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Chapter 12

The future of the vernacular

Towards new methodologies for the understanding and optimization of the performance of vernacular buildings

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Dwellings are built to serve a variety of functions, but one of the most important is to create living conditions that are acceptable to their occupiers, particularly in relation to the prevailing climates. Buildings do not control climate, which, apart from the wind or sun shadow that they cast, remains largely unaffected. But from within the dwelling can modify the internal climate, even though it is affected by the external conditions. The materials that are used, the forms they take, the volumes they enclose, and the services that are installed may all contribute to the 'micro-climate' that the house generates. This is not always precisely what the occupants require in temperature, ventilation or relative humidity.

Oliver (2003: 130)

Introduction

At the threshold of a new century, and faced with the potentially devastating impacts of climate change and the end of the 'fossil fuel age', questions are increasingly being asked on 'what types of buildings will be most resilient in the face of such challenges'.[1] Instinctively, many people's response is that traditional vernacular prototypes are best adapted to the different climates they occupy and therefore are better suited to provide sustainable prototypes for a future without cheap energy, far more so than energy expensive high-tech building types. But is this right? Here we question this response, in a search for genuinely resilient building types that will safely house people in the changing circumstances of the twenty-first century.

Historical, traditional and vernacular housing prototypes have been considered as inherently adapted to the constraints of the natural environment. A reliance on such deterministic assumptions has often led to misinterpretation of facts, wrong conclusions regarding appropriate technologies and design solutions in general, and in particular those relevant to low-cost housing for developing countries. This chapter analyzes a number of generic types of housing common around the Middle East and the Mediterranean, and assesses their actual performance vis-à-vis different low-tech upgrade and retrofit strategies. A number of methods and techniques were employed, including monitoring, modelling, numerical analysis, simulation and infra-red thermography. Investigations included different building technologies and materials, morphologies and details, under different arid conditions typical of the Middle Eastern and Mediterranean climatic regions, with a view to exploring methods of optimising the performance of vernacular prototypes to provide resilient buildings for the twenty-first century.

Performance stereotypes of the vernacular

It has become rather common to encounter in architectural publications statements advocating the study of vernacular and historical housing prototypes as a base for environmentally conscious design. One such typical statement is the following:

> . . . Temperatures (within Nabatean buildings) were controlled by proper construction of the walls. These were made three layers thick and were hermetically sealed on the outside and the inside with a porous insulating layer between. In addition, all openings of the living rooms faced south and west in order to benefit fully from the sun. Slot like windows placed below the ceiling facilitated ventilation but prevented, at the same time, the penetration of dust. In this way temperatures were always much higher in the rooms in winter and considerably lower than the heat on the outside of the building in the summer. The extremely small courts around which were grouped the living rooms only helped in this matter . . .
>
> Negev (1980: 30)

This, of course, is only an illustration. Similar examples are numerous and can be encountered throughout professional and academic literature describing different building types, systems and materials; among them internal courtyards, wind catchers, vaults and adobe. Traditional urban layouts in the Middle East and the Mediterranean are usually dense and built around courtyards, some internal and fully enclosed, others attached and/or semi-enclosed. It has been assumed and very frequently noted that this almost homogeneous dispersal of this building type implies an inherent microclimatic advantage. However, the matter was never thoroughly investigated, although in some of the few cases monitored results were contradictory to the theory.

It might be assumed that geometry, proportions and orientation could affect the thermal properties and behaviour of such spaces, and that their function might have been other than, or at least not solely that of climatic amelioration. Studies such as those by Rapoport (1969) suggested the existence of an obvious discrepancy between the environmental or climatic requirements of, and the behavioural patterns to be accommodated in, such spaces. This discrepancy is one explored in this chapter.

The densely built urban form typical of Middle Eastern and Mediterranean regions mentioned above created ambivalent microclimatic conditions. On the one hand it created narrow and winding streets and alleys with a very specific and often ameliorated microclimate, especially due to the shading of surfaces (Pearlmutter 1998). However, on the other hand this densely built-up form suffers from a reduced cooling potential both due to the restricted ventilation potential and due to the reduced Sky View Factor (SVF) of narrow spaces, which reduces outgoing long-wave radiation. This last parameter depends on the proportions of the open space, namely its width and height. The narrower a space in relation to its depth (or the height of its built-up edges), the smaller the proportion of sky dome 'viewed' by the surfaces, the less efficient the heat exchange between these surfaces and the sky dome. To compensate for the poor ventilation and the reduced SVF, many traditional settlements were aligned to ensure that the prevailing winds were efficiently channelled through the streets and alleys to flush the heat from them, and cool their users by convection and evaporation as appropriate (Bonine 1979).

Another way in which traditional architecture dealt with this problem was through the use of windcatchers. Such scoops or towers protrude above the densely built urban form and catch air flowing at higher velocities compared to that within the urban open spaces. This air is cooler than that within the city. However, at particular times of the day or year it may be at higher temperatures than those inside parts of the buildings such towers serve. In various cases the thermal and aerodynamic properties of the windcatchers have been discussed in a non-scientific way and a number of misconceptions regarding their actual function have developed over the last fifty years (Roaf 1990). Typical of these misconceptions is that the notable height of the windcatchers of Yazd in Iran, resulted from climate influences alone. In fact, their apogee in terms of height and elaboration of design and detail was largely influenced by the British–Chinese

12.1
Internal courtyards: Left: St Gerasimos Monastery (Deir Hajle), near Jericho; right: Patio de los Leones, Alhambra.

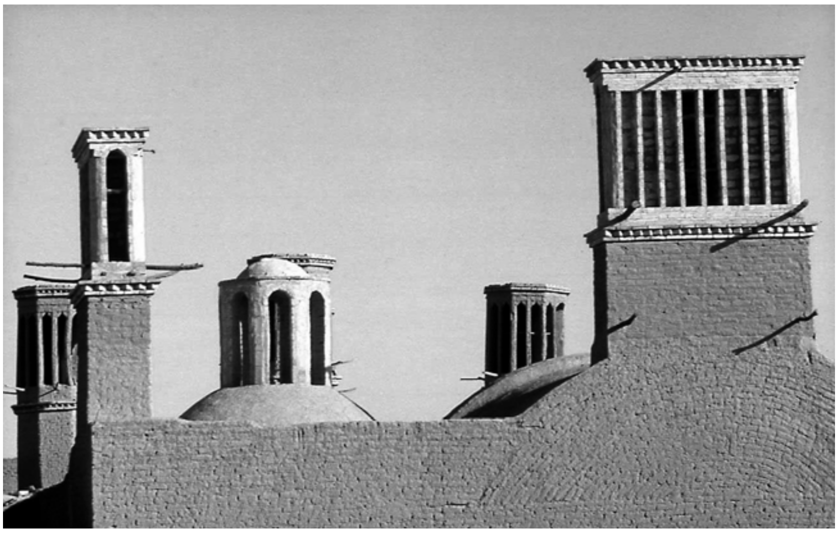
opium trade of the mid-nineteenth century, spurred on by the opening of Hong Kong as a major British port in the South China Sea. In this trade, the Yazdi farmer and merchant flourished, trumpeting their wealth and social elevation with a plethora of 'high' towers, not unlike the civic towers that sprouted around late Mediaeval and Renaissance cities in Europe (Roaf 1989). The sophisticated design, and enhanced height and climatic performance of these towers, resulted largely from the socio-economic conditions that created them.

Traditional building technologies and structural systems appear often to be viewed by architects as little more than aesthetic statements. However, the notion of copying vaults and domes as simple morphological emblems or attributes of 'desert', Middle Eastern or Islamic architecture carries with it the danger of misunderstanding and misinterpreting the underlying reasons for the evolution of particular construction systems, and their attendant detailed designs and performance characteristics, in the climates and environments in which they developed. Alternatively, the automatic justification for their existence and continued use, based on their perceived climatic advantages alone is also dangerous because it denies us the benefits of re-interpreting (understanding) rather than re-using (copying) the technology. It also relies on the veracity of those perceptions of performance. It is important to remember that under the considerable climatic constraints of the regions discussed in this chapter, wood is a scarce and expensive commodity.

Key performance issues within the vernacular

The readily available building materials in dry lands are soil and stone, both very poor in tensile strength. Thus, the structural systems developed through a long trial and error process, stretching over some nine millennia, were those that took advantage of the compressive strength of these materials. The dominant roofing systems in many parts of the Middle East are consequently vaults and domes, arches and sometimes 'latent' arches in the form of corbels. The question that should be asked is how such roofing systems actually work climatically, in relation

12.2
Windcatchers on the village of Nausratabad outside Yazd, Iran.



to their form and details, but again, as with the windcatchers, surprisingly little research has been done until fairly recently.

Soil has been used since the earliest excavated dwelling settlements dating back to the seventh millennium BC, with different techniques such as adobe bricks or rammed earth cast in moulds. Systems and techniques of building in both soil and stone have undergone long periods of detailed development and adaptation, building on the characteristics of the properties of the materials in each region.

Structural issues were key to the evolution of the crude building prototypes, with their characteristic systems and forms, such as the arches and vaults that emerged in response to the need to provide adequate shelter in these harsh climates. However, climatic considerations may often have been of secondary importance, after behavioural, economic and cultural influences, in the evolution of the detailed design of these buildings. Assuming an inherent climatic suitability or superiority of materials and form in vernacular buildings may be misleading, as demonstrated when their excessive thermal mass, and minimal, often unglazed fenestration, more or less necessitated by traditional constraints, are considered vis-à-vis the climatic conditions of different dry lands and deserts.

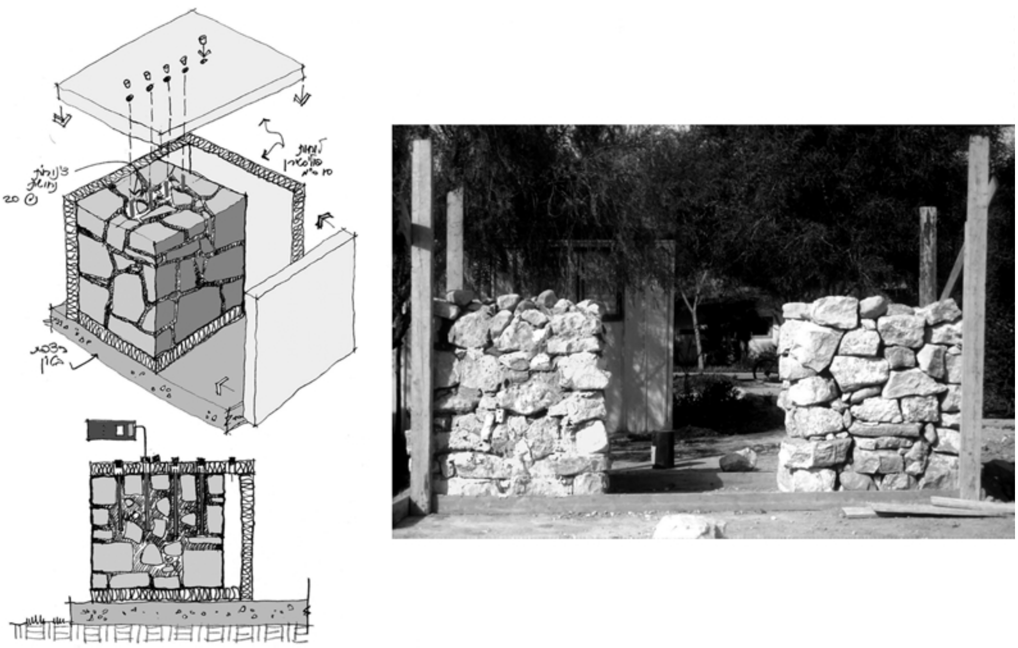
These issues become of special importance when inspected through the looking-glass of climate change and energy sources depletion. The former has been extensively discussed in recent years and in spite of a first reluctance to identify climate change as a planning and design issue, the close observation of changing climate patterns has shown the urgency needed in relating to them. Today it has become obvious that local and global changes are occurring at an accelerating pace, often observed as extreme droughts, storms, heat waves, cold spells, floods and aridization. Although the general trends seem to be those of global warming, it is anticipated that local cases of cooling may occur, such as in the case of the UK. Whereas technology was considered in the past to be a panacea, it has become obvious that current practices have severe limitations for a number of reasons. First and foremost, it has been shown that the current rate of energy consumption typical of industrialized countries, will eventually reach a forced decline due to the limitations of fossil fuel resources (Bartsch and Mueler 2000). At the same time, it has been shown that such intense and unrestricted fuel consumption has direct influences on climate, environment, health and the well-being of people (Jean-Baptiste and Ducroux 2003; Odum and Odum 2004).

In industrialized countries buildings are the biggest consumers of energy, using about half of it, invested mainly in heating, cooling, lighting, ventilation and movement. A vicious circle has been created in which such excessive use of energy adversely influences the built-up space and its microclimate, thus creating a higher demand for more energy to be invested in the buildings and their services (Santamouris *et al*. 2001; Steemers 2003). It is obvious that this is not the case in the less developed countries, where often the majority of the population is still rural, using traditional buildings and technologies, and having very limited access to fossil fuels or the building services technologies so widespread in the industrialized countries. For those masses of people the only obvious viable solution is the upgrade of traditional and vernacular buildings. However, for this to be possible it is necessary to study critically the actual behaviour of such buildings, their morphology, technology and systems.

Tools and methods

If we are to be able to really understand, and learn from, the extent to which traditional dwellings are suited to their natural environments, we need clear and systematic research methods for doing so. This paper outlines a programme of research applied to the houses of the desert regions of the Middle East and dry lands of the Mediterranean, designed to enhance our understanding of exactly how these buildings work in their climates.

The paper presents a range of methods used in this project, including theoretical and fieldwork studies undertaken by the Desert Architecture and Urban Planning Unit of Ben-Gurion University in the Negev Desert, Israel, and theoretical, simulated model studies undertaken within the Energy Efficient Buildings program in Oxford Brookes University, UK. The parametric studies described here include in-situ monitoring; 1:1 scale model monitoring; infrared thermography; thermal and daylight simulations; and numerical analysis. In several cases, 1:1 scale models were used to calibrate simulation tools. Investigations included different building technologies and materials, morphologies and details, under different arid conditions typical of the Middle Eastern climatic regions, as well as semi-arid and dry lands conditions typical of many Mediterranean areas. Indoor climate was analysed vis-à-vis visual and thermal comfort. The results have been used to assess heating loads, and these were used to estimate the probable indoor air quality and environmental implications due to the use of combustible fuels under poorly ventilated conditions.

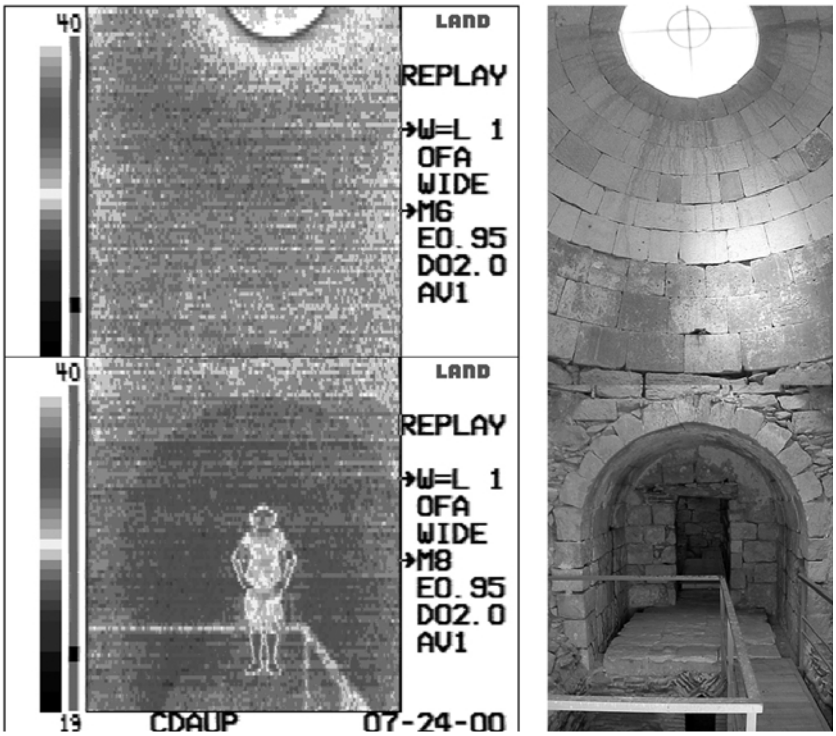


12.3
1:1-scale masonry models built and monitored under real conditions to allow simulations calibration; Left: drawing showing copper pipes embedded in the walls at twenty centimetres intervals to allow temperature measurements; right: models with lime mortar (left) and dry masonry with mud and rubble core before insulation.

In-situ surveys, data collection and literature reviews indicated that, although the overall number of specific house types of the region was relatively large, these could easily be grouped under generic types. Such grouping allowed the creation of a relatively limited, and manageable, number of prototypes common throughout the Middle East and the Mediterranean (Canaan 1932–3; Ragette 1980; Khammash 1986; Hirschfeld 1995). These house prototypes included various forms, morphologies and geometries, materials and technologies, geo-climatic location and dispersal, details and variations. A comprehensive study of such dwellings would eventually need in-situ monitoring, but the initial requirement was for the development of a methodology that would allow researchers to gain an overall understanding of the performance of the generic prototypes in a range of locations and climates.

First the methodology would have to provide appropriate strategies and solutions to overcome constraints such as limited access to potential sites, partial preservation of buildings, monitoring in occupied buildings, security and safety, and a large number of parameters. The solution chosen was a multi-partite protocol based on the following procedures and methods:

1. classification of types in time and space/climate
2. monitoring of available/accessible case studies
3. construction of scale and full size physical models
4. monitoring under real conditions
5. use of model monitoring results for the calibration of simulation programs



12.4
Roman bathhouse dome and interior, Avdat, Negev Highlands: Left: thermal image showing surface temperature variations at summer (July) noon; right: structural details – lighter stone hue indicates reconstructed part of the dome.

6 simulation of case studies and variations
7 infrared thermography for the verification of simulation results
8 numerical modelling combining parameters of simplified physical and simulated models
9 parametric studies of simulated upgrade and retrofit.

The prototypes examined up to the preparation of this chapter, and the procedures and protocols followed, are summed up in Table 12.1. They represent hundreds of runs of simulation models (primarily with simulation software Quick/Easy and Toolbox, but also Ecotect, Daylight and others), and hundreds of days of *in-situ* surveying, documenting and monitoring. Some of the results have been discussed and analysed, many of them summed in a number of papers submitted by graduate students as part of their assignments. Many of these have already been published as partial, type or site-specific studies (Meir, Pearlmutter and Etzion 1995; Pearlmutter and Meir 1995; Meir 2000 and 2002; Meir, Mackenzie Bennett and Roaf 2001; Meir and Gilead 2002; Meir and Roaf 2002; Peeters and Meir 2002; Runsheng, Meir and Etzion 2003a and 2003b).

Results and discussion

The results have been interesting both from the research point of view and from the educational one. Most historical and vernacular prototypes are, by nature, of

Table 12.1 Types and parameters used in this study, and research activities undertaken so far.

	Coastal	Lowlands	Highlands	Deep valleys
Building type				
Subterranean (cave/complex/earth integrated)		🏛🏠🌡	🏛🏠🌡📹	🏛🏠🌡
Conventional 1 storey	🏛🏠💾	🏛🏠🌡💾	🏛🏠🌡💾📹	🏛🏠💾
Conventional 2 stories	🏛🏠💾	🏛🏠💾📹	🏛🏠🌡💾	🏛🏠💾
Conventional 3 stories	🏛🏠💾	🏛🏠💾	🏛🏠💾📹	🏛🏠💾
Building material				
Adobe	🏛🏠💾	🏛🏠💾	🏛🏠🛠🌡💾	🏛🏠💾
Stone	🏛🏠💾	🏛🏠💾	🏛🏠🛠💾📹	🏛🏠💾
Light: woven fabrics, reeds etc.	🏛🏠	🏛🏠	🏛🏠	🏛
Light: reused fabrics, metal sheets etc.	🏠💾	🏠🌡💾	🏠🌡💾	
Plan				
Square	🏛🏠💾	🏛🏠💾	🏛🏠🌡💾	🏛🏠💾
Rectangular	🏛🏠💾	🏛🏠💾	🏛🏠🌡💾	🏛🏠💾
Wall section and details				
2 layers dry ± plaster (mud/lime)	🏛🏠💾	🏛🏠💾	🏛🏠🛠🌡💾	🏛🏠💾
2 layers + mortar ± plaster (mud/lime)	🏛🏠💾	🏛🏠💾	🏛🏠🛠🌡💾	🏛🏠💾
Fenestration				
Door only	🏛💾	🏛💾	🏛💾	🏛💾
Door + window (various orientations)	🏛🏠💾	🏛🏠💾	🏛🏠💾	🏛🏠💾
Door + windows (various orientations)	🏛🏠💾	🏛🏠💾	🏛🏠🌡💾	🏛🏠💾
Roof				
Flat	🏛🏠💾	🏛🏠🖩💾📹	🏛🏠🖩🛠💾	🏛🏠💾
Vault	🏛🏠💾	🏛🖩💾📹	🏛🏠🖩🛠💾📹	🏛🏠💾
Dome	🏛🏠💾	🏛🖩💾📹	🏛🏠🖩🛠💾📹	🏛🏠💾
Light pitched	🏛🏠💾	🏛🏠💾📹	🏛🏠🖩💾	🏛🏠💾
Courtyard				
Enclosed	🏛	🏛🏠🌡	🏛🏠🌡	🏛🏠
Semi-enclosed	🏛🏠	🏛🏠🌡	🏛🏠🌡	🏛🏠
Adjacent	🏛🏠	🏛🏠	🏛🏠🌡	🏛🏠
Portico	🏛🏠	🏛🏠🌡	🏛🏠	🏛🏠
Peristyle	🏛🏠	🏛🏠🌡	🏛🏠	🏛🏠

Legend: 🏛 historical; 🏠 contemporary vernacular; 🖩 numerical modelling; 🛠 physical modelling; 💾 computer simulation; 🌡 monitoring; 📹 infrared thermography.

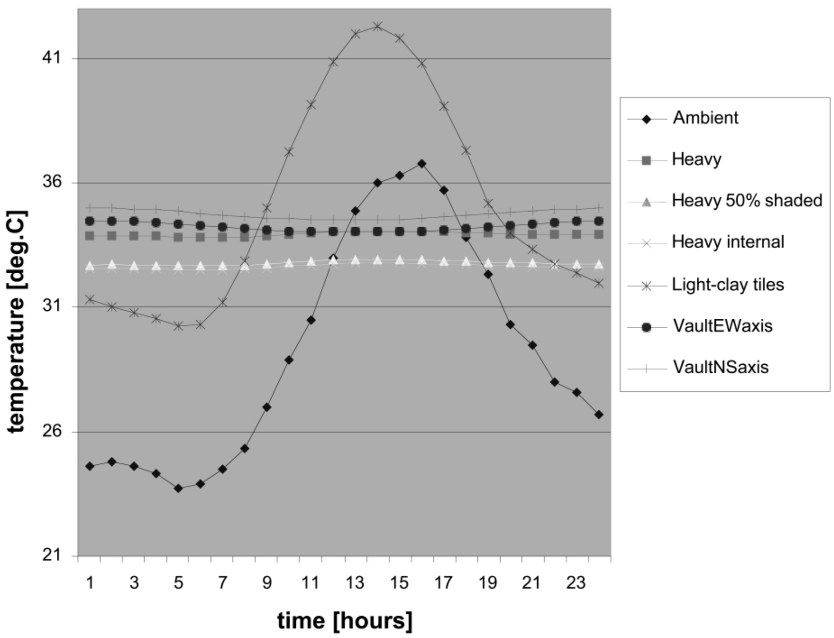
high thermal mass, with very limited fenestration area, usually unglazed. These properties make them very inert in relation to ambient daily fluctuations. However, this extreme inertia is counter-productive due to the inability of such structures to take advantage of solar gains in winter and of night cooling by cross ventilation in summer, primarily, but only, due to their limited fenestration size. Thus, the construction technology and building types traditionally considered to be, by default, adapted to the environmental constraints proved to be uncomfortably hot in summer and uncomfortably cold in winter for most of the hours of the day. The thermal performance of such buildings proved to be better in highland and mountain regions rather than the lowlands and more humid coastal plains. No significant differences were found between stone masonry and adobe construction.

Curved roofs were found to perform thermally better than flat ones by promoting more comfortable indoors. The geometric advantages of such roofs were originally investigated experimentally by Pearlmutter on test cells with negligible mass roofs (Pearlmutter 1993). Numerical modelling undertaken within the broader framework of the research described here showed similar results for massive curved roofs modeled under arid conditions (Runsheng, Meir and Etzion 2003a and 2003b). Results showed that a domed or vaulted roof absorbs more solar radiation than its corresponding flat roof. This increases with the increase of the half-dome or vault angle, but is insignificantly affected by the climatic characteristics and latitude of the location. However, the main reason for improved indoor conditions under a curved roof is exactly this enlarged surface area, which allows for more heat to be dissipated at night through radiation and convection. This, of course, limits the suitability of such geometry to areas with clear night skies, typical of continental and especially highland deserts, but not necessarily coastal ones.

Minor differences were found between vaults of different orientations. To quantify such discrepancies, numerical modelling was performed to estimate the insulation absorbed by vaulted and domed roofs, based on angular dependence of absorptance and solar geometry. A north–south facing vaulted roof was found to both reduce the solar heat gain of buildings in summer months and increase solar heat gain in winter months, compared to identical vaults facing east–west; the greater the proportion of area exposed to the sun, the smaller the amount of beam radiation that will be absorbed by a curved roof. Furthermore, results showed that even if absorptance were assumed to be constant this would affect the total solar heat gain of the roofs studied by less than four per cent (Runsheng, Meir and Etzion 2003a and 2003b). The role of the seemingly negligible windows positioned on the upper part of gable walls in such structures proved to be of very significant importance in the overall behaviour of the structures, when ventilation was applied to the model and the simulations.

The worst indoor temperature conditions measured and simulated were within buildings with light roofs. Shading was found to have a favourable effect in summer. However, having said that, it is important to mention that over fifty per cent of the thermal loads of buildings originate in the roofs and therefore

12.5
Monitored and simulated stone building on the Negev Highlands, with different roof details and configurations.



insulating a flat roof will have a much more profound effect than replacing it with a curved one.

Fenestration in such structures is typically negligible. In many cases it is limited to one opening only, a door. Where windows do exist they tend to be very small, a fact dictated by the construction technology and materials, as mentioned previously. Traditionally such apertures were unglazed, often totally blocked in winter to avoid heat losses, thus also minimizing delighting, while not solving entirely the problems of infiltration. This lack of fenestration and proper glazing materials did not allow the structures monitored and simulated to take advantage of the otherwise advantageous ambient conditions and temperature differences. In cases simulated with modified fenestration and operation regimes the improvement was limited, again due to excessive thermal mass.

One such case monitored and simulated is a stone structure typical of the Roman period in the Negev Highlands in Israel. It has an entrance door and four narrow and high slots (15 by 85 centimetres) located at about four metres above the floor in the wall perpendicular to that of the door. Both measured and simulated temperatures (for different orientations and operation modes of the windows and door) indicated a marginal rise of indoor temperature in comparison with an identical room simulated without windows. This marginal rise of approximately 0.5°C was similar in winter and summer, and may be attributed to air movement due to buoyancy differences and wind (Meir 2002).

Energy input for heating in winter, a necessity in most dry lands, turned out to be a significant burden. The most common sources of energy are firewood, dried dung and agricultural residue. Whereas the use of the former is considered one of the main contributors to desertification in semi-arid regions (Loevenstein *et al*. 1991; Sauerhaft *et al*. 1998), the use of all three has serious health implications, especially when they are burned within confined and poorly ventilated spaces, where the pollutants produced (some of which may well be carcinogenic) make respiratory complications as high as a thousand times more likely than when such biofuels are burned outdoors (Environmental Protection Agency 1995; Nazaroff *et al*. 2003).

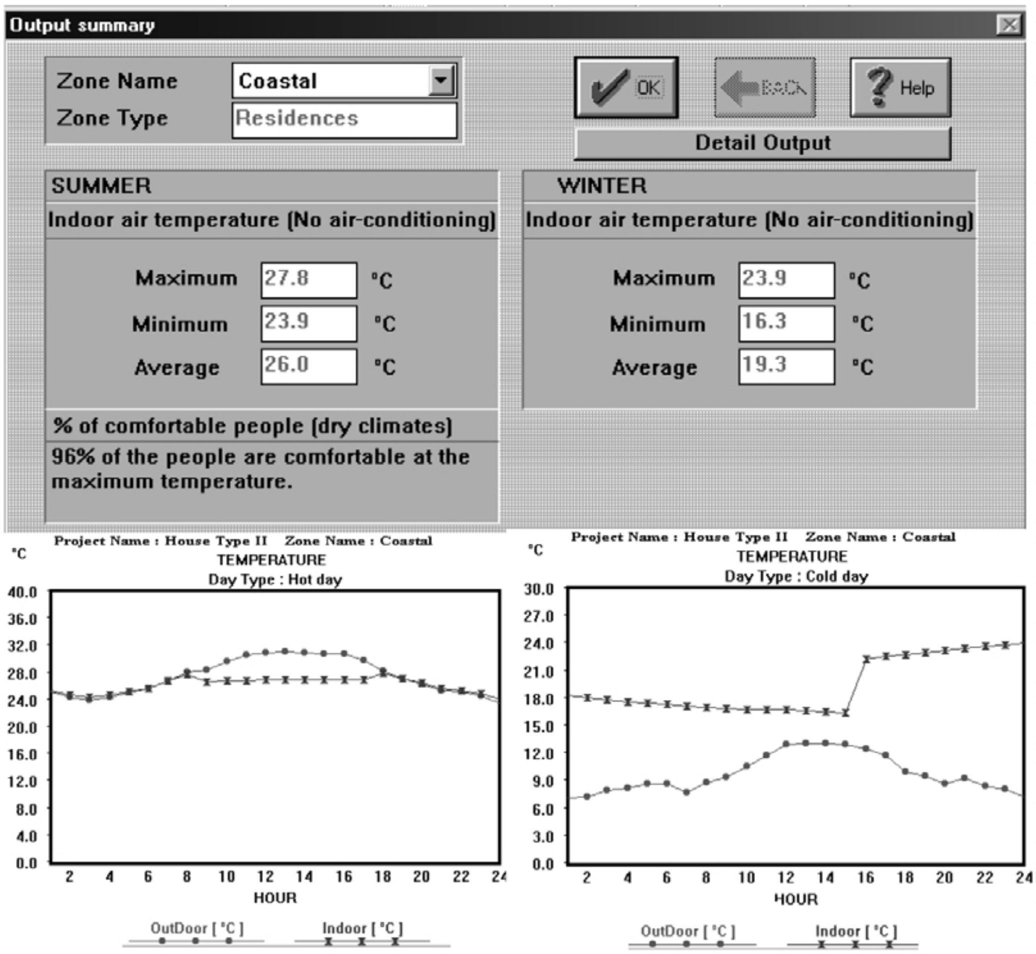
In many traditional settlements cooking is still done outside the main living quarters, either in a separate structure or in the open-air courtyard. However, winter heating is still a problem, since in many cases it is based on an open fire. Although no studies were done within this research regarding particles and pollutants common in the stone, mud or concrete buildings, or tin huts and tents, heated in this way in winter, the data available through parallel investigations point to some very disconcerting facts. Indoor air exposure to suspended particulate matter increases the risk of acute respiratory infections, one of the leading causes of infant and child mortality in developing countries. In Asia, such exposure accounts for between half a million and one million excess deaths every year. In sub-Saharan Africa the estimate is 300,000–500,000 excess deaths. Around 30–40 per cent of cases of asthma and 20–30 per cent of all respiratory diseases may be linked to air pollution in some populations (World Health Organisation 1999). Such cases may also be linked to poorly heated indoor spaces which encourage the growth of moulds whose spores are often allergenic (Smith 2003).

Fenestration alterations and enlargement, and roof insulation and/or shading were identified as vital for the improvement of thermal performance, especially when combined with a reasonable thermal mass, i.e. lower than that described above. A variety of insulating materials and details were investigated, among them various recycled materials. Simulation results showed that the 'resistive' insulation (that which resists or stops the passage of heat through a wall) plays a significant role only when the typically high thermal mass (the 'capacitive' insulation relying on the density and thermal capacity of the envelope to retard the heat flow) is reduced (Roaf et al. 2003). It was also demonstrated that the shading of heavy flat roofs can have a significant effect, lowering indoor temperatures by up to 3°C under certain conditions. Lightweight roofs, such as tile roofs already common in the Hellenistic, Roman and Byzantine periods, or, even worse, today's corrugated sheet metal roofs common in many developing countries, have an extremely negative effect on indoor temperatures, both in summer and in winter. Shading of flat roofs may have been a common practice in the past and can still be seen in Middle Eastern and Mediterranean villages, where vines provide summer shading, or where temporary shading is provided by 'transient layers' such as tobacco, peppers and other agricultural produce dried on the roofs. Fabrics may also have been used in the past, as indicated by details identified on the parapets of roofs.

These results showing poor indoor conditions explain the phenomenon of 'intra-mural migration'; i.e. the use of different parts of traditional housing prototypes for different parts of the year or the day, and especially the habit of sleeping on rooftops, balconies or in patios, where the summer night conditions may be significantly better than the indoor ones (Rapoport 1969). The educational aspects of this project, as it developed, were very important, too. Many of the students participating in different modules had been aware of the advantages of thermal mass in desert climates. Their intuitive reaction to the poor indoor conditions indicated by simulation was the addition of more thermal mass, which proved at best to have no effect. As a result, students participating in the project developed a much more realistic and practical attitude toward traditional building technology and details, and appropriate methods for the improvement of indoor climate and energy conservation. In most cases it was realised quite early on that part of the excessive thermal mass could be effectively replaced by insulation in

Table 12.2 An example of the simulation of heating and cooling loads of construction types, building parameters and modifications, in a highland desert climate – in this case, a mud building. Size indicates the estimated peak load demand for heating and cooling equipment. 'Units used' indicates the annual energy consumption.

									Cool plant		Heat plant	
		Summer			% of people comfortable at max temp.	Winter			Size KW	Units used KWh	Size KW	Units used KWh
Amman Mud		max	min	ave		max	min	ave				
AMud1	Base	23.4	22.5	23	100	4.9	4.7	4.8	0.1	33.5	1.7	2807.2
AMud2	Thicker roof	23.4	22.5	22.9	100	4.9	4.7	4.8	0.1	31.6	1.8	2851.4
AMud3	Thicker walls	23.4	22.5	22.9	100	4.9	4.6	4.8	0	7	1.4	2325.4
AMud4	Thinner roof	23.4	22.5	22.9	100	4.9	4.6	4.8	0.1	38.2	1.7	2796.8
AMud5	Thinner walls	23.9	23.1	23.5	100	5.2	4.9	5.1	0.2	75.2	2.5	4015.3
AMud6	Glass north window	23.4	22.5	23	100	5	4.7	4.8	0.1	36.7	1.8	2865.8
AMud7	Window in south	24.1	23.1	23.1	100	5	4.7	4.8	0.2	67.4	1.8	2870.9
AMud8	Internal insulation	24.2	22.1	23.2	100	5.2	4.5	4.8	0.2	52.8	1.4	2203.9
AMud9	Intermediate insulation	23.4	22.5	22.9	100	4.9	4.6	4.8	0	5.6	1.8	2711.4
AMud10	External insulation	23.4	2.5	23	100	4.9	4.6	4.8	0	9.8	1.2	1834.2
AMud11	Vent N window, E door	23.7	23.3	23.5	100	4.9	4.7	4.8	0.1	34.9	1.7	2740.1
AMud12	Vent W window, E door	23.5	17.1	20.1	100	4.9	4.7	4.8	1.7	129.3	1.7	2738.1



12.6
Building thermal performance improvements achieved through the introduction of compound wall constructions in simple houses in the Middle East, from an MSc study using the Building Toolbox model, by Rajat Gupta at Oxford Brookes University.

the centre or outside of compound wall constructions, with significant improvements to wall and building performance as a result (Meir, Mackenzie Bennett and Roaf 2001). The study also demonstrated that although summer cooling needs may be an important issue for certain arid regions (especially the hot continental valleys and the humid coastal plains), winter heating is vital for most arid regions, extremely so for the highlands and mountains.

Conclusions and implications

This ongoing study continues to highlight the need for the systematic research of historical, traditional and vernacular building types and technologies if we are to truly understand the living conditions of the past and present in such buildings. Such an understanding is vital if we are to improve living conditions for millions of people within a sustainable development framework (Roaf *et al.* 2004a). This, in turn, should take into account commonly available materials, construction methods and know-how, the opportunity for simple improvements and alterations at realistic costs, and particularly the possibility of enhancing comfortable indoor conditions with minimum auxiliary energy input.

Traditional and vernacular architecture is based on locally available materials and cultural dictates, which have given birth to interesting building forms and types, systems and details. Those should be studied and understood, yet in a critical way which will allow the true assessment of their interaction with climate vis-à-vis a rising demand for better, more comfortable and healthier indoor environments. The continuation of current, poor, practices within the vernacular building stock is worrying both from an environmental and a health point of view. Issues of poor indoor air quality and uncomfortable conditions are being further exacerbated by the growing numbers of people living in inadequate housing, and by the changing climate. Current research has established to a great degree of certainty the connection between urbanization, fossil fuel use, deforestation and land degradation, and unsustainable production processes on the one hand, and climate changes and unpredicted climatic extremes on the other hand. Such extreme climatic events, which are becoming more common in recent years, are leading to more uncomfortable indoor conditions and the accelerating processes of desertification, witnessed in the last few decades, in turn driving ever more people into ever poorer dwellings.

One of the important outcomes of this study, so far, stems from the counter-intuitive results of the monitoring and simulation studies. It is such 'intuition' stemming from 'common knowledge' and theoretically 'thoroughly established' historical paradigms that cause misconceptions and assorted problems, not least among NGOs and development organizations operating in developing countries, many of which are defined as deserts. Such misconceptions have given birth to housing units with massive walls and lightweight sheet metal roofing, as bad a solution as one could possibly conceive.

The majority of people in the world live in 'vernacular' buildings, evolved from antecedents in the distant past, and continually evolving into those buildings that will house future generations. Changing circumstances drive the evolution in buildings, just as the apogee of the opium trade in Hong Kong resulted in the great windcatchers of Yazd. The changes we face today are those of increasing populations, depletion of resources, pollution, rising prices of finite fossil fuels and climate change (Roaf *et al*. 2004b), each of which individually would be a reason for investing in improving the vernacular paradigms, but put together add up to a compelling imperative for change. Applied building performance studies such as those outlined above, can generate the understanding not only of how such buildings work today, but also of how they can be modified to optimize their performance in the future. This can be done with minimal economic and environmental costs, as some recent research is aiming at demonstrating, either by using local traditional solutions (Esteves *et al*. 2003) or by using innovative processes based upon traditional building methods, such as those using recycled or re-used waste materials (Garcia Chavez 2004).

We believe that, using these and other methods, every student in every school of architecture around the world should be taught to understand how local traditional buildings work in relation to the local cultures, climates, environments and economies within which they provide shelter. In so doing students will be able to acquire a deeper understanding of how buildings really perform, and can be improved. Such knowledge will provide an essential foundation from which to build the more resilient, and regionally appropriate, buildings that are essential if we are to survive the exigencies of the twenty-first century.

Notes

1 Numerous individuals, groups and institutions have contributed so far to this ongoing research. Parts of the parametric studies were undertaken by graduate students at the Department of Architecture of Oxford Brookes University, UK (2000–1), and the Albert Katz International School for Desert Studies, at the Blaustein Institute for Desert Research, Israel (2001–4). Infrared thermography processing was done in co-operation with Wolfgang Mutzafi-Haller. Partial results were summed in a paper co-authored by Meir, Gilead, Runsheng, Mackenzie Bennett and Roaf (2003). Access to and work in archaeological sites in Israel was facilitated by the Israel Nature and National Parks Protection Authority. The help of these and many others is kindly acknowledged.