatures, with whitewashed surfaces averaging 52.3°C and traditional mud plaster recording 49.7°C. Most significantly, the limited examples of vegetated roofs measured only 38.2°C average surface temperature, demonstrating potential for dramatic heat reduction. These measurements provide empirical evidence for material selection strategies that can substantially reduce solar heat gain.

QUALITATIVE ANALYSIS

Theme 1: Traditional Architectural Wisdom and Climate Adaptation

Conversations with local masons and traditional builders demonstrated that they knew much about climate-responsive methods of construction, learned over many generations, in the hot-arid climate of Punjab. The interviewees related in-depth knowledge of material thermal characteristics, time of year construction, and fundamentals of building orientation that balanced natural ventilation and reduced exposure to the sun. The conventional constructors also placed much emphasis on heavy walls that would slow down the heat intrusion, the proper location of openings to harness the local winds, and the utilization of local materials that were conducive to thermal properties. This local knowledge is a priceless climate change adaptation know-how that modernization has left much of the construction industry to adopt instead of standardized practices.

Theme 2: Economic Constraints and Cooling Access Inequality

Economic constraints were always identified by the resident interviews as the main obstacle to the implementation of effective cooling solutions, as low-income households could not afford to purchase air conditioning (or even a decent electric fan). Participants explained how extreme heat increases the socioeconomic inequalities already existing because richer households could leave to fewer hot areas or install mechanical cooling and poorer households suffered high-risk indoor temperatures. Electricity price to run fans constituted a big financial constraint to most of the families making them decide to sacrifice thermal comfort and other important requirements in the family. The relevance of this theme is that affordable active cooling systems that are passive and do not rely on the sustained use of energy are needed.

Theme 3: Disruption of Daily Life and Occupational Challenges

People spoke of grave interference with everyday life, sleeping habits, and labor output during hot spells as well as most having to completely restructure their lives around weather conditions. Participants described the situation of how the heat was extreme in the afternoon and delayed outdoor activities, cooking and household chores to the evening hours when the temperature had slightly reduced. The issue of sleep disruption was of specific concern, as the residents stated that they could not fall asleep despite sleeping on the roof and keeping the fans on. The outdoor employees and laborers reported loss of working hours and earnings by stating that extreme temperatures made day labor impossible, which came up with ripple effects on the economy even beyond thermal pain.

Theme 4: Health Vulnerabilities and Heat-Related Illness

The discussions shown in focus groups were full of apprehension with regard to heat related health effects especially on children, the aged family members, and the sick people. The respondents were reporting about such symptoms as terrible headache, feeling of being dizzy, nausea, and causing dehydration that demanded medical help. Parents were concerned about the exposure of heat to children and whether they could keep up with the required body hydration at school. Some of the participants shared accounts of emergency cases associated with heat stroke that required them to be admitted to the hospital and highlighted the life-threatening aspect of being exposed to extreme temperatures. This theme reveals the desperate public health aspects of heat mitigation in architecture.

Theme 5: Persistence of Traditional Cooling Practices

Though the inhabitants were modernized, they still used the ancient cooling methods such as roof watering, wetted curtains, construction of makeshift thatched huts and utilization of underground areas in times of intense heat. These practices were reported by participants as those that were passed by the earlier generations who did not access any mechanical cooling systems but had devised effective ways of managing heat. Seniors especially accentuated the cooling power of the traditional architectural elements such as high ceilings, cross-ventilation, and shaded courtyards, which were found in the past buildings. The fact that indigenous practices are perpetual indicates their own topicality, as well as the readiness of the community to embrace design solutions that encompass traditional wisdom.

Theme 6: Community Perceptions of Climate Change and Future Concerns
Citizens and specialists were concerned about the rising heat patterns, and most of the respondents remarked that the heat was rising significantly over the years and that heat waves were lasting longer and more frequent. Meteorological scientists gave evidence that supported these observations and forecasted further rise in temperature in the next few decades. The community members expressed the fear of the future habitable conditions of their cities in case the present trend of heat did not change due to substantial architectural and urban planning interventions. This theme shows that the community is well aware of the effects of climate change, and willing to accept adaptive architectural designs that would enhance the resilience of urban areas over time.

DISCUSSION

The findings of the research clearly reveal that traditional construction methods in extreme heat regions of Punjab have put up a risky and unacceptable thermal environment that endangers the health of the residents, diminishes the quality of their lives, and continues to create socioeconomic inequalities in terms of access to cooling. The numeric evidence of the indoor temperatures that are regularly above 50 degrees C and almost universal thermal discomfort is sufficient to create an urgency in terms of architectural intervention, and qualitative understanding of the available evidence indicates that communities still possess treasured traditional knowledge, and are open to passive cooling methods. The temperature variations found between building materials during a drama prove that the design types used in buildings have a considerable influence on thermal efficiency, with such conventional features as whitewashed surfaces and vegetated roofs providing considerable thermal protection over blank concrete and metal. The fact that indigenous cooling methods were still used even with the modernization pressure means that they are efficient and accepted by the culture, and prototype designs that use traditional wisdom as well as modern building science may meet the needs of wide adoption by the community, and tackle the challenge of critical heat stress.

CONCLUSION

This study confirms that the high temperatures in urban centers of Punjab is a serious habitability crisis that needs an urgent intervention by architecture through climate-sensitive design measures. The study captured dangerous thermal conditions in the indoors, rampant heat-related health effects, and high amount of disturbances to daily living in the cities under study, which proved that current building measures do not offer sufficient thermal safety. The research was able to determine effective passive cooling measures by examining the conventional architectural items, material thermal performance, and the local knowledge systems, which the local constructors and communities maintain. The final design prototypes that include reflective materials, utilizing strategic shading, maximized ventilation, and traditional cooling provisions will provide contextually suitable remedies that can enhance thermal comfort without overreliance on energy with the ability to be culturally acceptable and economical to be deployed across the heat-prone states of Punjab.

RECOMMENDATIONS

Urban development in extreme heat zones of Punjab in the future must require passive cooling measures to be integrated into the building codes, including reflective roof paints, proper thermal insulation, optimal building orientation, and natural ventilation to be enforced upon building codes and planning regulations. Vernacular climate responsive design principles have been sidelined by standardized construction practices and have to be reintroduced in the teaching and practice of architecture. The government agencies are to assist in carrying out affordable cooling interventions in the currently existing low-income housing via subsidized retrofitting schemes aimed at roof treatments, shading equipment and ventilation and deliberations. The future study needs to carry out thermal performance supervision of prototyped designs on a long-term basis and explore scalable cooling systems that suit densely populated urban areas where conventional courtyard-scale designs might not be a possibility.

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