Report Summary

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ENVIRONMENTAL PERFORMANCE OF BUILDINGS

A comparative study of building materials and construction techniques in Turkey

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Figure 1: Yasemin and Nevin in the Village of Şahmuratlı, Yozgat.

Figure 2: The Babayiğit House after a long winter.

This report summarises the findings of a collaborative project supported by the British Council under its Britain-Turkey Partnerships Programme. The project combined short-term measurements of environmental variables in and around selected buildings in Turkey with a series of parametric studies using a computer simulation model. The measurements were taken in four, single-storey, detached buildings in the village of Sahmuratli in Yozgat, Central Anatolia (latitude 40^{o}N) over short periods in the summer and autumn 2002. Comparative study of the recorded data has highlighted the importance of the thermal properties of external and internal building elements and revealed differences between buildings of traditional construction and those built recently. To investigate thermal performance in more detail as well as provide the basis for more general conclusions, computer modelling was undertaken and a series of thermal simulation runs were performed. To reach this stage in the project, dimensional and constructional surveys were carried out of each of the buildings to obtain numerical data for the three-dimensional CAD models and to identify the construction of building elements. The first sets of thermal simulation runs were performed under similar weather and occupancy conditions of those of the actual to predict hourly indoor temperatures that were then compared with the temperature readings taken on site. Following calibration of the thermal models against measured data, a series of parametric studies were then performed for each of the buildings by varying the thermal properties of constructional elements measuring the effect of these changes on occupant thermal comfort in summer and on the likely energy consumption for space heating in winter. These studies have provided valuable insights on the kind of construction techniques and building materials required for improving the thermal performance of residential buildings in the central regions of Turkey.

The report that follows describes the climate of the region, the selection of buildings for the study, the methods followed for the surveys, measurements and simulations and the results obtained for each of the buildings studied. Comparisons have been drawn between the performance of different materials and techniques and general conclusions relate to the next stage of research.

Climate And Climate-Responsive Building Design

The climate of the study area is characterised by cold winters and warm summers. Winter outdoor air temperatures are near or below freezing in December and January, staying below thermal comfort values for much of the period between October and April, Fig. 3. In summer, the outdoor air temperature rises to peaks above 30ºC in July and August, and displays considerable diurnal fluctuation. Figure 3. shows a plot of daily maximum, mean and minimum values for each month against thermal comfort bands derived from thermal neutrality as a function of seasonal adaptation to outdoor conditions. The figure also gives plots of direct and diffuse solar irradiance on a horizontal surface in W/m2. These have similar seasonal patterns to those of the air temperature with mean daily total values for global (direct plus diffuse) radiation of 1.7 kWh per m2 in December (lowest sunshine month) rising to a mean daily of 7.7 kWh/m2 in July.

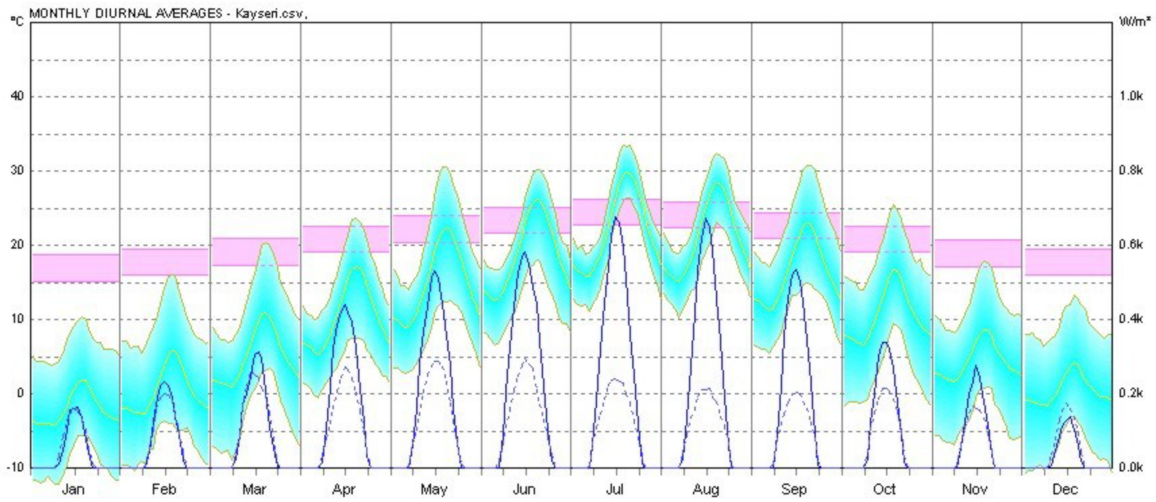

Figure 3: Diurnal range of outdoor air temperature (green bands) and solar radiation on a horizontal surface (values of direct radiation shown by solid blue lines and diffuse by broken lines) for Kayseri plotted against thermal neutrality bands (shown in pink).
(Source: Meteonorm software for generation of hourly weather data and Weather Tool software for graph).

This climatic profile suggests that for summer, in addition to solar control, it is necessary to have adequate thermal capacity in the building structure to provide an interim heat sink that can prevent overheating and occupant thermal discomfort indoors, whilst night-time ventilation and/or radiative cooling can act as the means of permanent heat dissipation from the building. For winter, if indoor temperatures of 15-20ºC are to be maintained indoors in order to provide adequate occupant thermal comfort, a high level of thermal insulation will be required to cope with the very large temperature differences (in the region of 20K and at times higher than 30K in the coldest months) that will result between indoors and outdoors. Sunshine levels on south-facing vertical surfaces are high throughout the winter (averaging some 3.0 kWh/m2 per day throughout the heating season) suggesting that passive solar gains can make an important contribution to space heating loads. Figure 4 provides an indication of the theoretical potential for climate-responsive design based on weather data for Kayseri.

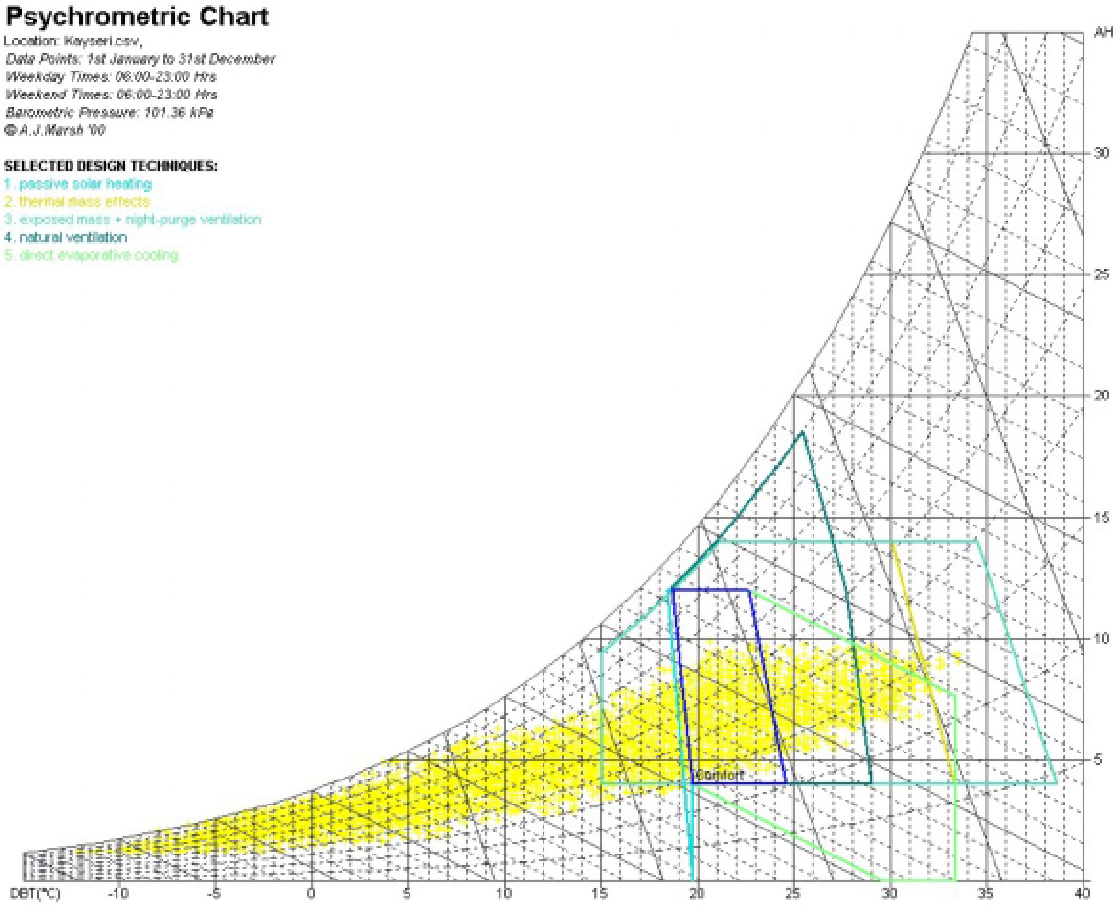

Figure 4: Hourly data for a Kayseri year plotted against thermal comfort zones on psychrometric chart (Source: Meteonorm and Weather Tool software).

The weather data required for this study were obtained from the database included in the Meteonorm software1. This included hourly and mean monthly values of ambient air temperature, relative humidity, solar radiation and wind direction and velocity based on readings of meteorological stations in the vicinity of the city of Kayseri. A further dataset was produced in the same way for Goztepe, a location with a milder climate, and was used for comparisons. The weather data generated by Meteonorm were reformatted for use with the Weather Tool2 and Ecotect3 software to produce the graphs shown below and to drive the thermal simulation runs discussed in following sections of this report.

[1] Meteonorm version 4.06 (2000). Meteotest, Bern.
[2] WEATOOL v1.10 (2001). Square One Ltd.
[3] Ecotect v5.0 (2002). Square One Ltd.

Partnership Visits

The first partnership visit took place in August 2002. Yasemin Somuncu of the Architectural Association in London came to the Middle East Technical University where she briefed the Ankara team on the use of the equipment and software, and was able to help with the initial setting up. In March 2003, Françoise Summers and Nevin Gezer travelled to London where they attended the conference and workshops at the Architectural Association. Finally Simos Yannas came to Turkey in April

The Data Loggers

The Tinytag data loggers (Fig. 5) are used to record temperature and humidity data at predetermined intervals over set periods of time. This particular type of instrument can be used both inside and outside since it has been designed to withstand extreme environments. In this project two loggers are being used; one placed inside the building and the other one outside. The loggers should not be placed in direct sunlight, near heat producing apparatus or exposed to precipitation. Placement in a discrete location ensures that they do not get moved or lost. It must be noted that short wave radiations can interfere with the data collection. The interior data logger should be placed in a location where there is control over openings, such as windows, and activities. All changes must be recorded.

GLM is the software with which the data loggers are launched and downloaded. It allows the duration and interval readings for the measurements to be set as desired.

Figure 5: Tinytag data logger with the sensor protected by a black spherical frame.

Collecting Data in Şahmuratlı Village

Data was collected in the village of Şahmuratlı, Yozgat in August, September, October 2002 and March 2003. Charts displaying the data are appended. Four houses were chosen as described below.

Four, single-storey, detached dwellings were selected for the study in the village of Sahmuratli in Yozgat, Central Anatolia (latitude 40^oN). One of the buildings is occupied during late spring and autumn only, whilst the other three are occupied throughout the year. All four buildings have relatively small, single glazed windows distributed evenly on their elevations. Figure 6 shows plans of the buildings at same scale identifying the rooms where the temperature and humidity readings were taken. The buildings differ in their levels of thermal insulation and thermal capacity.

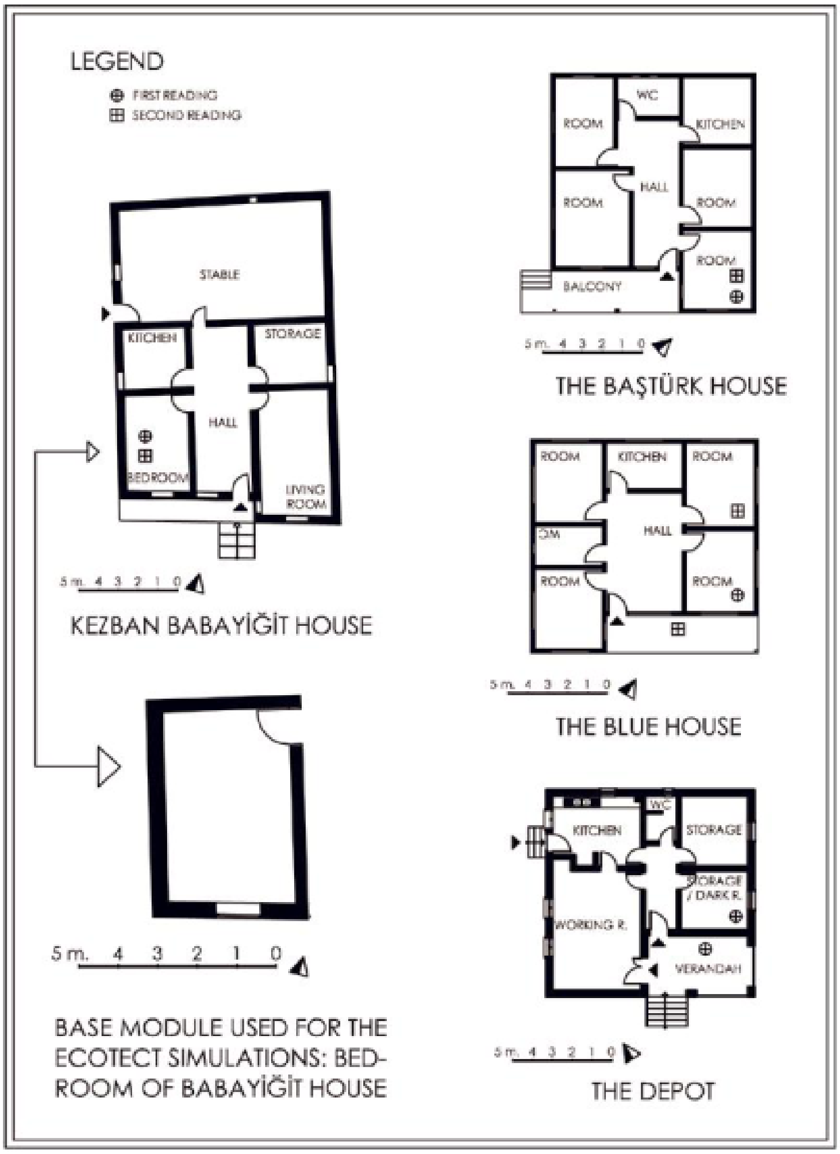

Figure 6: *Plans of the four selected dwellings to same scale.*

- Kezban Babayiğit House: traditional stone and mud-brick wall construction with flat Roof.
- Blue House: recent construction of single leaf hollow brick wall with pitched roof
- Baştürk House: as above.
- The Depot: recent construction with thermal insulation on hollow brick external walls and on pitched roof.

Figure 7: The Babayiğit House.

Figure 8: The Blue House

Figure 9: Photo Showing the Garden (South) Elevation of the Bastürk House.

Figure 10: The Kerkenes Depot House.

Data and charts

When the data is downloaded, charts are produced to illustrate the results graphically. Each house that has been studied was measured in order to produce CAD drawings and 3D models. The different building materials and architectural elements have been noted.

Ecotect software is used to make models of existing structures and to simulate different environments that could be created as a result of the modification of architectural elements and building materials.

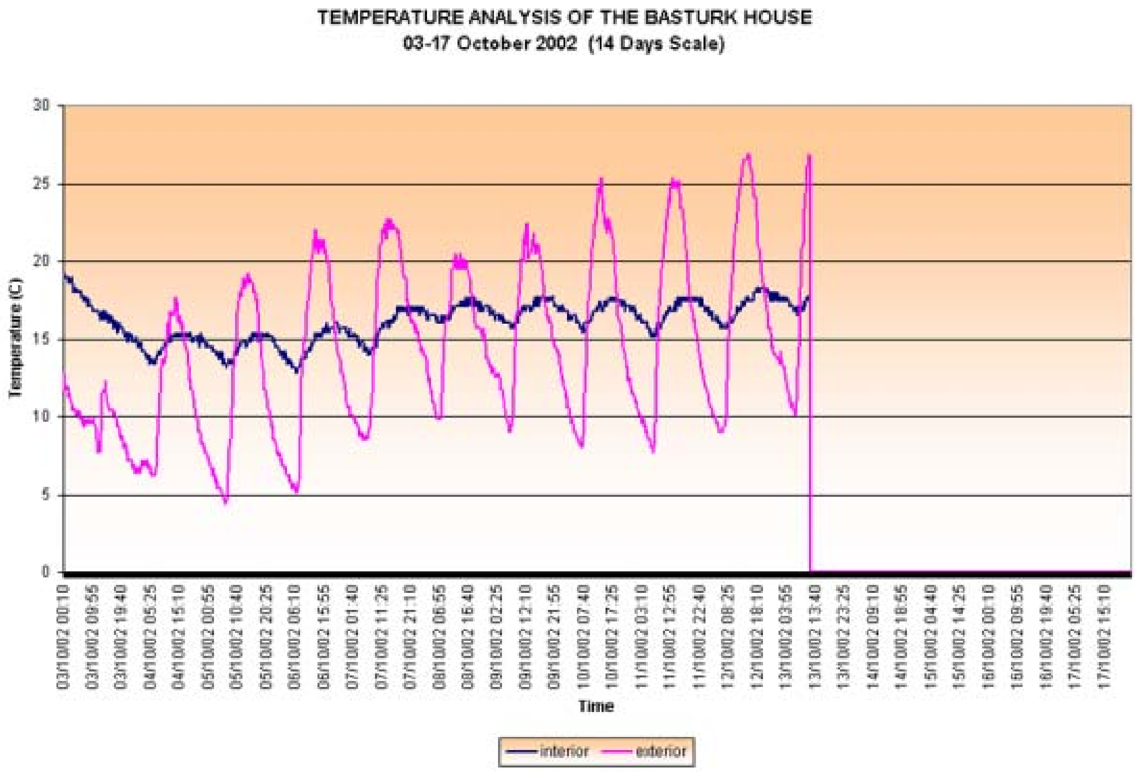

Figure 11: Temperature Analysis of the Basturk House (03-17 October 2002).

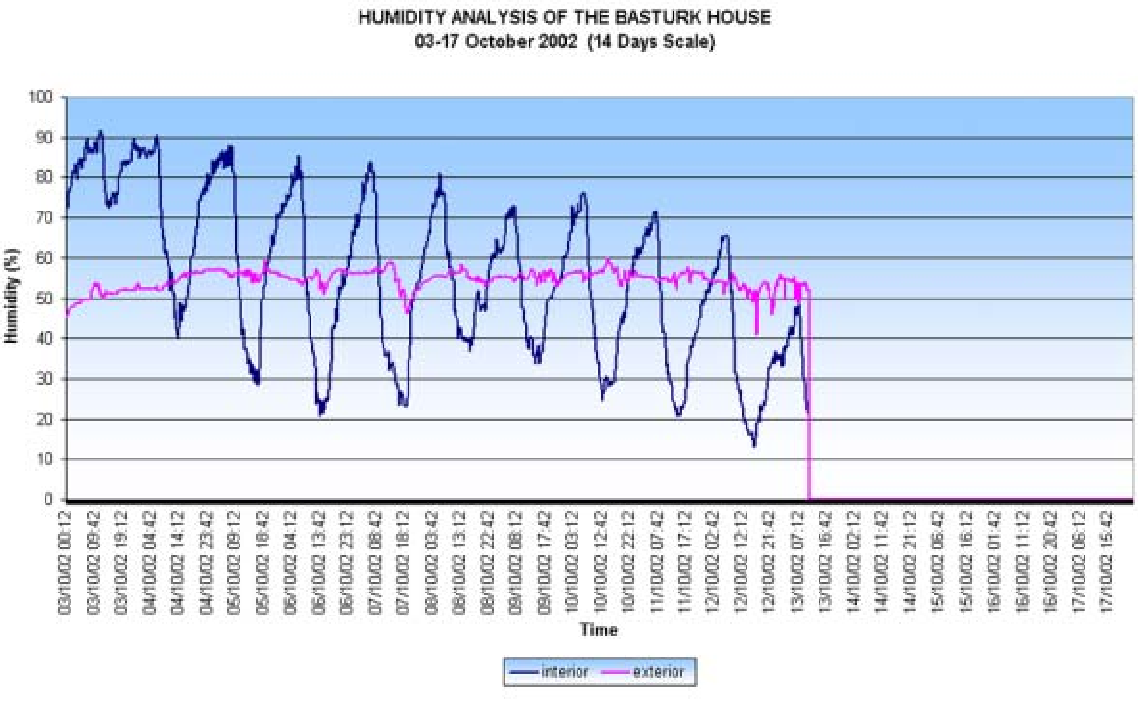

Figure 12:. Humidity Analysis of the Bastürk House (03-17 October 2002).

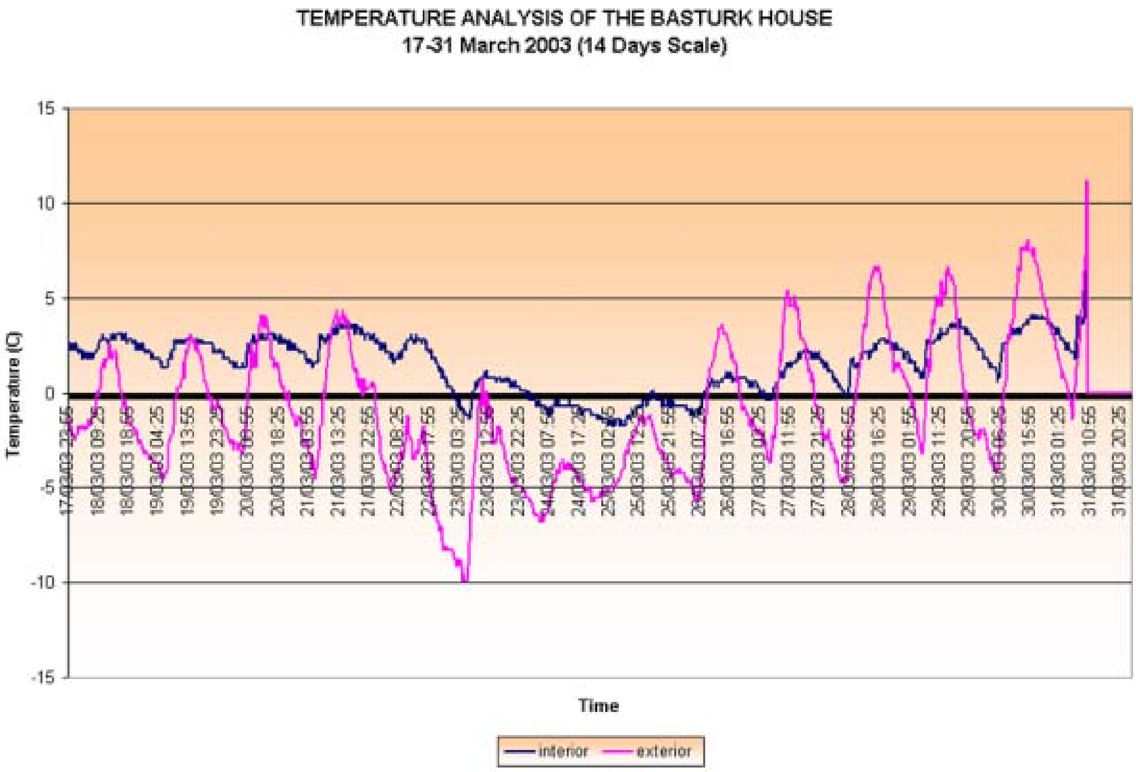

Figure 13: Temperature Analysis of the Bastürk House (17-31 March 2003).

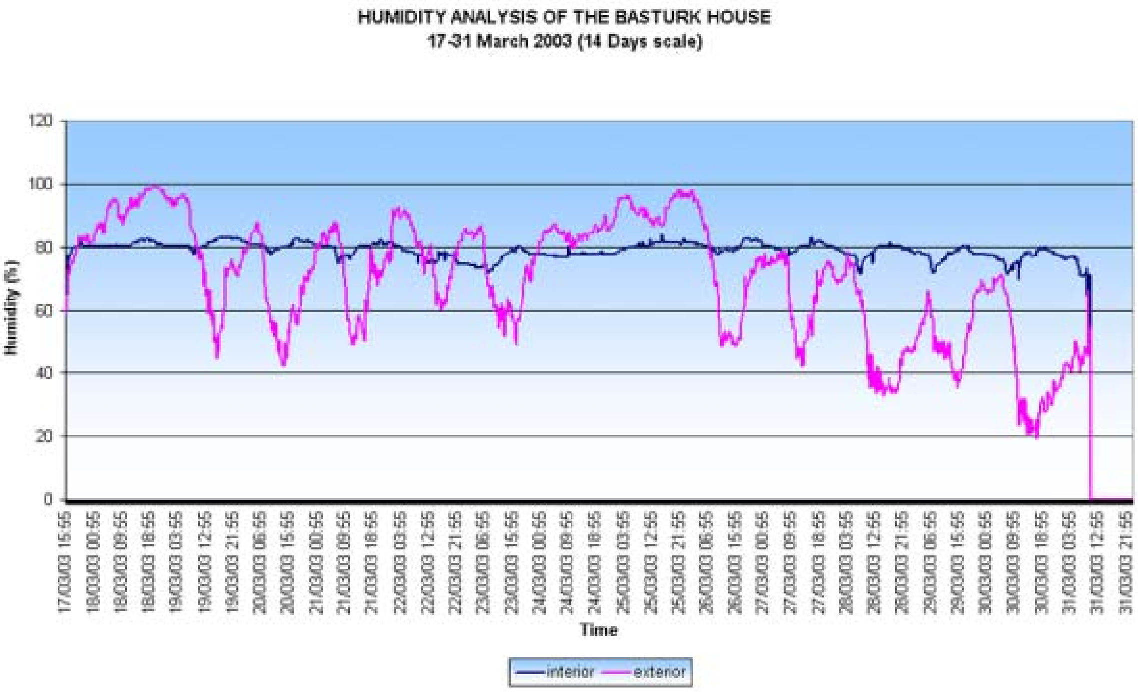

Figure 14: Humidity Analysis of the Bastürk House (17-31 March 2003).

Results

The first set of results given in the graphs below are based on simulations performed on the model of the Bastürk House and are shown for the room where the data loggers were placed for temperature and humidity readings. Internal and external walls were modelled as built of a layer of 190mm hollow brick plastered on both sides. The thermal transmittance (U-value) calculated for this construction was of 1.63 W/m^2K and the thermal admittance (Y-value) 4.54 W/m^2K. For the room with the data loggers the total thermal conductance of the external envelope was of 55.9 W/K and the total thermal admittance of internal surfaces was of 382.6 W/K. As the room is exposed to the outside on three of its sides the external wall represent a considerable proportion of the rate of heat loss through the building envelope. The room's air exchange rate was assumed as 0.5 air changes per hour (ac/h). The room had a floor area of 76.532 m2 and single glazed windows of 3.1m2 total area. Comparison between measured and simulated data for this configuration for a day in October shows a good match.

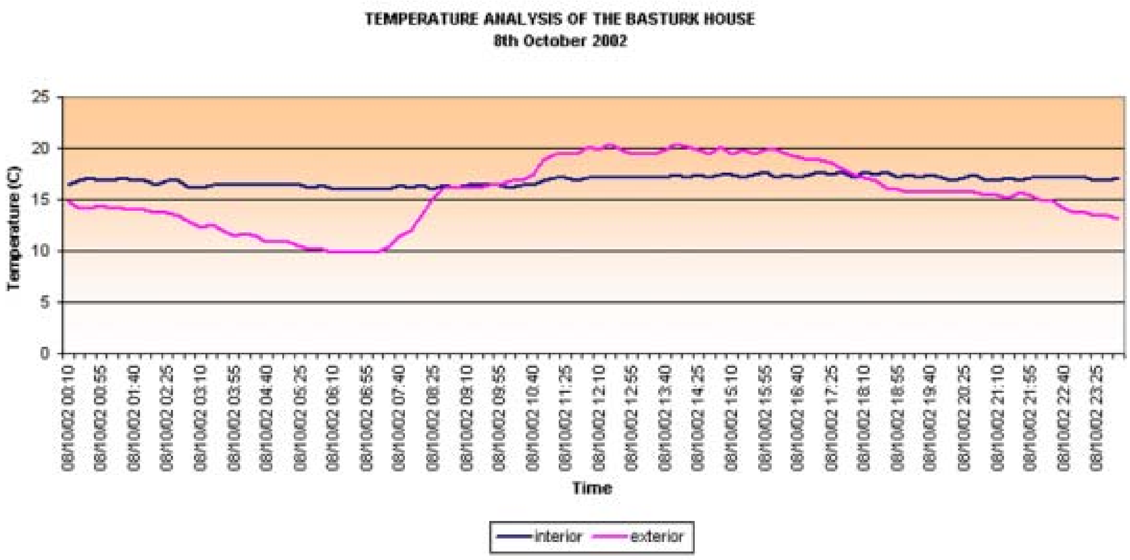

Figure 15: Graph Showing Temperature Distributions. (8th of October)

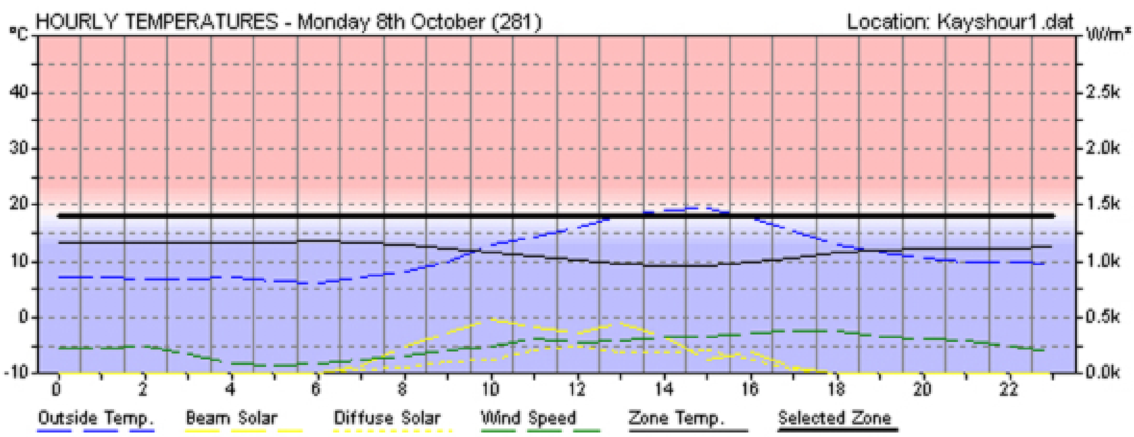

Figure 16: Graph Showing Hourly Temperature Distributions. (8th of October)

A further set of simulation runs was used to investigate the effect on thermal performance of different materials. This is shown in the graphs below as a comparison between the simulated monthly heating and cooling loads resulting from maintaining internal temperatures at a mean of 18ºC in the heating season and 26ºC in summer using a hypothetical air-conditioning system.

Figure 17 shows results for the thermal configuration of the house as built and as summarized above. In the second run the house was modelled with mud-brick internal and external walls plastered on both sides. This configuration was calculated to have a U-Value of 1.24 W/m2K and Y-Value of 4.32 W/m2K. In a third run the house was modeled with external walls as being of two layers of hollow bricks with 100mm thermal insulation in the cavity giving a U-Value of 0.30 W/m2K and Y-Value of 3.52 W/m2K.

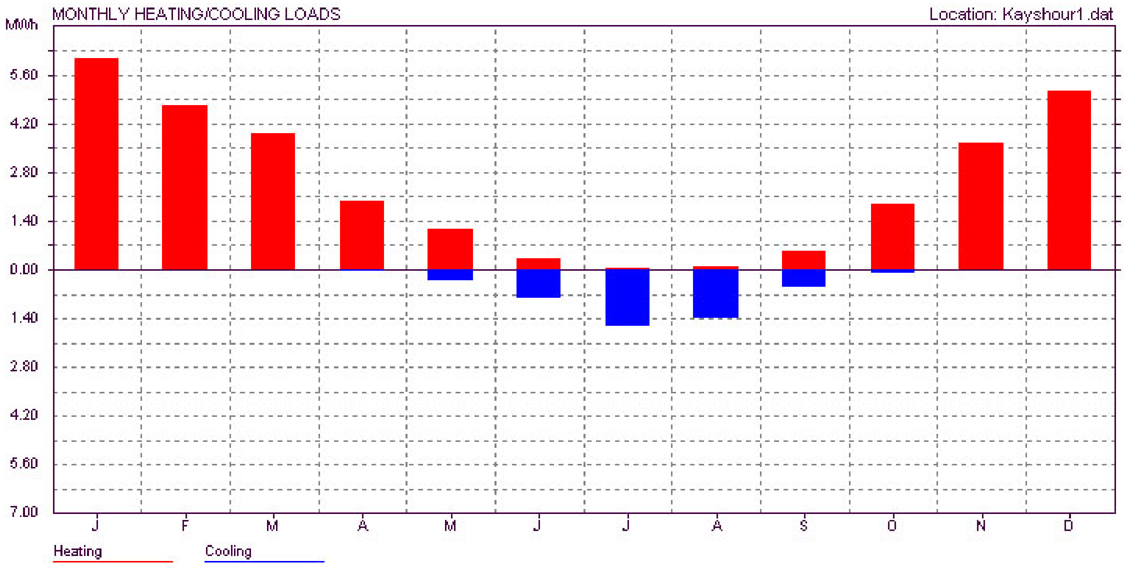

Figure 17: Monthly Heating/Cooling Loads of Basturk House with Hollow-Brick Walls.

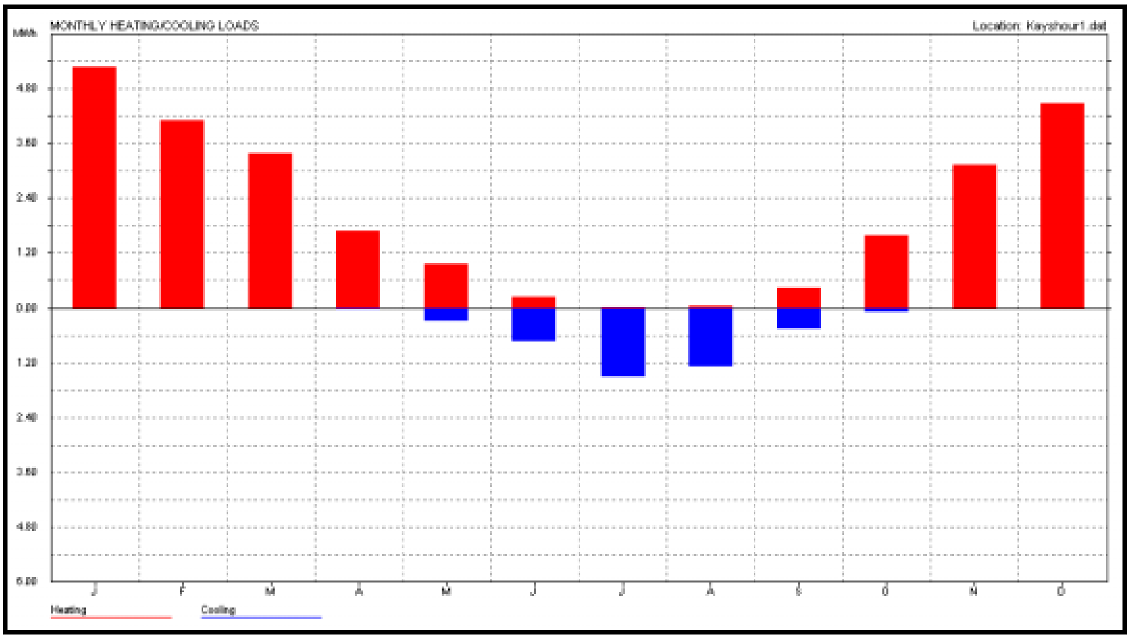

Figure 18:Monthly Heating/Cooling Loads of Basturk House with Mud-Brick Walls.

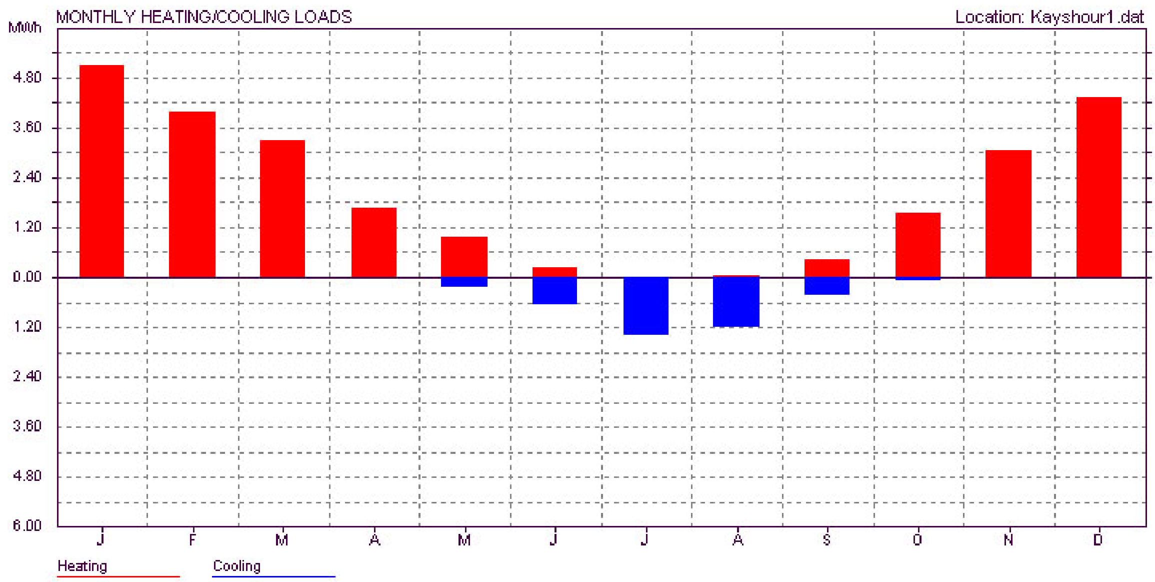

Figure 19: Monthly Heating/Cooling Loads of Basturk House with Hollow Brick Walls with Insulation.

Comparisons between results show that the mud-brick wall configuration could provide a considerable decrease in heating loads compared to the uninsulated hollow brick wall (owing to its lower calculated U-value), but has a lesser effect on cooling loads (its calculated admittance value is very similar to that calculated for the brick construction). As expected the effect of thermal insulation applied to a cavity wall construction is shown to lead to a considerable reduction in space heating loads. In a cold climate like Yozgat's, heating loads dominate the annual year energy requirements, so reducing those would be a priority and the mud-brick walls could provide an advantage compared to uninsulated hollow brick.

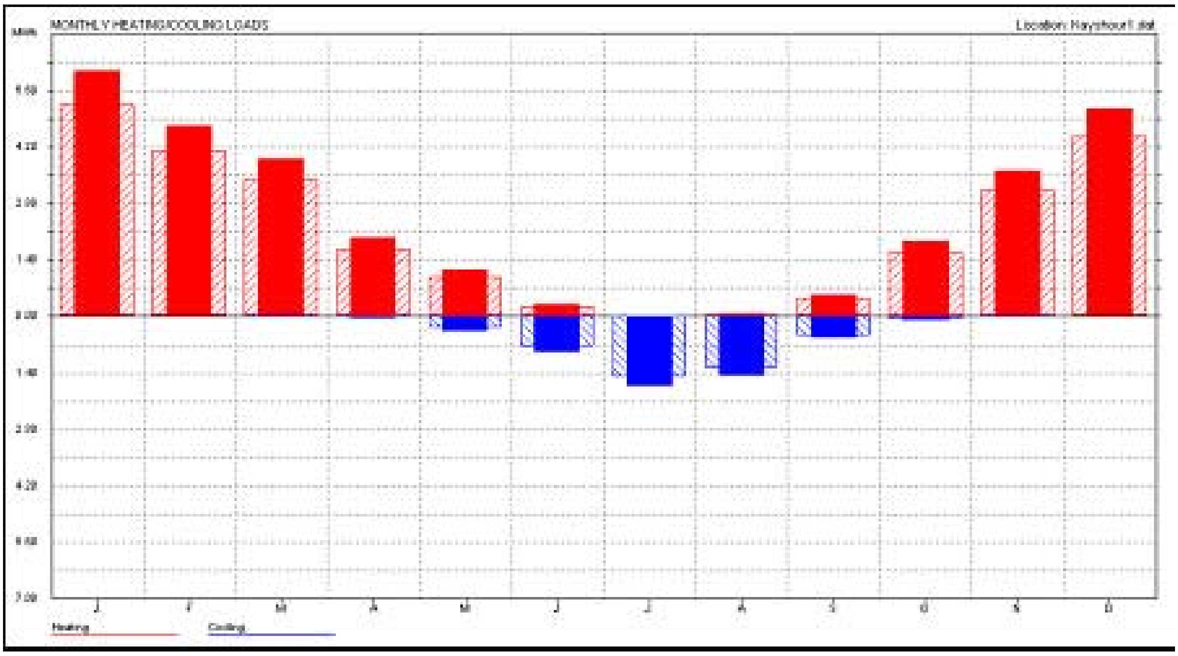

Figure 20: A Comparative Graph Showing Monthly Heating/Cooling Loads of Basturk House with Hollow- Brick and Mud-Brick Walls. Hatched Bars Showing the loads with Mud-Brick Walls and Solid Bars Showing the loads with Hollow-Brick Walls.

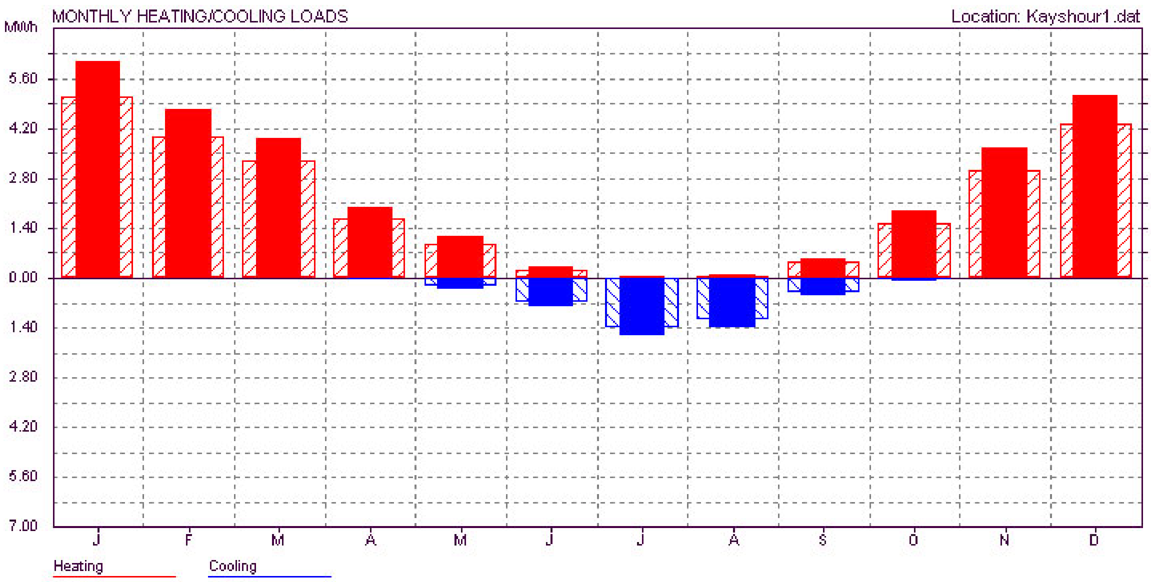

Figure 21: Comparative Graph Showing Monthly Heating/Cooling Loads of Basturk House with Hollow-Brick with and without Insulation. Hatched Bars Showing the loads with Hollow-Brick Walls with Insulation and Solid Bars Showing the loads with Hollow-Brick Walls without Insulation.

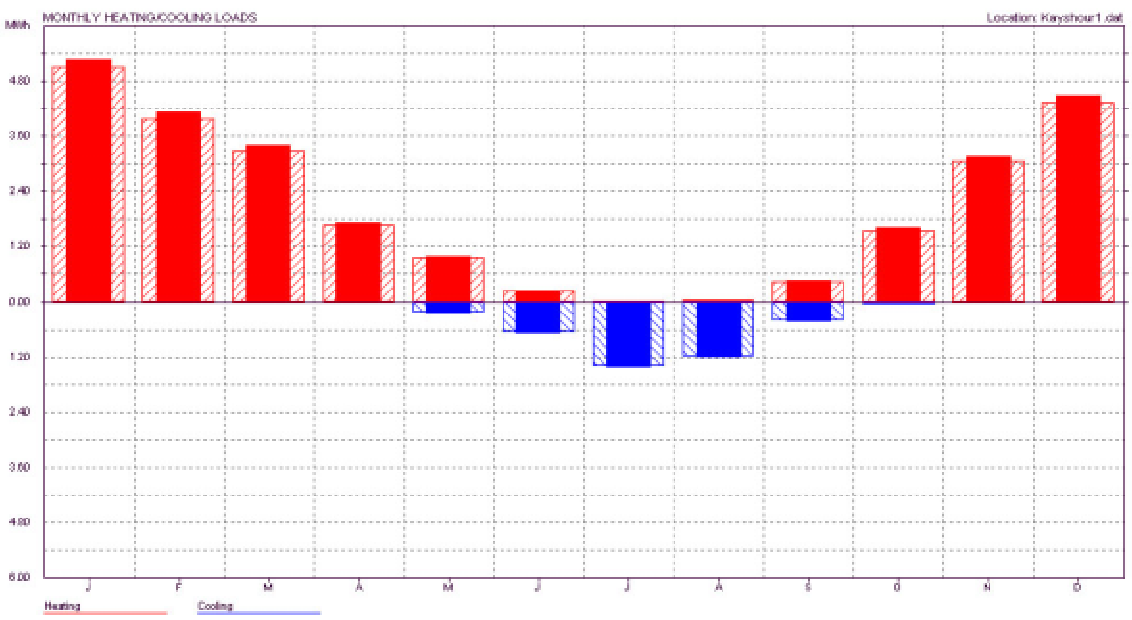

Figure 22: A Comparative Graph Showing Monthly Heating/Cooling Loads of Basturk House with Hollow-Brick-Insulation and with Mud-Brick Walls. Hatched Bars Showing the loads with Hollow-Brick Walls with Insulation and Solid Bars Showing the loads with Mud-Brick Walls.

It is possible that the U-value and Y-value calculations which are based on speculative values of the thermal properties of the hollow brick and mud brick constructions may be in error. Establishing more accurate values will require experimental testing of the thermal properties.

Similar results were obtained for the other case study buildings. Of special interest are the results for the Babayigit House. Fig. 5.10. which illustrate the effectiveness of its sandstone and mud-brick combination compared to the standard current hollow brick construction.

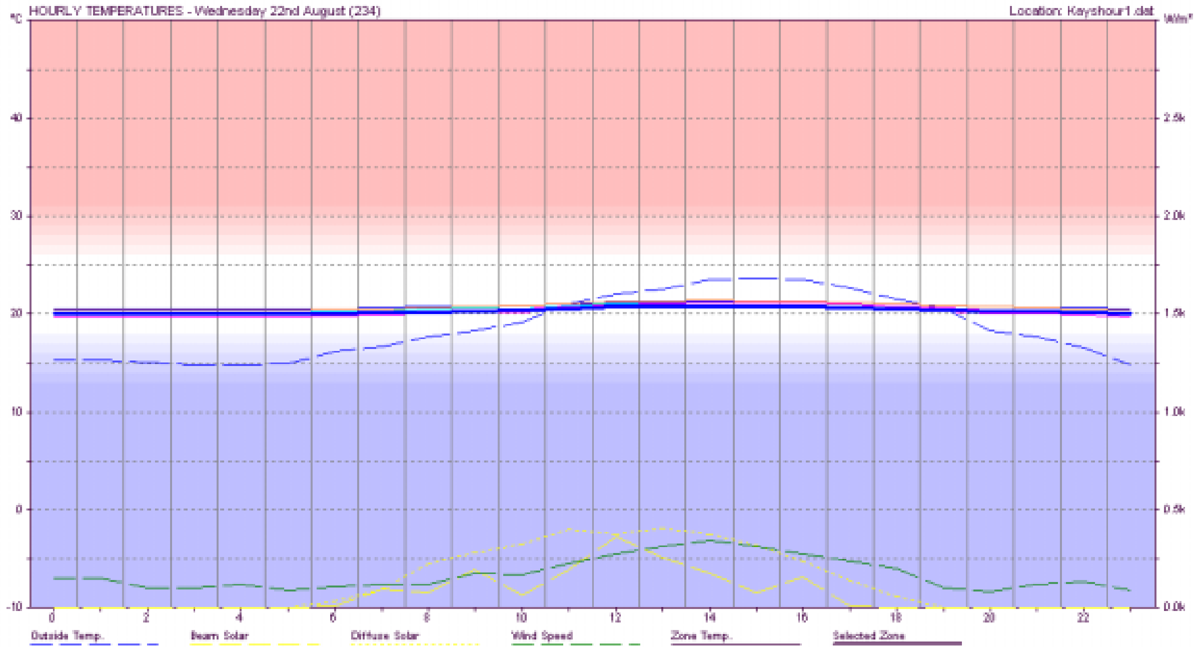

Figure 23: Graph Showing the Hourly Temperature Distribution of Babayigit House with Stone and Mud-Brick Walls. (23rd of August).

Conclusions

The fieldwork, measurements and analytic work carried out under this project have provided valuable insights on the thermal performance of detached dwellings of traditional and contemporary construction in the climatic regions of central Anatolia. These will help inform the design of a prototypical experimental dwelling that is planned as a second stage of collaboration between the partners of the present project.