A parametric study of traditional housing prototypes from the Middle East

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ABSTRACT

Historical, traditional and vernacular housing prototypes have been considered as inherently adapted to the constraints of the natural environment. Such a deterministic attitude has often led to the wrong conclusions regarding appropriate technologies and solutions in general, and in particular those relevant to low cost housing for developing countries. This paper analyses a number of generic types of housing common around the Middle East and the Mediterranean, and assesses their performance vis-à-vis different low-tech upgrade and retrofit strategies. A number of methods and techniques were employed, including monitoring, modeling, numerical analysis, simulation and infrared thermography. Investigations included different building technologies and materials, morphologies and details, under different arid conditions typical of the Middle Eastern climatic regions.

INDEX TERMS

Climate; Construction; Energy efficiency; Modelling; Sustainability

INTRODUCTION

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). This, of course, is only an illustration. Similar examples are numerous and can be encountered throughout the professional (and academic) literature.

To address such issues in a systematic way, this paper presents a combined operation including theoretical and fieldwork studies undertaken by the Desert Architecture and Urban Planning Unit in the Negev Desert, Israel, with theoretical, simulated model studies undertaken within the Energy Efficient Buildings program in Oxford Brookes University. The parametric studies undertaken include *in-situ* monitoring; 1 : 1 scale model monitoring;

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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 semiarid and drylands conditions typical of much of the Mediterranean area. 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.

This paper summarizes interim results of ongoing research, parts of which have been presented at previous PLEA Conferences.

METHODS

In situ surveys, data collection and literature survey indicated that although the overall number of specific cases was relatively large, these could be easily 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, 1932–1933; Ragette, 1980; Khammash, 1986; Hirschfeld, 1995). These included various forms, morphologies and geometries, materials and technologies, geoclimatic location and dispersal, details and variations. Their systematic study would eventually need *in situ* monitoring, but first of all there was need for the development of a methodology that would allow for checking and coordinating actions. This methodology would have to provide appropriate strategies and solutions to overcome several problems and limitations, such as access to potential sites, partial preservation of buildings, monitoring in occupied buildings, security and safety, and a large numbers of parameters. The solution chosen was a multi-partite system based on the following procedures and protocols:

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;
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 paper, and the procedures and protocols followed are summarized in Table 1. They represent hundreds of runs of simulated models (primarily with Quick/Easy and Toolbox, but also Ecotect, Daylight, and others), and hundreds of days of *in situ* surveying, photographing 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, 2000; 2002; Meir and Gilead, 2002; Meir and Roaf, 2002; Meir *et al.*, 1995, 2001; Pearlmutter and Meir, 1995; Peeters and Meir, 2003; Tang Runsheng *et al.*, 2002).

Table 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 one storey	🏛🏘💾	🏛🏘🌡💾	🏛🏘🌡💾📹	🏛🏘💾
Conventional two stories	🏛🏘💾	🏛🏘💾📹	🏛🏘🌡💾	🏛🏘💾
Conventional three stories	🏛🏘💾	🏛🏘💾	🏛🏘💾📹	🏛🏘💾
Building material				
Adobe	🏛🏘💾	🏛🏘💾	🏛🏘🛠🌡💾	🏛🏘💾
Stone	🏛🏘💾	🏛🏘💾	🏛🏘🛠💾📹	🏛🏘💾
Light: woven fabrics, reeds etc	🏛🏘	🏛🏘	🏛🏘	🏛
Light: reused fabrics, metal sheets etc	🏘💾	🏘💾	🏘🌡💾	
Plan				
Square	🏛🏘💾	🏛🏘💾	🏛🏘🌡💾	🏛🏘💾
Rectangular	🏛🏘💾	🏛🏘💾	🏛🏘🌡💾	🏛🏘💾
Wall section and details				
Two layers dry ± plaster (mud/lime)	🏛🏘💾	🏛🏘💾	🏛🏘🛠🌡💾	🏛🏘💾
Two 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 modeling; 🛠 physical modeling; 💾 computer simulation; 🌡 monitoring; 📹 infrared thermography.

RESULTS AND DISCUSSION

The results have been quite interesting from the research point of view. Most historical and vernacular prototypes are, by nature, of 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 counterproductive due to the inability of such structures to take advantage of solar gains in winter and of night cooling by cross-ventilation in summer. Thus, the construction technology and building types traditionally considered by default adapted to the environmental constraints proved to be uncomfortably hot in summer and very much so in winter for most of the hours of the day.

The thermal performance of such buildings proved to be better on highland and mountain regions rather than the lowlands and more humid coastal plains. No significant differences were found between stone masonry and adobe construction. Minor differences were found between vaults at different orientations, which tended to be almost as poor as flat massive roofs. It is important to stress that such conclusions are based on monitoring, simulation and thermal imaging. These also comply with numerical modeling, which sowed that for certain geometric configurations, the heat flux through curved roofs may eventually have an overall result similar to that of flat roofs, due to the different in/out ratio during day and night (Tang Runsheng *et al.*, 2002). Fenestration typical of such structures had very limited effect even when glazed.

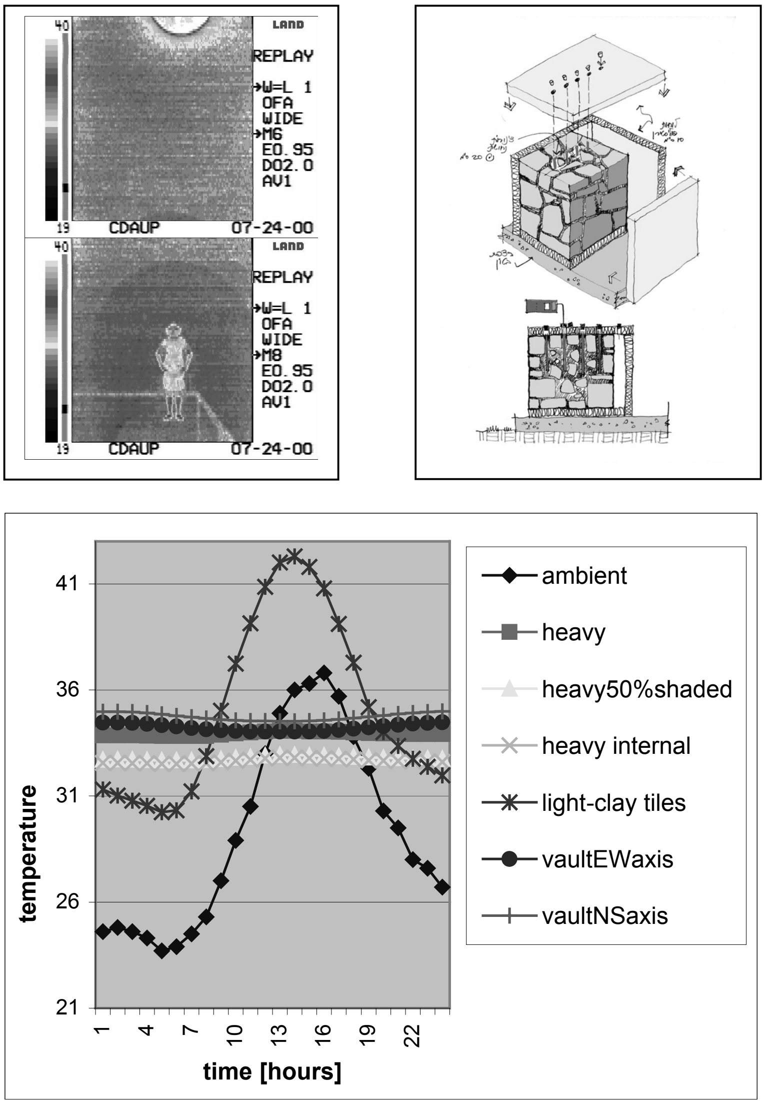

Figure 1 Top left: surface temperatures within a stone building with dome; top right: 1 : 1 masonry model built and monitored under real conditions to allow simulations calibration; bottom: simulated stone building with different roof details and configurations.

Energy input for heating in winter—a necessity in most drylands—turned out to be a significant burden. The most common sources of energy are firewood and dried dung. Whereas the use of the former is considered to be one of the main contributors to desertification in semiarid regions, the use of both has serious health implications, especially when burned within confined and poorly ventilated spaces.

Fenestration alterations and enlargement, and roof insulation and/or shading were identified as vital for the improvement of thermal performance. A variety of insulating materials and details was investigated, among them various recycled materials.

Simulation results showed that insulation plays a significant role only when the typically high thermal mass of the buildings is reduced. 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, and that lightweight roofs, such as tile roofs which became common in religious and public buildings in the Roman and Byzantine periods, have an extremely negative effect on indoor temperatures, both in summer and in winter. Shading of 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 explain the phenomenon of 'intramural migration', namely 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 seem to be significantly better than the indoor ones.

The educational aspects of the project were very important, too. Many of the students had been aware of the advantages of thermal mass in dry climates. Their intuitive reaction to the poor indoor conditions indicated by simulation was addition of 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 realized quite early that lowering the amount of thermal mass was indeed a necessity.

The study also demonstrated that although cooling needs in summer may be an important issue for certain arid regions (especially the hot continental valleys and the humid coastal plains), heating is vital for most arid regions, extremely so for the highlands and mountains.

CONCLUSIONS AND IMPLICATIONS

This ongoing study has shown the need for the systematic research of historical, traditional and vernacular building types and technologies towards establishing the base for a better understanding of living conditions in the past, as well as in the present. Such an understanding is vital for the upgrading of living conditions within a sustainable development framework. This should take into account commonly available materials, construction methods and know-how, simple improvements and alterations, and especially the possibility to create comfortable indoor environments with minimum auxiliary energy input. The ramifications of current practices are more than worrying both from an environmental and a health point of view. They are exacerbated by the growing numbers of people living in unsustainable housing types, by the enhanced desertification processes witnessed in the last few decades, and by the interface of these two.

One of the important outcomes of this study so far stems from the counterintuitive results of 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 developmental 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.

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