A systematic approach to scientific study of traditional architecture

Ardeshir Mahdavi[1], Lyudmila Lambeva[1], Dina K. Shehayeb[2], Alaa El-Habashi[3]

[1] Department of Building Physics and Building Ecology
Vienna University of Technology, Vienna, Austria
[2] Housing and Building National Research Center, Giza, Egypt
[3] Faculty of Architecture, University of Monofiya, Egypt

ABSTRACT: We present the systematic framework and the initial results of an effort to obtain, analyze, and interpret data from traditional "hammam" (bath) buildings in six Mediterranean countries. This work is part of a larger interdisciplinary research effort supported by the European Union with the aim of a comprehensive understanding of the technical and social aspects of hammams, including their current state, role, and functionality, as well as their future potential. We specifically illustrate the matrix of outdoor and indoor environmental parameter to be monitored together with the corresponding instrumentation tools and data collection processes. These parameters mainly relate to the thermal and visual performance of the objects studied (air temperature and humidity, wind velocity, solar irradiance, illuminance, etc.). We describe how data thus obtained will be used to calibrate computational (simulation) models of the buildings. Such models can be used to better understand the specific bio-climatic performance features of traditional architecture and to evaluate alternative options for their improvement, restoration, and reuse.

Keywords: Traditional architecture, hammam, building performance and diagnostics

1. INTRODUCTION

Traditional buildings are believed to embody numerous intelligent design features, emerged and refined through the historical process of adjustment to local climatic conditions and social functions [1]. To tap into this potentially rich source of design knowledge, a deeper understanding of the working of such environmentally adapted buildings is necessary. Toward this end, the typically available general qualitative descriptions of the respective design strategies are insufficient. Rather, detailed performance analyses are needed that are based on high-resolution empirical performance data.

The present contribution attempts to introduce a systematic framework applied in an effort to obtain, analyze, and interpret data from traditional buildings. Specifically, local climate and building performance data are to be collected for six traditional hammam buildings in the Mediterranean countries. This work is part of a larger interdisciplinary research effort supported by the European Union with the aim of a comprehensive understanding of the technical and social aspects of hammams, including their current state, role, and functionality, as well as their future potential [2].

The present contribution focuses specifically on the matrix of outdoor and indoor environmental parameters to be monitored together with the corresponding instrumentation tools and strategies. These parameters mainly relate to the thermal and visual performance of the objects studied (air temperature and humidity, wind velocity, solar irradiance, illuminance, etc.). We describe how data thus obtained is intended to be used toward calibration of computational (simulation) models of buildings. The application of such simulation models can deepen the better understanding of the specific bio-climatic performance features of traditional architecture. Moreover, such digital models can facilitate the evaluation of alternative options for the improvement, restoration, and reuse of such traditional buildings.

2. METHODOLOGY

2.1 General approach

The main objectives of the research effort are to:

a) Collect local climatic data;

b) Collect data pertaining to indoor conditions in the selected building objects;

c) Collect data concerning the construction methods and materials used in the buildings;

d) Analyze and interpret the collected data in view of the buildings' salient design features (location, massing, apertures, thermal mass, etc.);

e) Create a digital performance simulation model of the building using collected building construction and local climate data;

f) Calibrate the digital models using collected indoor climate data;

g) Use the calibrated digital models toward assessment of the buildings' performance and prediction of the consequences of alternative options for the renovation, restoration, reuse, and adaptation of traditional buildings.

2.2 Research objects

Six operating hammam buildings have been designated as the main study objects of the project. These are located in Egypt, Turkey, Morocco, Palestine, Syria, and Algiers. In order to enable comparisons – particularly from the morphological point of view – it is intended to consider a number of additional hammams in these countries for further studies. The first case study was conducted early 2006 in Cairo, Egypt. Thereby an operating hammam and a currently inoperative hammam were visited and studied by an international team of experts, supported by a local team of architects and conservation specialists.

2.3 External conditions

Reliable, detailed, and up-to-date data pertaining to the micro-climatic conditions at the respective sites of the selected objects are currently not available. Such data is, however, for the evaluation of the performance characteristics of buildings indispensable. Thus, within the framework of the project, the external micro-climatic conditions are to be monitored using a dedicated weather station in the close proximity of each of the six operating building objects over a period of at least one year. The weather stations are to monitor outdoor air temperature and relative humidity, wind speed and direction, and global horizontal irradiance (see Table 1).

Table 1: Monitored external climate parameter

Parameter	Symbol	Unit
Outdoor air temperature	θ_e	^oC
Outdoor air relative humidity	RH_e	%
Global horizontal solar irradiance	$E_{e, glob, hor}$	$W \cdot m^{-2}$
Wind speed	v	$m \cdot s^{-1}$

2.3 Internal conditions

To gain quantitative building performance data, indoor climate conditions are also to be monitored over a period of one year in a number of representative rooms in each building object using autarkic data loggers. The parameters captured by the loggers include indoor air temperature and relative humidity as well as illuminance (see Table 2).

Table 2: Monitored indoor environmental parameter

Parameter	Symbol	Unit
Indoor air temperature	θ_i	^oC
Indoor air relative humidity	RH_i	%
Illuminance	E	lx

2.4 Construction information

The construction of the main constitutive building components (such as walls, doors, windows, roofs, etc.) are to be documented systematically based on local expert information and available literature. If possible, complementary material tests are to be performed on a case by case basis. The results (a number of layer properties of the constitutive building components) are to be uniformly structured in terms of a building component documentation template (cp. Table 3). Thereby, the layers' thickness, density, thermal conductivity, specific heat, and vapor diffusion resistance are to be specified.

Table 3: building component documentation template

Department of Building Physics and Building Ecology (Director: Univ. Prof. Dr. A. Mahdavi), Vienna University of Technology, Austria						
Building Component Catalogue	Project: Hammam, Task: O		Object:		Location:	
Component:	Layers	Thickness **d** [m]	Density **ρ** [kg.m^{-3}]	Conductivity **λ** [W.m^{-1}.K^{-1}]	Spec. Heat **c** [J.kg^{-1}.K^{-1}]	Diff. Res. **μ** [-]
Sketch:						
	R_{si} [m^2.K.W^{-1}]: R_{se} [m^2.K.W^{-1}]:	**Σ = d** [m]:	**m** [kg.m^{-2}]:	R_t [m^2.K.W^{-1}]:	**U** [W.m^{-2}.K^{-1}]:	

2.5 Energy source

One of the tasks within the overall framework of the hammam project is the study and evaluation of the buildings' energy systems. Thereby the energy source types (fuel, electricity, etc.), and the type and quality of water and space heating systems are specified. Such information, together with the hammam use and heating schedules will provide additional information toward generation of digital performance models of the buildings.

3. A CASE STUDY

3.1 The object

As mentioned earlier, the objects of the first case study were located in central Cairo, Egypt. An operating hammam was designated as the main object for technical assessment and data-collection purposes (see Figure 1). A second – currently inoperative hammam – was visited for comparison and benchmarking purposes (see Figures 2 and 3). Given the currently effective project confidentiality requirements and related agreements with the respective owners, these hammams are not identified here with their actual names, but referred to using the following codes, namely EC_OP (for the operational hammam) and EC_NO (for the currently non-operative hammam).

Figure 1: Hammam EC_OP; Interior views. Left: caldarium; right: passage from frigidarium to caldarium (pictures by A. Mahdavi)

Figure 2: Hammam EC_NO; Interior view of frigidarium (al-maslakh; picture by A. Mahdavi)

Figure 3: Hammam EC_NO; Interior view of caldarium (beit al-harara; Picture by A. Mahdavi)

3.2 Weather station

Since it was not possible to install the weather station directly on the roof of the hammam EC_OP, it was mounted on the roof a close-by building some 300 meters away (see Figure 4).

Figure 4: Weather station location (picture by A. Mahdavi)

3.3 Internal data loggers

Seven indoor data loggers were placed in different locations in the hammam (cp. Figures 5 to 7). Care was taken to collect data (cp. Table 2) from thermally distinctive Hammam zones, including the entrance area, frigidarium, and caldarium.

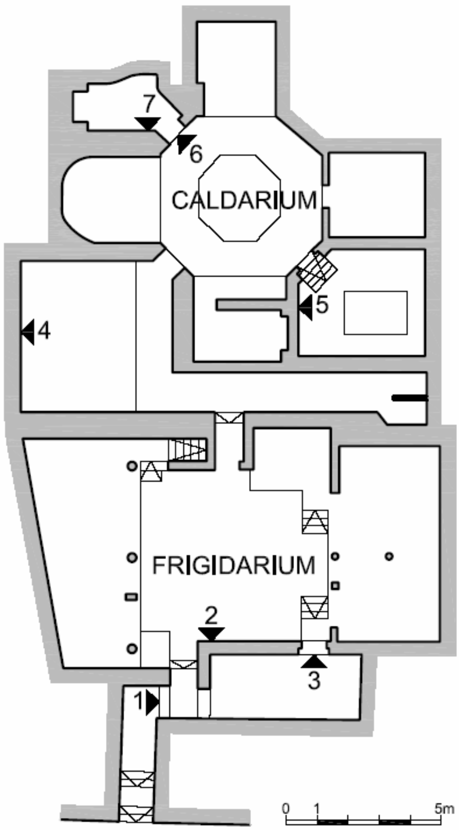

Figure 5: Schematic hammam plan with pointers to the locations of the 7 internal data loggers (the plan was generated based on a sketch provided to the authors by J. Bouillot)

Figure 6: Installation of indoor climate data loggers in caldarium, hammam EC_OP (picture by L. Lambeva)

Figure 7: Data logger mounted in the shower space adjacent to caldarium, hammam EC_OP

3.4 Initial data

Weather station data and indoor climate data in hammam EC_OP are being collected continuously since March 2006. Figures 8 to 11 provide an impression of the initial results. Figure 8 shows the outdoor air temperature (WS) and indoor temperature measurements in four positions in hammam.

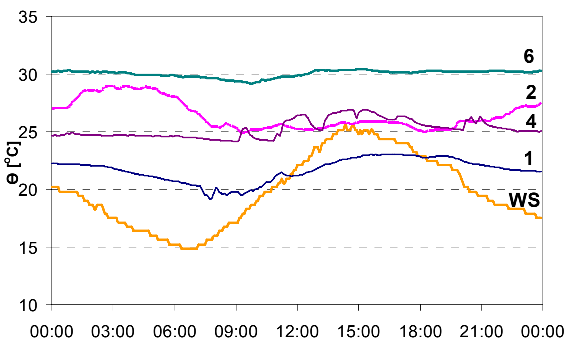

Figure 8: Measured outdoor (WS) and indoor temperature levels in hammam EC_OP (04.03.2006). See Figure 5 for indoor sensor positions

Figure 9 shows the measured outdoor (WS) and indoor relative humidity levels in EC_OP.

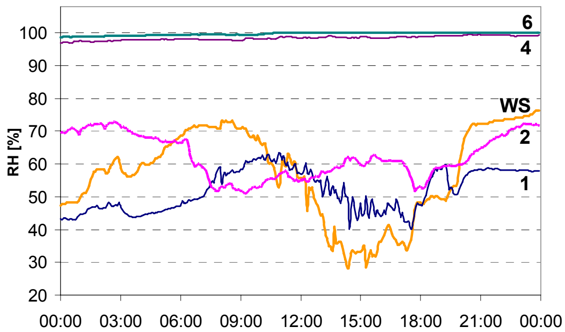

Figure 9: Outdoor (WS) and Indoor relative humidity levels in hammam EC_OP (04.03.2006). See Figure 5 for indoor sensor positions

Figure 10 shows the same information in terms prevailing water vapor pressure levels in order to provide a more clear indication of differences in water vapor presence in different hammam zones.

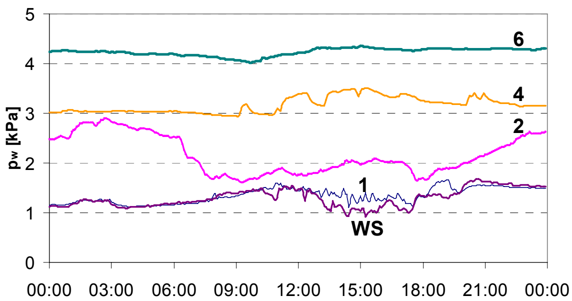

Figure 10: Outdoor (WS) and Indoor water vapor pressure levels in hammam EC_OP (04.03.2006). See Figure 5 for indoor sensor positions

Figure 11 depicts measured horizontal illuminance levels (at a height of about 1 m above the floor) in various spaces in hammam EC_OP.

3.5 Initial Observations

Data is being collected for object EC_OP since March 2006. The installation of sensors in the other five hammam buildings is to be completed before the end of 2006. Upon collection of sufficient amount of data, a thorough comparative analysis of the environmental performance of these buildings will be possible. As to the object EC_OP, certain initial observations can be made, despite the rather small amount of data collected to date:

i) Comparison of measured outdoor and indoor temperature values suggests the temperature swing dampening effect resulting from the considerable thermal mass of the structure (cp. Figure 8);

ii) Both temperature and relative humidity measurements confirm the expected gradation of indoor climate conditions from the entrance (frigidarium) area toward the hot and wet hammam core (caldarium) (cp. Figures 8 to 10);

iii) Consideration of occupancy use patterns is indispensable for the understanding of certain aspects of the collected indoor environmental data. For example, air temperature and relative humidity measurements in zone 2 of EC_OP point to an increase around 2:00 am to 5:00 am (see zone 2 readings in figures 8 to 10). This increase cannot be explained based on data monitored by weather station, as, during this time period, outdoor air temperature shows a decrease and relative humidity remains relatively stable. A possible explanation of this circumstance points to the occupancy pattern. The frigidarium area in this hammam is used for overnight stay by travelers using hammam. The presence of these users (and the operation of two table-top stoves that provide boiling water for tea and contribute to space heating) may explain the raise in both temperature and humidity during the night hours.

iv) Consideration of occupancy use patterns may be also useful to explain the reason for certain conditions in the hammam. For example, the temperature of the intermediate space (as captured by sensor 4) may appear to be rather low (see Figure 8), thus raising concerns regarding possible harm to the users (i.e., catching cold). However, the use pattern of this intermediate space may provide an explanation. In case of EC_OP, this space is used by men as a temporary relief zone (from extreme heat and humidity) between successive stays in caldarium. Women, on the other hand, use this space as a socialization realm after they are done with caldarium and are already clothed.

v) Given the small transparent portion of building envelope (probably a result of both privacy concerns and an attempt to avoid low surface temperatures), the illumination of hammam spaces makes little use of daylight. Illumination levels (rather low in some spaces) are – even during the daylight hours – primarily provided by electrical lighting (cp. Figure 11).

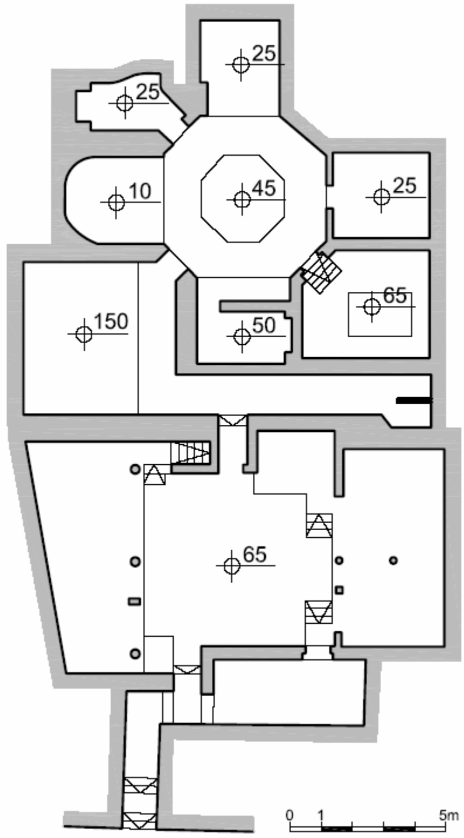

Figure 11: Measured horizontal illuminance levels (expressed in lx) in various spaces of hammam EC_OP (03.03.2006)

3.6 Preparatory model generation work

As mentioned earlier, one of the possible applications of the collected external and internal climatic data is to support generation of digital simulation models of the research objects. Toward this end building geometry, component specifications, and weather data are primarily necessary as input parameters (cp. Figure 12). Upon the availability of such data in the required level of resolution, an initial simulation model can be generated. Thereby, additional input data regarding internal loads (people, lights, heating introduced in the spaces via hot water delivery) and ventilation effects will be assumed based on available documentations of hammam use patterns as well as boiler capacity and operation schedule. These assumptions will be subsequently tested and refined based on consideration of multiple iterative simulation runs.

By comparing the prediction results of the simulation models with corresponding measured indoor environmental parameters, the models can be calibrated. Such calibrated models can not only provide insights as to the performance characteristics of the buildings, but can also be used to assess, compare, and ultimately evaluate the consequences of various alternative restoration and adaptation options for the future use of traditional buildings.

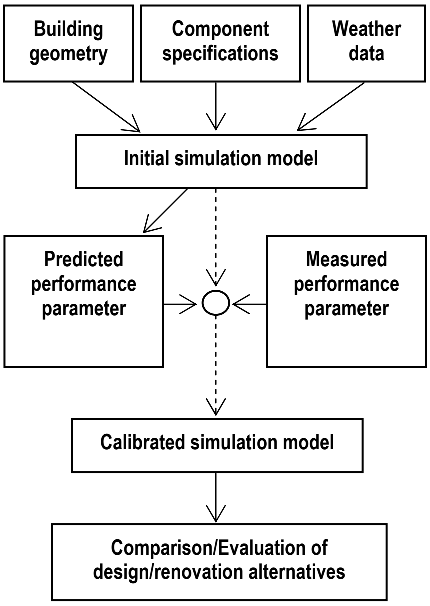

Figure 12: Schematic illustration of the process of simulation model generation, calibration, and application

4. CONCLUSION

Using the example of historic hammam buildings, we presented a systematic approach for the scientific study of traditional buildings. This approach involves the collection of detailed high-resolution data pertaining to:

i) Building geometry and construction;
ii) Energy system for water and space heating and illumination,
iii) External and internal climatic data, and
iv) Use and occupancy patterns.

Such data can support the understanding of the salient design features of traditional architecture and support, thus, the restoration of existing objects and the design of new ones. This can be specifically facilitated by the generation of calibrated digital performance models of the buildings based on data collected in the course of the project.

REFERENCES

[1] Mahdavi, A. A Human Ecological View of "Traditional" Architecture. Human Ecology Review (HER). Autumn 1996. Volume 3, Number 1. pp. 108 - 114.
[2] http://www.hammams.org.

ACKNOWLEDGEMENTS

The research presented in this paper is supported, in part, by a grant by the European Union; project: "Hammam, Aspects and Multidisciplinary Methods of Analysis for the Mediterranean Region", EU-FP 6th contract no: 517704.

The authors would also like to acknowledge the support of Dr. Dalila El-Kerdany, the leader of the local case study group in Cairo and the members of her team.

Mohamed Elwazir and Abdeslam Taleb supported the authors toward the assembly and installation of the weather station for external data monitoring.

Dr. El-Habashi is supported by Omneya Abdel Baar and Mohamed Mokhtar in performing regular data downloads from weather station and internal data loggers.