

The background features a complex, abstract pattern of thin, overlapping lines in shades of blue, green, and yellow. These lines flow and curve across the frame, creating a sense of movement and depth. A faint, light-colored grid is visible in the background, particularly on the right side. A diagonal watermark reading 'COPYRIGHTED MATERIAL' is overlaid across the center of the image.

TOWARDS AN ARCHITECTURAL HISTORY OF PERFORMANCE

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Mehran Gharleghi and Salmaan Craig*

AUXILIARITY,
PERFORMANCE
AND PROVISION
IN HISTORICAL
PERSIAN
ARCHITECTURES

Despite its extensive empire, Persia historically presented a challenging environment for the building of structures and infrastructure. The mountainous landscape of the Iranian plateau has an arid or semi-arid climate with distinct seasonal variations and temperatures that fluctuate throughout the day. Despite this, water management and soil-fertilisation strategies and passive environmental modulation in architecture were all highly developed previous to the 19th century so as to be finely attuned to the local context, while also responding to the greater demands of a centralised empire. Here **Michael Hensel, Defne Sunguroğlu Hensel, Mehran Gharleghi and Salmaan Craig** discuss and illustrate their detailed findings of the performance of historic structures. These include qanats (water canals), water cisterns, ice houses and pigeon houses as well as the seminal Khaju Bridge in Isfahan and the Boroujerdi's House in Kashan.

The clouds, the wind, the moon, and the sun,
For your comfort, and at your behest run.
They toil continuously for your satisfaction,
Should you not halt, monitor your action?
— Sheikh Muslih-uddin Sa'di Shirazi,
Prologue to the Gulistan (or Rose Garden), 1258¹

The distinguished German architect Frei Otto described an obvious, significant and often overlooked trait of architecture when he stated that 'constructions are auxiliary means, not an end in themselves'.² 'Auxiliariness' implies intentional and cohesive relations beyond the physical limits of a construction that embed it intensively into a larger dynamic context. As an example, Otto specified that a bridge is auxiliary to the road system of which it is part. Yet architectures can be simultaneously auxiliary to several systems including conditions that are not man-made. The eminent American architectural scholar David Leatherbarrow elaborated that architecture always 'participates in numerous authored and un-authored conditions'.³ This includes, for example, the interaction of constructions with the local climate and the resulting production of a microclimate, and suggests that if 'participation' and its consequences are not thought-through the resulting conditions will be accidental and possibly unsuitable. The difference between Otto's notion of auxiliary and Leatherbarrow's notion of 'participation' rests, therefore, in the fact that the former entails intentional functional relations, while the latter takes place whether considered by the architect or not.

Consequently, the realisation arises that the extent to which architectures are auxiliary to all sorts of conditions, as well as the kind and degree of their participation, can be made a central concern of architectural design and the means by which architecture enacts and expands its repertoire of making provisions for habitation. These provisions may cater for humans or other species, potentially even entire agro- or ecosystems, and can help to sustain local economies, depending on the auxiliary relations and resulting conditions that are involved. Moreover, the combined relations between auxiliary, participation and projected provision are traits of an alternative approach to sustainability that resonates with the specific take of Paul Reitan, Professor Emeritus of Geological Sciences at the University of Buffalo:

Successfully sustainable human societies must ... be as attuned as possible to their local and regional environments, their geo-ecological support systems; lifestyles must be adapted to the ecosystems in which societies live and which support them with cultures, practices, economic systems, and governing policies each adjusted to fit their area, not a single dominant culture or way of living spread across the globe. This would be a world of multiple, diverse societies with their numbers also adjusted to what regional geo-ecological support systems can sustain.⁴

This understanding would have seemed entirely obvious to ancient Persian 'planners' and masterbuilders. The particular environmental challenges faced by the Persian builders included the largely arid or semi-arid climate of the mountainous landscape of the Iranian plateau with distinct seasonal differences and steep seasonal and daily temperature gradients. Context-specific water management and soil-fertilisation strategies, passive environmental modulation in architecture and related settlement pattern were all finely attuned to the context. The size of the country also posed a challenge. At 1,648 million square kilometres (636,296 square miles), today Iran is the eighteenth largest country in the world. Yet throughout its history the Persian Empire was often considerably larger. Thus the development of massive infrastructure and refined local architectures took place concomitantly, and auxiliary was a self-evident requisite. The associated development and exchange of knowledge and skills is embedded in whatever is left of the historical built environment, and is worth examining for knowledge that can be updated and put to task today.

During the time of the Achaemenid, or first Persian Empire (c 550–300 BC), the so-called Persian Royal Road connected vast stretches of the empire. It is thought that the Assyrians built the oldest part of this road, but it was substantially reorganised and extended into the Royal Road under Darius I (c 550–486 BC). Its purpose was to facilitate fast communication and post via couriers, and long-distance trade, and it coincided in parts with the Silk Routes, a network of land and water trade routes that connected Asia with Europe and North and East Africa, with the Persian Empire located at the centre. Along these routes, not only goods, but also knowledge, was conveyed. Roads, bridges, post stations, caravanserais, water reservoirs and other types of constructions facilitated this efficient system in a locally specific manner and were improved upon through the exchanges facilitated by the routes network. There was thus no conflict between ‘global’ and ‘local’ aspects. On the contrary, it can be clearly discerned that the exchange of knowledge led to major improvements in the locally specific built environment of the Persian plateau and other parts of the Persian Empire. In particular during the Safavid era under Shah Abbas I (Shah Abbas the Great) (1571–1629) and later Shah Abbas II (1632–66), new heights of refinement and complexity of architectures were reached. Recently experts have begun to emphasise the remarkable impact of the multi-ethnic and multi-religious population of Isfahan under the rule of Shah Abbas I on the remaking of the city and its architecture, when the shah pronounced Isfahan the new imperial capital in 1598. Dr Emma Loosley pointed out that ‘a variety of communities lived and worked alongside each other’ and that ‘Abbas was ahead of his time in discerning the practical and economic value of a multicultural society’.⁵ The accumulative effect of this coexistence and the already rich history of architecture led to an abundance of civic, representational, vernacular and special-purpose architectures that were characterised by a high level of integrated functional capacity and formal expression.

Designing Flows: Qanats and *badgirs*

Many architectures of historical Persia display the masterly deployment of the flow of water and air to provide a habitable environment. In the case of water it often had to be brought from afar, stored and distributed. In the case of airflow, the purpose was passive ventilation and thermal conditioning. In numerous examples the flows were correlated in an advantageous manner, and the outcomes were invariably immensely well-calibrated constructions and architectures of stunning beauty and performance. Two key elements were a water management system (qanat) and the wind towers (*badgir* and *kbishkhan*).

In ancient Persia rivers were sparse and often seasonal. This made alternative methods of water management an indispensable necessity to provide continuous irrigation for agricultural purposes and drinking water for settlements in the largely arid regions of Persia. The combination of fertile soil and precipitation-rich mountain ranges made it viable to collect groundwater at the foot of the mountains with a system of subterranean canals called qanats. The oldest existing qanats in Iran date from around 1000 BC. It is generally thought that this system was developed in Persia and that it was gradually diffused from here westwards to the arid zones of Mediterranean North Africa, Italy and Spain, and eastwards to Afghanistan,

Pakistan and Turfan in Northwest China. The most extensive qanats found to date are up to 70 kilometres (43.5 miles) long and located in the Kerman region. On average, however, qanats were about 5 to 10 kilometres (3 to 6 miles) long. The exactitude of the slope of the qanat was of vital importance to prevent destructive flow conditions or stagnation. Qanats feature vertical shafts at an interval of on average of 25 metres (82 feet), which are necessary both for the construction and the ventilation of the system. Their subterranean location made it possible to avoid extensive evaporative water loss, contamination of the water, as well as substantial damage through floods and earthquakes. A system of smaller channels (*kariz*) enabled the distribution of water from the qanats to water cisterns of individual buildings, and so on. Appointed individuals (*meerab*) were responsible for the operation of the *kariz* and the filling of the water cisterns. Maintenance was crucial as qanats, *kariz* and water cisterns needed to be periodically cleaned due to sediments.

Wind towers (*badgir* and *kbishkhan*) were an integral part of a series of interrelated strategies for passive building climatisation in the hot and arid regions of Iran that are characterised by a steep day-to-night temperature gradient. Settlements are typically arranged in a dense manner to minimise thermal impact. Buildings are constructed from adobe bricks and walls are very thick to gain high capacity for thermal regulation and heat transmission resistance. The *badgir*-type wind towers are chimney-like structures that serve the purpose of passive ventilation and interior climatisation. The orientation of openings at the exposed upper part of the wind tower and the arrangement of the vertical air ducts and dividing blades inside is directly related to various types of functions and local conditions.⁶ Mehdi Bahadori elucidated that wind towers ‘differ in the height of the tower, the cross-section of the air passages, the placement and number of openings and the placement of the tower with respect to the structure it cools’.⁷

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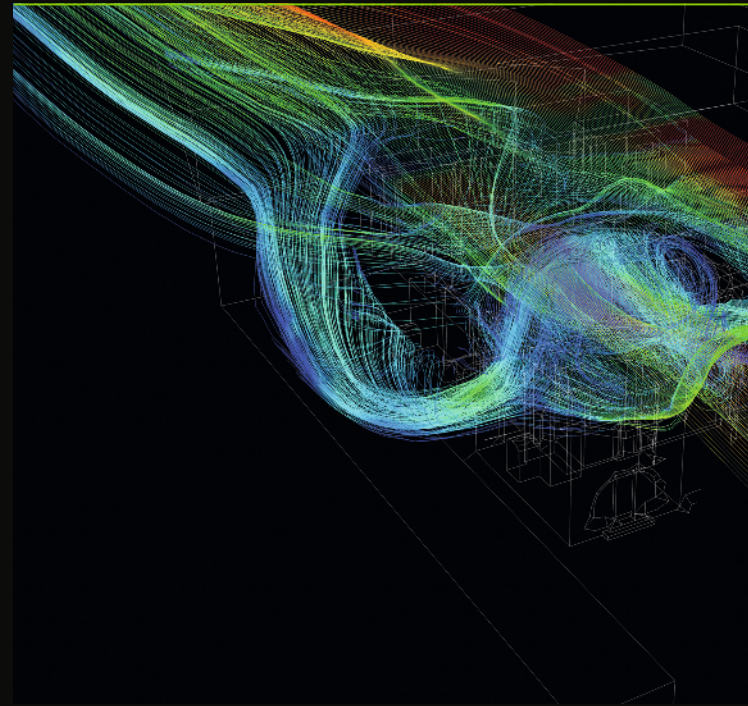
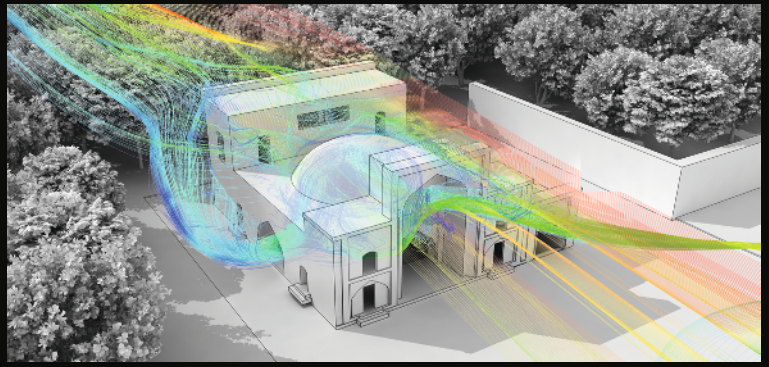
Through simple shutters, different air ducts inside the wind tower could be closed to change its function from mono-directional to bidirectional or multidirectional, depending on the required use. Bahadori explained that:

the operation of the tower depends on wind conditions and the time of day ... when there is no wind at night the tower operates like a chimney, circulating air by pulling it upward and through the tower openings ... when there is a wind at night, the air is forced in the opposite direction; the rooms are cooled by night air coming down the tower ... when there is no wind during the day, the operation of the tower is the reverse of a chimney. The walls of the upper part of the tower have been cooled during the previous night. Hot air comes in contact with them and is cooled. Being denser than the hot air, the cooled air sinks down through the tower, creating a downdraft ... when there is a wind during the day, the rate of circulation is increased.⁸

This short excerpt from Bahadori's detailed report begins to show just how versatile the use of the wind towers can be. This can be enhanced when the airflow is combined with a fountain or water basin to achieve additional evaporative cooling. Windcatchers were also frequently used in combination with a qanat. In this case a mono-directional arrangement with leeward-facing opening of the windcatcher made use of the pressure differential to draw out air from the building. An air channel external to the building served as an inlet through which air was drawn downwards to an underground qanat and chilled through evaporative cooling. This cooled air was then drawn into the basement and other parts of the house.

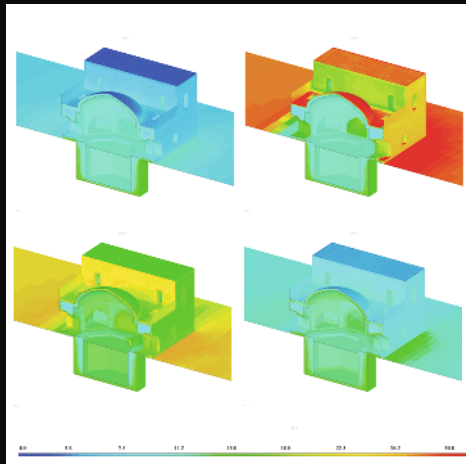
The *khishkhan*-type wind tower is a dome with an opening placed on the roof of buildings that enabled both ventilation and indirect light into the space below – typically the main hall or living room. It could also be used for evaporative cooling, covered with a wooden mesh, clay, or dried plants and moistened in order to cool the air flowing into the building.⁹

Sophisticated historical Persian architectures typically combine numerous strategies for the production of suitable microclimates for a variety of purposes, as can be seen from the selected examples.



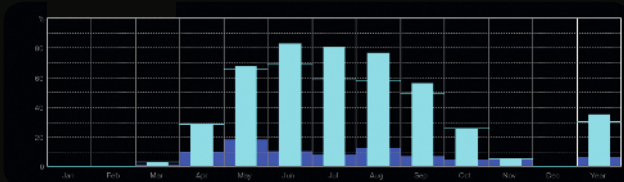
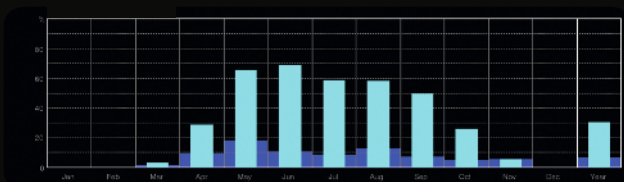
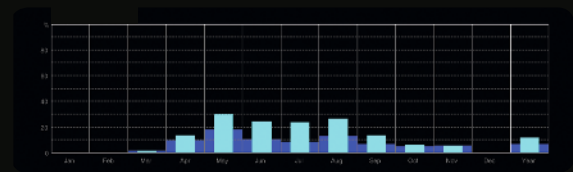
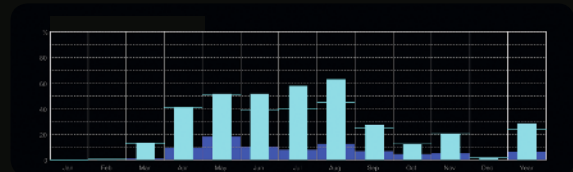
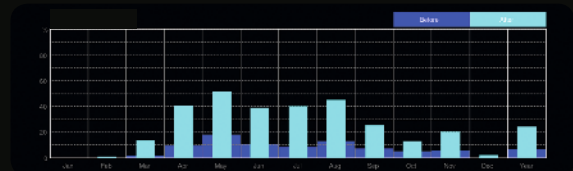
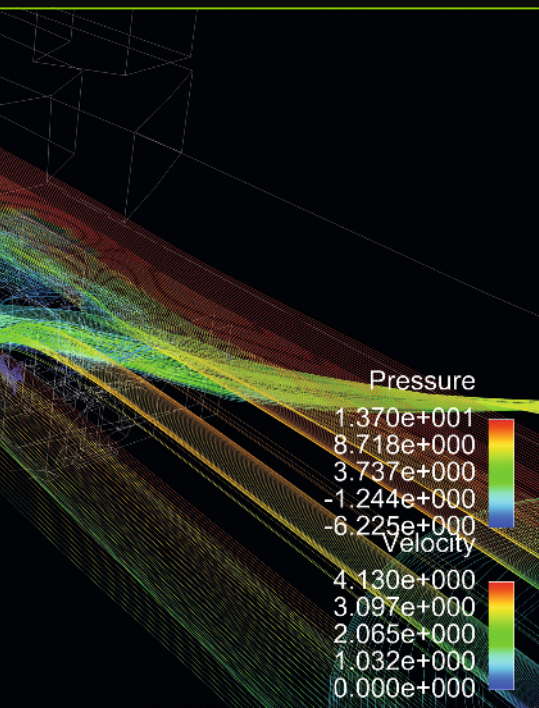
Sustainable Environment Association – SEA (Salmaan Craig, Mehran Gharleghi, Michael Hensel, Amin Sadeghy and Defne Sunguroğlu Hensel), Computational Fluid Dynamics Analysis, Sheikh Ahmad Jam Water Reservoir, Kashan, 2011
above and pp 28–9: In this reservoir, built around 1630, natural cross-ventilation evaporates water at the surface that helps maintain the cool temperature of the water. (Temporary software licences sponsored by EnSight®.)

SEA, Heat Transfer Analysis, Sheikh Ahmad Jam Water Reservoir, Kashan, 2011
opposite top: Ground and water entail two types of thermal inertia. Due to the large thermal mass volume, the temperature within the water storage remains constant while the outdoor temperature fluctuates significantly. The analysis of a 24-hour cycle from 19 to 20 April was carried out by RadTherm®.



Water Cisterns

Subterranean Water Cisterns (*ab-anbar*) for the storage of drinking water were built either to collect water from qanats or, alternatively, where no qanats were available, to collect the water of sporadic torrential rainfall in the arid desert areas of the Iranian plateau. To enable proper cooling, resistance to water pressure and the impact of earthquakes, cisterns were built underground. Shahram Khora Sanizadeh of the Water Resource Institute in Iran estimates the storage capacity of historical water cisterns to vary from 300 to 3,000 cubic metres (10,594 to 105,944 cubic feet).¹⁰ The cisterns were made from specially made bricks (*ajor ab anbari*) and mortar (*sarooj*), which consisted of 'sand, clay, egg whites, lime, goat hair, and ash in specific proportions, depending on location and climate'.¹¹ This type of mortar is thought to be quite resistant to water penetration. The cistern was enclosed by a vault or dome to maintain the water at a desired temperature and to protect it from dust and pollution. Access and maintenance was via stairs to the underground cistern that were typically covered by a vaulted entrance (*sar-dar*). The cisterns were filled during the winter with cold water at a temperature just above freezing. To keep the water cool throughout the year, the cisterns were in some regions equipped with multiple wind towers. The airflow across the water surface generated by the windcatchers removes evaporating water and prevents the warming up of the deeper layers of the water in the cistern as 'the heat from the air is almost entirely spent in evaporating the water at the surface'.¹²



SEA, Passive Cooling Strategies, Kashan, Isfahan, 2011

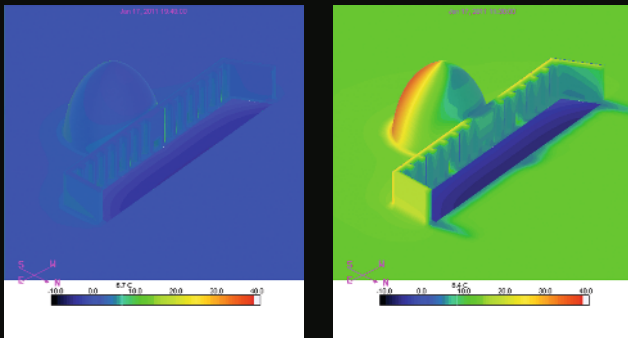
above and left. The charts show the effectiveness of different passive cooling strategies in Kashan. From top to bottom: thermal mass effect, exposed mass and night purge ventilation, natural ventilation, direct evaporative cooling and indirect evaporative cooling.

Ice Houses

Some experts assume that ice houses originated in China around 800 BC.¹³

The purpose of the Iranian ice makers and ice houses (*yakh-cha*) was the production and storage of ice for human consumption. The ice houses commonly featured subterranean chambers covered by a large dome made from mud-brick that often reached 20 metres (66 feet) in height. Ice and snow could be brought from nearby mountains or harvested from frozen lakes in the winter, or produced next to the ice houses. It was then stored in the chamber and packed with straw or sawdust for insulation.

East-west-oriented shallow pools up to a length of 100 metres (328 feet) and more, and widths between 10 and 20 metres (33 and 66 feet) were backed on their southern side by a tall adobe wall that could shade the entire pool during the winter ice-making period, and protect the pools from the impact of the sun and wind-induced convective heat gain to reduce melting during the day. The accurate height of the east-west wall was of key importance: it needed to be high enough to shield the pool, but not so high that it would reduce the exposure of the water surface to the visible sky. The latter was essential to maintain maximum heat loss of the water through radiation. Additionally, each pool was flanked to the east and west by lower walls for the same purpose. During the cold winter nights the pools were filled with a shallow layer of water that would freeze overnight and could be harvested as ice in the morning.¹⁴ The construction and management of the labour-intensive breaking, moving and storing of the ice required an integrative approach of immense accuracy. Various considerations needed to be correlated and calibrated: the critical dimensions of the structure, the labour associated with harvesting the ice, and the production of maximum quantities.

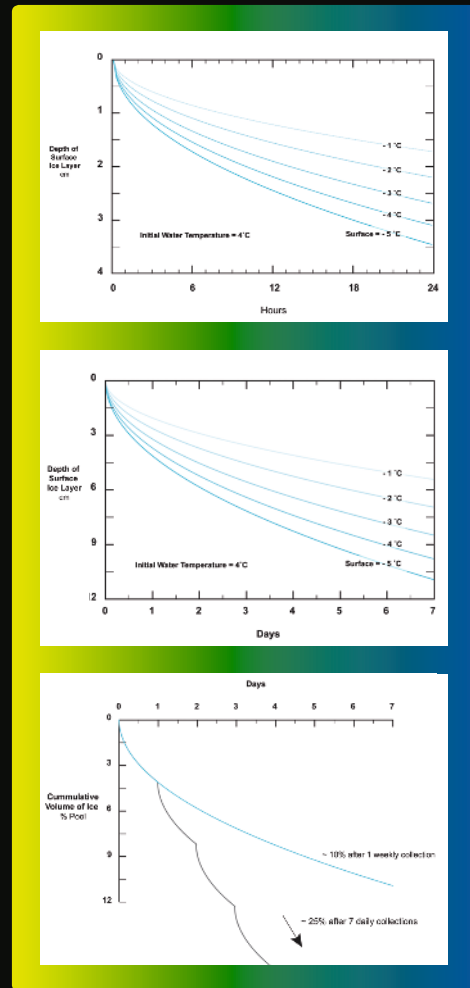
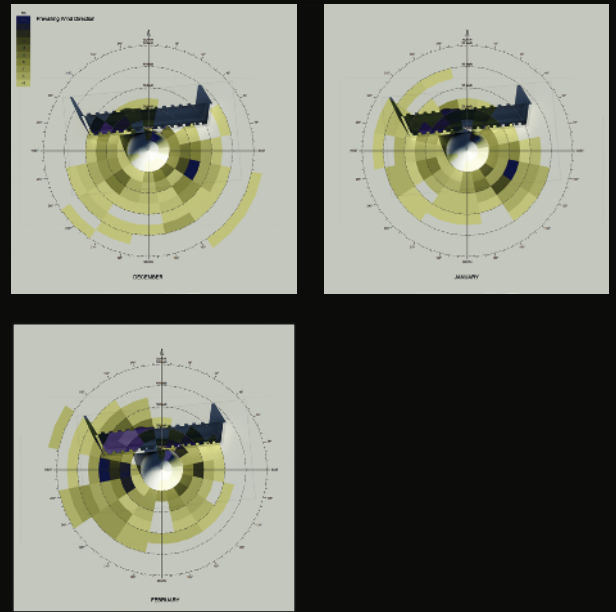


SEA, Heat Transfer Analysis, Ice House, Meybod, 2011

above: A transient thermal analysis of the ice house shows the evolution of temperatures over three days in winter. While the ambient temperature rarely dips below 0°C (32°F), the pond's exposure to the cold sky – coupled with the protection from the wind and sun afforded by the wall – create amenable conditions for the production of ice. Note that the surface of the water in the pond remains below zero, day and night.

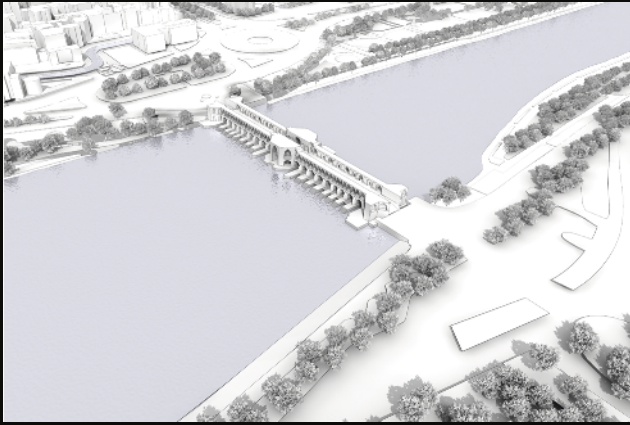
SEA, Prevailing Wind Direction, Ice House, Meybod, 2011

top: The winter wind roses show that the pond is sheltered from the prevailing wind. At warmer than 0°C (32°F), the wind would reduce the rate of ice production or increase the rate of melting.



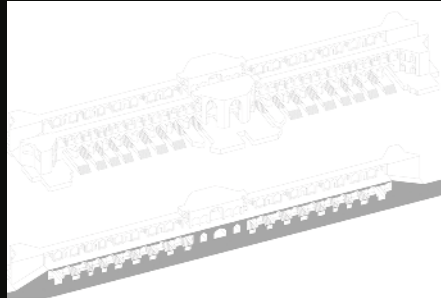
SEA, Ice Production Rate, Ice House, Meybod, 2011

above: Assuming conservatively that the body of water is an average 4°C (39.2°F), the rate of ice production over time – for progressively colder pond surface temperatures – can be calculated. These effects combine to give the curve that describes the rate of ice production its distinctive shape, as shown in the diagrams.

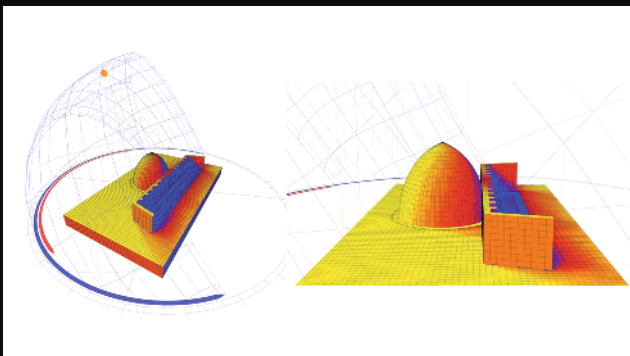
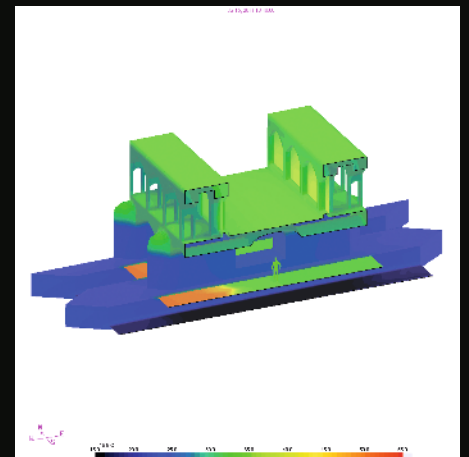
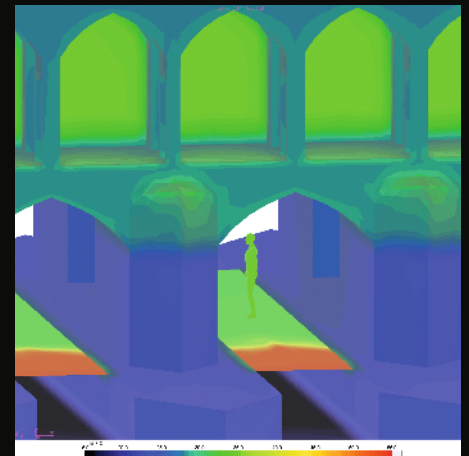


The Khaju Bridge

The Khaju Bridge (*pol-e khajoo*) was built around 1650 under the Safavid Shah Abbas II on the foundations of an older bridge spanning across the Zayandeh River in Isfahan. The 132-metre (433-foot) long and 14-metre (46-foot) wide two-storey masonry bridge has a 7.5-metre (25-foot) wide roadway on its upper storey that is framed on both sides by arched spaces, while the lower storey comprises a vaulted space that can only be reached by pedestrians. The bridge weir combines 18 low-flow deep channels equipped with sluice gates with stepped cascades for large flood flows, which serve to dissipate hydraulic energy.¹⁵ The sluice gates regulate the water level of the Zayandeh River for the irrigation of upstream gardens and so on.



Its highly sophisticated hydraulic performance prompted Dr Mehrdad Hejazi at the Faculty of Engineering at the University of Isfahan to posit that the Khaju Bridge 'represents the ultimate achievement of Persian hydraulic engineering'.



SEA, Solar Analysis, Ice House, Meybod, Yazd, 2011

bottom left: The wall was dimensioned to protect the water pond from the deleterious effects of sun and wind, without obstructing the pond's exposure to the clear night sky. This balance was essential in order to create ice in ambient temperatures above 0°C (32°F). The analysis shows that during the winter the pond receives no direct sunlight.

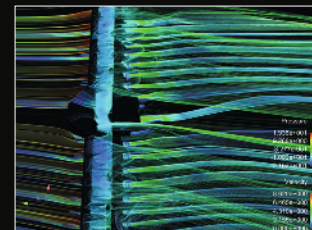
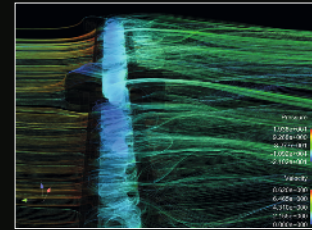
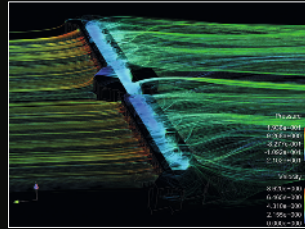
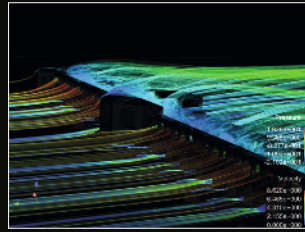
SEA, Axonometric and Section, Khaju Bridge (pol-e khajoo), Isfahan, 2011

top and centre left: The upper level of the Khaju Bridge (c 1650) serves as a roadway, while the lower comprises a vaulted public space.

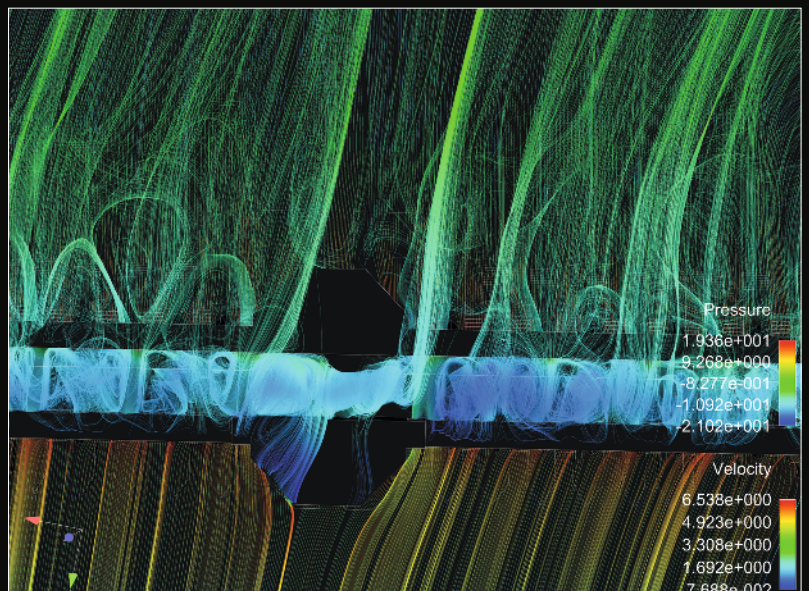
SEA, Heat Transfer Analysis, Khaju Bridge (pol-e khajoo), Isfahan, 2011

centre and bottom right: The analysis shows the likely surface temperatures of the Khaju Bridge during an average summer afternoon. The combination of shading and high thermal mass along with the accelerated ventilation and evaporative cooling make the communal areas a comfortable environment.

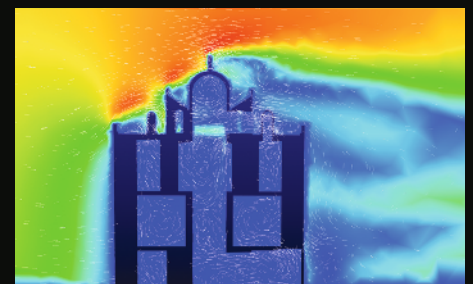
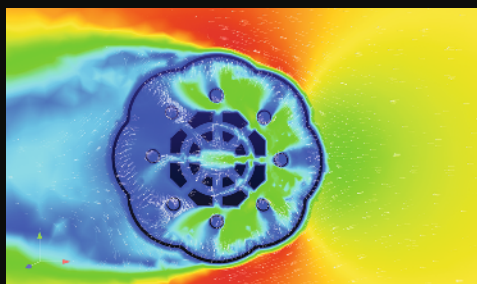
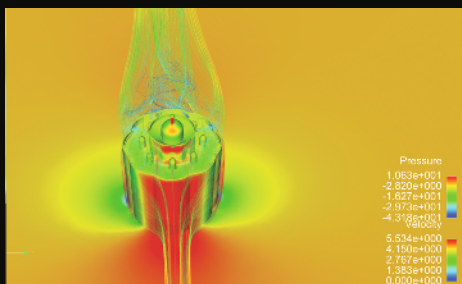
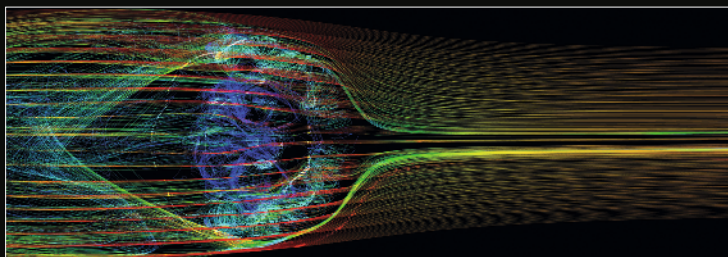
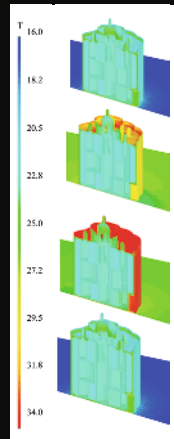
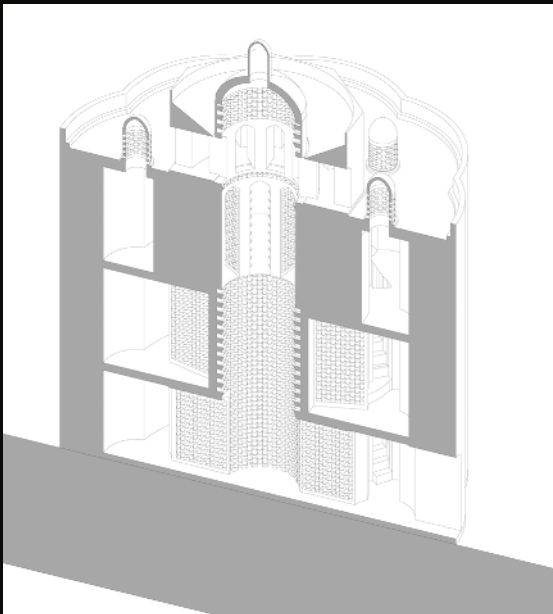
Its highly sophisticated hydraulic performance prompted Dr Mehrdad Hejazi at the Faculty of Engineering at the University of Isfahan to posit that the Khaju Bridge ‘represents the ultimate achievement of Persian hydraulic engineering’.¹⁶ Yet its sophisticated fulfilment of its primary functions, its auxiliary relation to the urban circulation system and its central role in water management, are only part of the story. The need to construct a bridge with functional requirements related to water management was tackled in an opportunistic manner. The stepped chutes on its downstream side double up as seating for public use. Here, as well as in the tier of arches and vaulted space of the lower storey, evaporative cooling and the generated turbulent airflow generate a comfortable microclimate. From this perspective the spatial and material organisation of the bridge weir is inherently multifunctional. It thus combines a civic project with an unexpected provision of a climatically comfortable public space for appropriation and social assembly. Additional features are the pavilions for the shah placed on the upper level in the centre of the bridge facing up- and downstream.



The bridge weir combines 18 low-flow deep channels equipped with sluice gates with stepped cascades for large flood flows, which serve to dissipate hydraulic energy. The sluice gates regulate the water level of the Zayandeh River for the irrigation of upstream gardens and so on.



SEA, Computational Fluid Dynamic Analysis, Khaju Bridge (pol-e khajoo), Isfahan, 2011
The analysis suggests that the evenly spaced arched openings on the upper level allow wind to penetrate into the roadway at a lower speed, around 3.2 kilometres (2 miles) per second, creating a comfortable environment along the path.



Pigeon Towers

During the Safavid period, another remarkable special-purpose building type flourished in the Isfahan region – the pigeon towers. The main function of these up to 20-metre (66-foot) tall buildings was to provide shelter for wild pigeons and to collect their dung as fertiliser for agriculture, in particular for growing melons, as well as for the softening of leather. Aryan Amirkhani and colleagues described that ‘the pigeon towers of Isfahan are a perfect example of humans and nature working together in the name of mutual interest ... by attracting wild pigeons with seed and safe place to roost, the towers acted as a natural collection point for waste which could then be used as fertilizer’.¹⁷ Circular or rectangular in plan with internally buttressed walls, pigeon towers could either be freestanding as single structures, or be integrated into the outer walls of gardens. The larger towers could house well over 10,000 pigeons. Such towers consisted either of a single hollow space or drum, or of an inner one enclosed by an outer drum. Some were organised in plan as eight connected drums around a central one, thus increasing the surface area of the interior and therefore also the number of pigeonholes. Atop the towers, turrets with honeycomb brickwork provided entry and exit for the pigeons. Humans accessed the towers usually only once a year to harvest the dung.¹⁸

Interestingly, structures for the exact same use can be found in Anatolia, whether the large rectangular dovecotes (*boranhane*) in the Diyarbakir region¹⁹ or the often densely clustered half-above- and half-below-ground examples built on the steep slopes of the Kayseri region. The latter are characterised by a stone-made above-ground tower-like part (*burc*) that is rectangular, square, circular or ellipsoidal in plan and provides access for the pigeons, and a cave-like rock-hewn underground part (*kushane*) that accommodates the nests. A short tunnel and a door from the lower part of the slope provided human access for dung harvesting.²⁰

Given the rich variation in articulation and use of these types of buildings it would be very interesting to undertake a comparative analysis and to see what can be learned from these examples for present structures that can house other species for the benefit of the human environment.

SEA, Axonometric Views and Heat Transfer Analysis, Pigeon Tower, Isfahan, 2011

top: The combination of thermal mass and openings in the turrets of pigeon towers maintained low internal surface temperatures and high ventilation rates. As this transient thermal analysis in RadTherm shows, the thickness of the multiple adobe walls is tuned to buffer daily temperature fluctuations effectively. (Sponsored by RadTherm®)

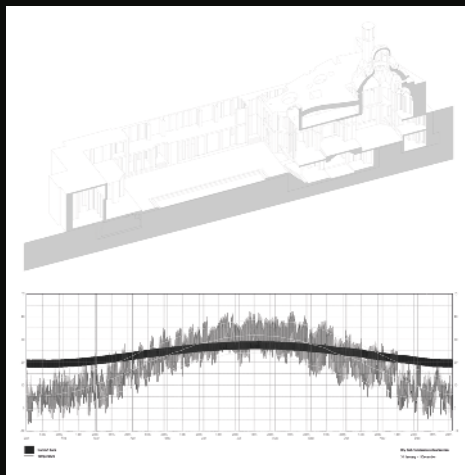
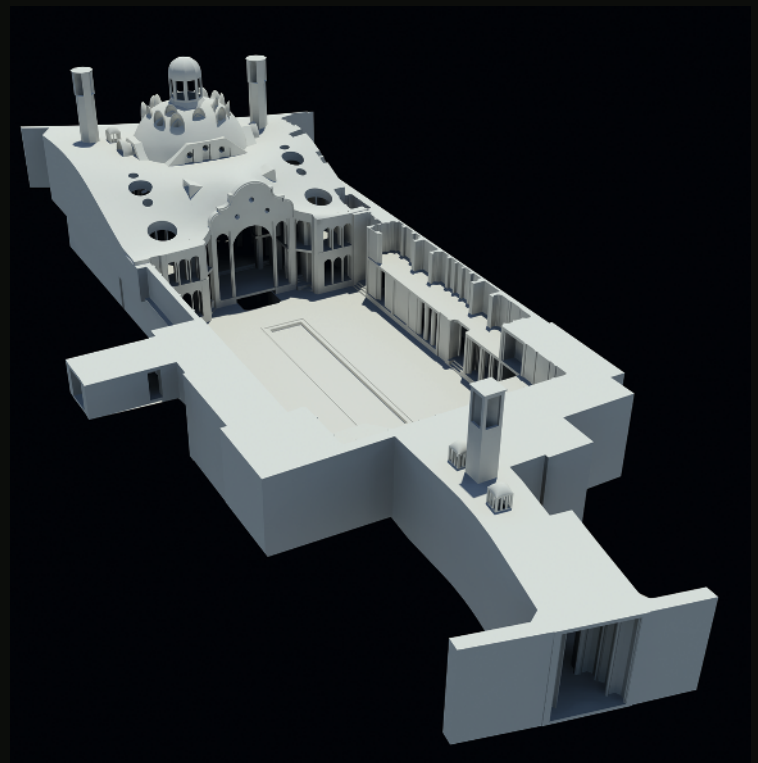
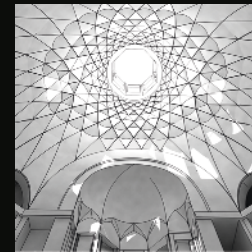
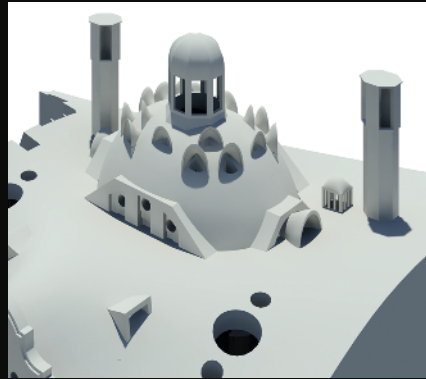
SEA, Computational Fluid Dynamic Analysis, Pigeon Tower, Isfahan, 2011

centre and bottom: The analysis of the Safavid period (1501–1736) pigeon tower shows how wind-driven ventilation occurs throughout the structure. In the absence of wind, the internal structure of the tower, and the difference in temperatures between top and bottom, would likely induce a natural stack effect. (Temporary licences sponsored by EnSight®)

Boroujerdi's House

During the 19th century, the illustrious architect Ostad Ali Maryam Kashani designed, among other projects, a number of highly sophisticated houses for wealthy clients in the city of Kashan. These include, most notably, the Tabatabaeis' House (Khaneh Tabatabaei-ha) (c 1850) and the Boroujerdi's House (Khane-ye Boroujerdiha) (1857).

Surrounded by a densely built fabric, the Boroujerdi's House is introverted and dominated by a rectangular courtyard with its long axis stretching roughly from north-northeast to south-southwest. The plan organisation shows a sequence of linked spaces that constitute the entrance to the building from the north and lead into the courtyard. The latter is flanked by a series of linked narrow spaces and terminated by the main building mass to the south, which is organised as a matrix of interconnected spaces. This kind of organisation facilitates the correlation between climatic modulation, in this case passive ventilation and cooling, and the use of space. A pool in the courtyard facilitates heat loss through evaporation, and the plantation provides increased humidity and shading for the courtyard and building surfaces to prevent thermal gain. The arched and domed roofscape provides self-shading and thus the reduction of thermal impact. Intriguingly, the undulating earth-coloured roofscape resonates with that of Antoni Gaudí's Casa Milà in Barcelona (1910), not unlike other roofscapes in Kashan. Yet the highly expressive and sculptural roofscape of the Boroujerdi's House is clearly intended to be experienced as an artistic work in its own right. The house features three *badgir*-type chimney-like wind towers and a very sophisticated *khishkhan*-type dome. The former serves the entrance area in the north and the main living area to the south; its effect is further enhanced by the openings in the *khishkhan*-type central dome of the main hall. Interestingly, the placement of the openings and the internal geometric articulation and adornment of the dome are intricately related, and coordinate geometry with indirect light sources, thus demonstrating a highly coherent design down to the detail. In some areas, ventilated interstitial spaces are used between the outer roof surface and the inner ceilings, further preventing thermal gain.



SEA, Dry Bulb Temperature, Boroujerdi's House (Khane-ye Boroujerdiha), Kashan, 2011

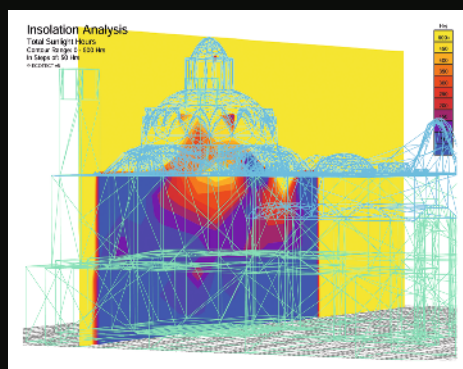
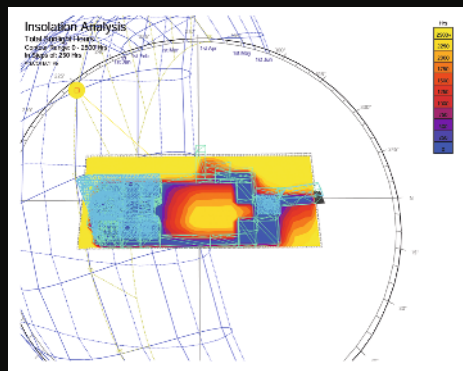
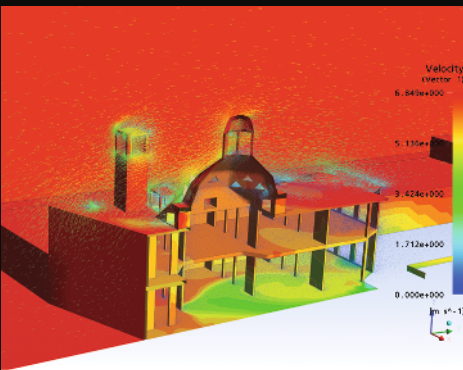
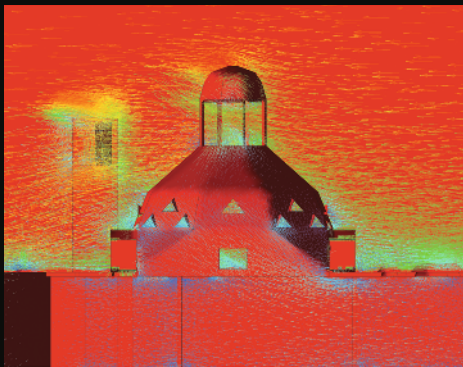
left: The annual dry bulb temperature reveals dramatic temperature fluctuations through the different seasons. Passive climate strategies employed in the design of the Boroujerdi's House (1857) include a central courtyard, natural cross-ventilation, evaporative cooling, indirect light penetration, night purge ventilation and various types of wind towers.

SEA, 3-D model, Boroujerdi's House (Khane-ye Boroujerdiha), Kashan, 2011

The images show the intricate relationship between the interior and the exterior of the dome. The design of the Boroujerdi's House demonstrates high-level integration of spatial quality and structural and environmental performance.

Looking Backwards to Project Forwards

The general performative capacities of the projects discussed above have been known and elaborated in expert papers over decades. Such capacities have here been situated as part of a new approach to the study of architectural history that focuses on architectural performance and is based on the notion of auxiliary, as well as to employ contemporary environmental expertise and associated computer-aided analysis to examine the specific ranges of environmental modulation and functional integration in such projects. For projects with a narrow scope of function and exclusive of habitation by humans or other species, these ranges can be more constrained, while projects for human habitation provide for a more heterogeneous environment that offers choice. Further analysis will be necessary to unlock this complexity to inform contemporary designs, and to better understand the finely nuanced corresponding ranges to inform contemporary architecture and the sustainable provisions it will need to make. Described here are the beginnings of an effort that requires a broadly based interdisciplinary, forensic and projective take. ▽



SEA, Solar Analysis, Boroujerdi's House (*Khane-ye Boroujerdiha*), Kashan, 2009

The analysis shows that the annual direct sunlight exposure is considerably lower on the south side, which is the reason why it was intensively used during the summer. The bottom image reveals that the annual direct sunlight penetration via the dome into the lower levels of the living area is almost zero. The combination of indirect sunlight penetration and natural ventilation maximises the passive cooling performance of the house.

SEA, Computational Fluid Dynamic Analysis, Boroujerdi's House (*Khane-ye Boroujerdiha*), Kashan, 2009

The central dome of the Boroujerdi's House provides highly sophisticated ventilation. Spilling water on the plants at the top part of the dome around noon helped to cool down the air while other roof openings allowed for further air and indirect light penetration.

Notes

1. Sheikh Muslih-uddin Sa'di Shirazi, *Prologue to the Gulistan (or Rose Garden)*, 1258, translated by Dr Iraj Bashiri, 2004. See: www.angelfire.com/rmb/bashiri/Sadi/SadiGulistan.pdf (accessed 12 September 2011).
2. JM Songel, *A Conversation With Frei Otto*, Princeton Architectural Press (New York), 2008, p 11.
3. D Leatherbarrow, 'Architecture Oriented Otherwise', Lecture at the Oslo School of Architecture and Design, 28 April 2011.
4. P Reitan, 'Sustainability Science – And What's Needed Beyond Science', *Sustainability: Science, Practice, & Policy* 1(1), 2005, pp 77–80. Online at: http://sspp.proquest.com/archives/vol1iss1/communityessay_reitan.pdf (accessed 12 September 2011).
5. See, for instance, E Loosley, *Messiah and Mahdi: Caucasian Christians and the Construction of Safavid Isfahan*, East & West Publishers (London), 2009, p 4. This defies the notion that so-called 'multiculturalism' is a contemporary condition that can be declared a 'failed project' by our politicians.
6. For a detailed elaboration of different types of windcatchers, their cross-sectional articulation and associated CFD analysis, see MM Zarandi, 'Analysis on Iranian Wind Catcher and its Effect on Natural Ventilation as a Solution Towards Sustainable Architecture (Case Study: Yazd)', *World Academy of Science, Engineering and Technology* 54, 2009, pp 574–579. Online at: www.waset.org/journals/waset/v54/v54-101.pdf (accessed 12 September 2011).
7. MN Bahadori, 'Passive Cooling Systems in Iranian Architecture', *Scientific American* 238(2), 1978, pp 144–54.
8. Ibid.
9. K Pirnia, 'Windtower', in G Memarian (ed), *Iranian Architecture*, Nashr Soroush Danesh (Tehran), 2008, pp 538–54.
10. SK Sanizadeh, 'Novel Hydraulic Structures and Water Management in Iran: A Historical Perspective', in M El Moujabber, M Shatanawi, G Trisorio Liuzzi, M Ouessar, P Laureano and R Rodriguez (eds), *Water Culture and Water Conflict in the Mediterranean Area*, CIHEAM-IAMB (Bari), 2008, pp 25–43. Online at: <http://ressources.ciheam.org/om/pdf/a83/00800922.pdf> (accessed 10 September 2011).
11. Ibid.
12. K Pirnia, op cit.
13. A Aryan and O Hanie, 'Historical Traditional Building Techniques in Some Iranian Vernacular Constructions', *The Heritage Journal*, Vol 4, 2009, pp 47–73.
14. K Pirnia, op cit.
15. H Chanson, 'Historical Development of Stepped Cascades for the Dissipation of Hydraulic Energy', *Transactions of the Newcomen Society for the Study of the History of Engineering and Technology* 71(2), 2001–2, pp 295–318.
16. MM Hejazi, *Historical Buildings of Iran: Their Architecture and Structure*, WIT Press (Southampton), 1997, pp 94–5.
17. A Amirkhani, P Baghaie, AA Taghvaei, MR Pourjafar and M Ansari, 'Isfahan's Dovecotes: Remarkable Edifices of Iranian Vernacular Architecture', *Middle East Technical University – Journal of the Faculty of Architecture* 26(1), 2009, pp 177–86. Online at: http://jfa.arch.metu.edu.tr/archive/0258-5316/2009/cilt26/say1_1/177-186.pdf (accessed 12 September 2011).
18. Ibid.
19. A Bekleyen, 'The Dovecotes of Diyarbakir: The Surviving Example of a Fading Tradition', *The Journal of Architecture* 14(4), 2009, pp 451–64.
20. V Imamo lu, M Korumaz and C Imamo lu, 'A Fantasy in Central Anatolian Heritage: Dove Cotes and Towers in Kayseri', *Middle East Technical University – Journal of the Faculty of Architecture* 22(02), 2005, pp 79–90. Online at: http://jfa.arch.metu.edu.tr/archive/0258-5316/2005/cilt22/say1_2/79-90.pdf (accessed 12 September 2011).