ENVISIONING OUR FIRST-PRINCIPLES PREDECESSORS: LEGACIES OF CLIMATIZATION IN ANCIENT ANATOLIAN STRUCTURES

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Introduction

In most buildings designed today, energy consumption exceeds the standards set by the World Green Building Council, and reports by the Energy Information Administration state that building-sector energy consumption is expected to continue growing in the coming decades. This fact conflicts with the mission of global institutes of architecture to drive fundamental change in architectural practice with regard to energy consumption through the development of adaptive and resilient building environments that can preserve natural resources while providing direct access to low-cost, rapidly renewable energy resources. One track toward this fundamental change resides in the lessons provided by vernacular structures whose attributes have adapted over time to modulate factors dictated by the natural environment1.

With the aid of state-of-the-art performance modeling tools, our understanding of these structures has advanced to disclose the progressions, shifts, and continuities of passive climatization across history. Instead of focusing exclusively on the romanticized beauty of building form itself, these tools allow researchers to establish an associative relationship between systems of physical enclosure and the resulting built environment. Patterns of spatial organization can be mapped to local climate inputs, revealing a historical vocabulary of climatization that provided improved comfort ranges, well suited for seasonal inhabitation.

By adding emphasis on the passive climatization potential of historical structures relative to variable inputs, including prevailing winds and solar path, this paper presents a new method of interpreting and communicating vernacular heritage. The ancient Anatolian region and its repository of engrained knowledge serves as the area of investigation, encompassing a territory that stretches from

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the Aegean coastline in the west to the Mesopotamian plateau in the southeast. The settlements investigated cover a 6000-year period, from the Neolithic Age settlement of Çatalhöyük to the Roman Period settlement of Mardin, and thus enable a longitudinal assessment of vernacular architectural responses to varying environmental inputs.

**Background**

**Vernacular Heritage**

Vernacular heritage is a designation for structures that contain indigenous forms of knowledge from centuries of experience built on the relationship between material construction constituents and local eco-social factors. While vernacular heritage takes on many different elements within architectural design, this paper draws from distinct architectural characteristics that reframe our understanding of heritage moving forward; namely how thermal comfort was achieved through principles of spatial organization in relation to local climate conditions. In vernacular structures located in temperate climates, thermal comfort is often achieved through passive daylighting, heat mitigation, and ventilation control.

However relevant these structures are in contemporary planning, they are declining in use and being replaced by buildings that tend to favor supplemental technologies for high performance outcomes instead of offsetting energy use with the material enclosure itself². This homogenization of building culture makes vernacular structures around the world extremely vulnerable to desuetude and calls into question how new forms of representation can highlight alternative facets of our built heritage as further substantiation of its relevance amidst an ever-growing energy crisis³. With the aid of performance modeling tools, our understanding of centuries of knowledge embedded within such structures can be clearly visualized in a holistic and integrated manner.

**Computational Simulation**

Today, with use of state-of-the-art computer simulation programs, much can be envisioned about the unique performance characteristics of historical structures and their connection to the immediate environment. Computer simulation platforms offer a highly interactive and diverse toolset to researchers, facilitating testing sequences which acutely disclose how a range of historical building configurations intensively shape the behavior of light, heat, and airflow present within the extensive environment. As a set of tools that create observable output states⁴,

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they reinforce the first-principles, physical relationships adhering between a building and its ambient environment, and are distinctly relevant when identifying patterns of spatial organization across distinct periods of time.

**Envisioning Climatization**

Passive climatization is the act of modifying the natural environment through the employment of purely architectural strategies, putting building attributes to task in order to establish adequate levels of comfort within the built environment. Using building constituents to provide adequate heating, cooling, and lighting is central to an architect’s domain and returns architectural design to its first principles, the fundamental roots of satisfying human comfort needs from predominantly renewable sources. In this sense, developing methods that allows researchers to reconnect to this art of climatization, otherwise displaced by electro-mechanical conditioning systems in recent decades, has immense value in light of current energy crises.

Consequently, for such a methodology to fulfill such a task, it must provide adequate visualization of heat, wind, and light within the inhabitable spatial zones of a building complex. Instead of focusing on the physical forms of vernacular structures alone, this approach measures the associative relationship between the physical, spatial boundaries and the atmospheric characteristics of the interstitial space itself. This paper present the methods used to flesh out both the range of boundary types and the resulting spatial vocabulary utilized by early cultures.

**Methodology**

**Analysis Methodology**

In this study, portions of three Anatolian settlements from diverse time periods are analyzed to disclose the heritage of signature intermediary space types found in the region. Each of these space types are digitally reconstructed and analyzed using state-of-the-art computational simulation platforms to identify how early populations organized intermediary spaces around constraints dictated by climate. Polygon meshes derived from image-based modeling and background raster images representing each ancient settlement are scaled and located within the simulation domain, serving to approximate the building boundary conditions for each group of structures (Fig. 01). Computer simulations analyze the performance of those boundary conditions by assigning environmental states to each domain. In generating observable output states, this analytical method provides critical insight into processes such as air change, daylighting levels, and radiant heat gain occurring relative to the boundary configurations of each intermediary space type (Fig. 2). Furthermore, these tools allow the testing of associative relationships between spatial configurations and environmental flow fields through the rapid adjustment of simulation states, including wind direction, sun position, and alternative boundary
configurations. Once this relationship is established between the intermediary enclosure system and the locally specific environment, findings are compared to identify archetypal patterns of performance and space, highlighting underlying continuities as well as shifts in spatial organization across distinct periods of ancient building practices.
Two primary simulation-tool types are used in this study: ray tracing tools and computational fluid dynamics tools. Ray tracing tools model the influence of solar gain and daylighting, measuring the areas of incident gain, shadow, and illumination on the surfaces of each intermediary space type. Computational fluid dynamics tools, on the other hand, model the influence of prevailing airflow; measuring airflow patterns, air velocities, and pressure differentials within the flow field of each space type. This coupled approach places emphasis on first-principles relationships between environmental factors, such as the solar path and prevailing wind, and the physical boundaries of each space type.

The base platforms used to carry out the analysis are McNeel® Rhinoceros™ and Autodesk® Ecotect Analysis™ with plug-in components, such as Desktop Radiance, Autodesk® Project Vasari, Simulation CFD, and WinAir4, used to expand the domain range of the basic platform. While these simulation tools are still in development phases, validation tests are run using an array of tools from high to low resolution to ascertain the bandwidth of reliable information provided across all platforms. Within the spectrum of performance-modeling platforms, low-resolution simulation tools are those that provide a highly interactive graphic user interface appropriate for use during early analysis stages. These simplified simulation tools are preferred because of their provision of wide-ranging analysis options; they are suited well for use by those who seek to examine the various parameters that characterize environmentally responsive vernacular-design strategies. With regard to ray tracing tools, three programs are tested: the native engine within Ecotect Analysis; Vasari’s solar radiation tool; and the reverse ray tracing tool provided by Desktop Radiance. The ray tracing tool tests indicate that while the reverse ray tracing tool was better able to predict the loss of energy from solar ray redirection, all three tools were adequate in representing the areas of incident gain.
and shading that would influence the thermal characteristics of the intermediary space types studied (Fig. 3). With regard to computational fluid dynamics tools, three programs were tested: WinAir4; the wind tunnel feature in Project Vasari; and Simulation CFD. The computational fluid dynamics tools tests indicate that while higher resolution tools like Simulation CFD and Project Vasari were able to predict a higher range of flow behavior, all three tools were adequate in modeling the basic flow-velocity differentials around spatial boundary conditions (Fig. 4).

Case Study Analysis

Anatolian Climate

The region of Anatolia, or modern day Turkey, is classified in the Köppen system as temperate with hot and dry summer seasons. This climatic region resides approximately between 36-42 degrees north of the equator and between 27-44 degrees east of the prime meridian. Major cities where baseline weather data is collected and maintained for this study include Izmir (38°N, 27°E) along the western Anatolian coastline, Ankara (40°N, 33°E) in central Anatolia and the Iranian city of Tabriz (38° N, 46°E), the nearest weather location to eastern Anatolia. Significant seasonal variation is present in all three weather locations, with daytime high-temperature averages in the winter ranging from 3-12°C and in the summer ranging from 28-33°C. Prevailing winds in the region generally come out of the north with year-round average speeds ranging from 4-6 m/s and with peak velocities in the summer ranging from 15-18 m/s. Finally, from winter to summer solstice, the sun’s elevation angle in the region shifts from 25-75° when measured at noon.


**Ancient Anatolian Structures**

In order to assess the effectiveness of the proposed method when envisioning the progressive characteristics of climatization across a building tradition, ancient vernacular building types located in Anatolia are examined to determine how systems of physical enclosure are put to task to achieve high-performance outcomes. Ancient complexes taken under study include the following: terraced structures in the Neolithic settlement of Çatalhöyük, dating to the 6th millennium BCE; domestic courts of the southeastern Anatolian city of Titriş Höyük, dating to the 3rd millennium BCE; and modular courtyards in the southeastern Anatolian city of Mardin, dating to the 2nd century CE. These sites were selected because they exhibit a clear progression of intermediary space types that aid the transition between harsh climatic conditions and modulated interior environments. One would presume the importance of these space types to be paramount in such a temperate climate, as they serve as transitory spaces, allowing user groups to adapt use patterns to the signature extremes of environment present within temperate climate regions. Therefore, one could conclude that these space types are crucial to achieving passive climatization in regions such as Anatolia, which necessitate building boundaries to shape sun, wind, and temperature extremes. This study focuses on particular types of intermediary spaces that are centrally located within the spatial disposition of their associated settlements, namely, courtyard and arcade spaces.

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Fig. 5. Partial reconstructions of Çatalhöyük. From left to right, clockwise: an aerial perspective; a plan; and a section. ‘C’ indicates the midden/courtyard space

Source: Mellaart 1967 and Tim Frank.

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At the Neolithic settlement of Çatalhöyük early courtyards emerged with the function of middens. Midden courtyards were larger spaces located central to settlement areas and defined by clusters of earthen living units surrounding them (Fig. 5). While public spaces like plazas or streets were not prominent in the early levels of Neolithic settlements like Çatalhöyük, the midden served as an early form of common space used primarily to store rubbish⁶. While these early courtyards appear not to have been inhabited for long periods of time, it is interesting to note, nonetheless, that their environmental behavior so closely resembles that of their Anatolian successors.

In the Early Bronze Age city of Titriş Höyük courtyards took central positions within standardized domestic housing units. Like the midden courtyards at Çatalhöyük, each court was open to the sky and contained a cobbled stone flooring system. However, the domestic courtyards of Titriş Höyük differ from the middens at Çatalhöyük in the character of communication patterns that served them. While the midden was presumably accessed by ladder from the rooftops of contiguous structures above, if entered at all, evidence from Titriş Höyük reveals pathways that would have provided shared access to courtyards from neighboring earthen spaces integral to the domestic compound. Furthermore, such lines of communication corresponded to points of entry to each house as well as the street network serving the settlement itself (Fig. 6). These characteristics suggest the evolving role of this space type within collective societies and suggests that its performance characteristics were found suitable to the population is served⁷.

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Similar to Titriş Höyük, the courtyard is central to each domestic housing unit in the Roman city of Mardin. Unlike that of its predecessor, the spatial vocabulary in Mardin is strictly derived by a 4-meter square module. As the module repeats to form each domestic housing complex, variations in the degree of spatial enclosure provide a spatial gradient from fully enclosed, as in the case of the private room, to fully open, such as at the southern terrace. This gradient provides a rich inventory of intermediary space types, including the eyvan, the revak, and the courtyard space itself (Fig. 7). The eyvan is a vestibule space that serves to transition from the open courtyard to an enclosed room, while the revak is a type of inner arcade that opens towards the courtyard through the use of an applied boundary and serves as an extension of the courtyard space with the addition of an overhead plane. These are important advances in intermediary space types in Anatolian architecture whose performance characteristics shed light on why the courtyard shifts to include perimeter types of semi-enclosed space, like the arcade and vestibule, in the 2nd century CE.

Outcomes

Analysis results disclose interesting correlations between the evolving configuration of intermediary space types in ancient Anatolian structures and the resulting principles of passive climatization. These principles include passive heating through provisions of radiant solar gain and wind sheltering during cold

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winter months; passive cooling via natural ventilation and shading during hot summer months; and the maintenance of transitory zones during spring and fall months with optimal climate conditions.

Passive heating in temperate climates largely involves the use of energy from the sun to provide warmth and to buffer cold winter air. When simulating incident solar gain during summer months the courtyards show a development of space types distinctly suited for radiant heat gain. At Çatalhöyük, concentrated heat gain is present on the northern faces of the midden courtyard; at Titriş Höyük and Mardin, however, spaces adjacent to the northern edge of courtyards begin to be delineated so as to collect significant amounts of incident solar gain. When simulating air-change rates during winter months, the courtyards exhibit only slight air change within their lower spatial pockets. The rectangular courtyard running parallel to the prevailing wind direction at Çatalhöyük, however, encourages moderate air change within the courtyard space, while the square courts at Titriş Höyük and the rectangular courtyard oriented perpendicular to the prevailing wind at Mardin improve the buffering capacity of cold winter winds, respectively (Fig. 8).

Passive cooling in temperate climates predominately includes buffering of heat from the hot summer sun and evaporative cooling provided by natural ventilation. When simulating the shading potential of the courtyards during summer months, the tall, bounding perimeter walls enable the capacity to protect the southern edges of the courtyard spaces. Of greater note, however, is how Titriş Höyük and Mardin extend their courtyard spaces into adjunct areas, with higher degrees of enclosure and added protection from the hot summer sun. These spaces, regardless of orientation, create a new set of intermediary spaces with direct access to the exterior environment, yet with a high degree of protection from extreme elements of the natural environment.

![Fig. 8. Computer simulations of passive heating strategies at the winter solstice (December 21st). From left to right: Çatalhöyük; Titriş Höyük; and Mardin. The top row presents solar exposure; the bottom row presents wind velocities in each courtyard space. Source: Tim Frank.](image)
When simulating wind-driven ventilation rates during summer months, the courtyards again demonstrate very little air change because of their positive pressurization. The aforementioned intermediary spaces contiguous to the central courtyard, however, enable increased air velocities in the transitional zones where spatial circuits have generated differential pressurizations (Fig. 9).
The maintenance of optimal zones in temperate climates is mainly achieved through areas of expressed solar and airflow gradation where ranges of sun and wind exposures are available to inhabitants. When simulating changes in solar radiation in courtyards during spring and fall months, we find a natural gradation from more to less solar exposure as one moves from the north to the south sides of courtyard spaces. At Titrüş Höyük and Mardin, however, the spatial gradient and the resulting shifts in solar exposure are doubly present as one moves along the east-west axis, because of the spatial layering in both examples. When simulating wind-flow vectors during the spring and fall months, mild turbulence develops in courtyards, while in adjunct spaces, such as the revak and eyvan at Mardin, more stable and laminar air currents persist (Fig. 10).

**Conclusion**

The initial outcomes presented in this paper are part of a larger research project that envisions first-principles approaches to building, as encapsulated in the vernacular traditions of ancient to modern cultures. Specifically, the work looks at intermediary space types and associated architectural attributes as they modulate the temperate climate of the Mediterranean region. As evidenced above, the courtyard takes full advantage of the temperate Mediterranean climate, whereby wind and sun directions are oblique to one another. Solar energies predominantly come from the south, while wind energy is northerly in origin. This creates a seasonal and climatic ring around courtyards, making northern spaces winter zones, southern spaces summer zones, and east-west spaces transitory zones that support activity shifts from morning to night during fall and spring seasons.

The passive climatization functions of intermediary spaces recognized here reveals new knowledge about the progression of decision-making that constitutes the built heritage of ancient Anatolia. In using simulation tools to reverse engineer climatization strategies employed by ancient populations, the work develops a new appreciation of vernacular structures. These tools allow us to gain insight into how building enclosure systems were tasked by ancient societies to provide zero-energy solutions that respond to human needs with clean renewable energy sources, such as prevailing wind and solar energy. In this sense, these tools and associated methods offer alternative meanings to notions of heritage. Instead of solely considering heritage as a purely consistent formal motif, we can also consider it to mean traditions in passive climatization. The Anatolian courtyard is an exceptional example of this. While formally the courtyard appears to be neutral and centralized in its configuration, it is actually quite eccentric in providing myriad thermal zones for inhabitants to employ.
Furthermore, the full extent of passive climatization strategies identified by these case studies has clear relevance in contemporary times and extends the survival of these traditions by highlighting their continuing cogency. These examples embody alternative approaches to sustainable development that create heterogeneous series of thermal zones instead of a number of homogenously steady-state environments enabled by high-grade energy systems. Further work is needed in using these analysis routines to bridge the gap between ancient structures and those undergoing preservation threat in contemporary times. By extending the legacy of passive climatization into modern urban planning, a community of building developers and officials can envision new sets of characteristics about building culture that not only foreground their relevance in given climate systems, but also facilitate conceptualizing how they can be adapted for myriad new uses.