CALIBRATING BUILDING SIMULATION MODELS BASED ON INDOOR AND OUTDOOR ENVIRONMENTAL MONITORING

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ABSTRACT

We present the systematic framework and the initial results of an effort to obtain, analyze, and interpret indoor and outdoor environmental data for traditional buildings in six Mediterranean countries. We specifically illustrate the matrix of outdoor and indoor environmental parameter to be monitored together with the corresponding instrumentation tools and data collection processes. We describe how data thus obtained will be used to calibrate 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.

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 (Mahdavi 1996). 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, computational simulation models can provide analytical support. However, to be effective, such simulation models need to be calibrated based on reliable empirical information. We present in this contribution the systematic framework and the initial results of an effort to obtain, analyze, and interpret indoor and outdoor environmental data for 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 and future potential (Hammam 2006). 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.

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) Create a digital performance simulation model of the building using collected building construction and local climate data;
e) Calibrate the digital models using collected indoor climate data;
f) 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.

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. The first case study was conducted early 2006 in Cairo, Egypt. The second case study was conducted in July 2006 in Ankara, Turkey.

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 monitor outdoor air temperature and relative humidity, wind speed and direction, and global horizontal irradiance (see Table 1).

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 1
Monitored external climate parameter

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

Table 2
Monitored indoor environmental parameter

Parameter	Symbol	Unit
Indoor air temperature	θi	°C
Indoor air relative humidity	RH_i	%
Illuminance	E	lx

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. Thereby, the layers' thickness, density, thermal conductivity, specific heat, and vapor diffusion resistance are to be specified.

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.

Preparatory model generation work. An important application 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.

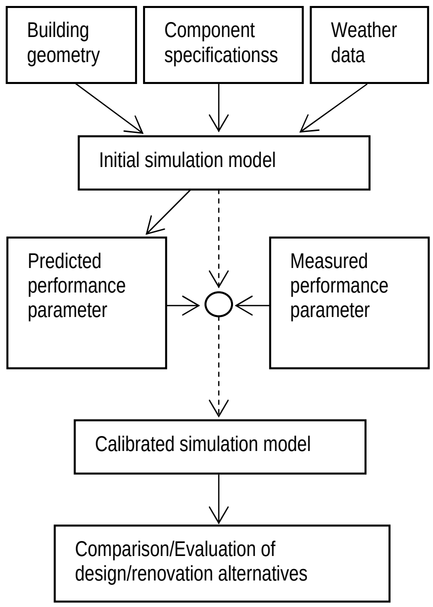

Figure 12 Schematic illustration of simulation model generation, calibration, and application

DATA COLLECTION: A CASE STUDY

The object. 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).

Weather station. The weather station was mounted on the roof a close-by building some 300 meters from hammam location.

Internal data loggers. Seven indoor data loggers were placed in different locations in the hammam (cp. Figures 5 to 7).

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.

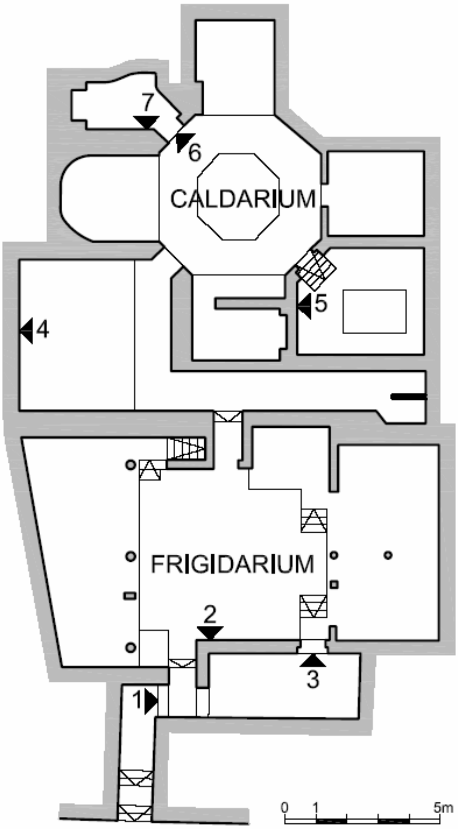

Figure 5 Schematic Cairo hammam plan with locations of the 7 internal data loggers (plan was generated based on a sketch by J. Bouillot)

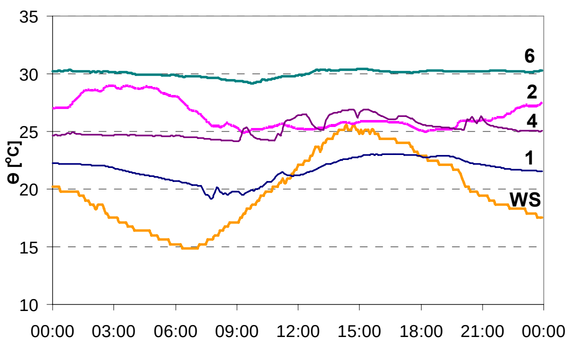

Figure 8 Measured outdoor (WS) and indoor temperature levels in hammam EC_OP (04.03.2006). See Figure 5 for indoor sensor positions

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

Initial Observations. Data is being collected for object EC_OP since March 2006. Data monitoring equipment for a second hammam in Ankara, Turkey was put in place in July 2006. The installation of sensors in the remaining four hammam buildings is to be completed early 2007. Upon collection of sufficient amount of data, a thorough comparative analysis of the environmental performance of these buildings will be possible. Subsequently, the calibration process of the performance simulation models for these buildings can be initiated.

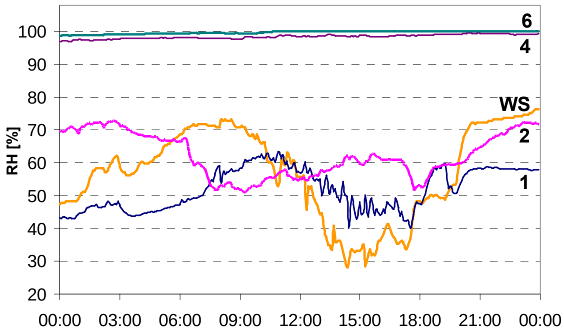

Figure 9 Outdoor (WS) and Indoor relative humidity levels in hammam EC_OP (04.03.2006). See Figure 5 for indoor sensor positions

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

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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. Dina Shehayeb and Dr. Alaa El-Habashi for the collection of information pertaining to Cairo case study.