Comparative Studies of Traditional and Contemporary Construction in Turkey

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ABSTRACT: The paper reports on the findings of a comparative study of buildings of traditional and contemporary construction in the Central Anatolia region of Turkey. The study consisted of short-term measurements in four residential buildings, followed by computer simulation studies. The buildings varied in their levels of thermal insulation and effective thermal capacity and the effects of these differences are highlighted by the results.

1 INTRODUCTION

The aim of this collaborative project was to compare the thermal performance of buildings of traditional mud-brick construction with contemporary structures of reinforced concrete and brickwork. Measurements were taken in four, single-storey, detached residential buildings in the village of Sahmuratli in Yozgat (latitude 40ºN), Central Anatolia over short periods of time between August 2002 and May 2003. To investigate thermal performance in more detail, as well as provide the basis for some general conclusions, thermal modelling was also undertaken. Following calibration of the thermal models against measured data, a series of parametric studies were carried out by varying the thermal properties of constructional elements and measuring the effect of these changes on occupant thermal comfort and on space heating and cooling.

The paper describes the climate of the region, the selection of buildings for the study, the methods followed for the measurements and simulations and the results obtained in this first stage of the work.

2 CLIMATE AND BUILDING DESIGN

The climate of the study area is characterised by cold winters and warm summers. Outdoor air temperatures are near or below freezing in December and January, staying below thermal comfort range for much of the period between October and April, Fig. 1. In summer, the outdoor air temperature rises to peaks above 30ºC in July and August, and displays considerable diurnal fluctuation. Figure 1 shows the range of daily maximum and minimum values of outdoor air temperatures for each month against thermal comfort bands derived from thermal neutrality temperatures [1]. The figure also gives the profiles of direct and diffuse solar irradiance on a horizontal surface in W/m^2. 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 m^2 in December (lowest sunshine month) rising to a mean daily of 7.7 kWh/m^2 in July.

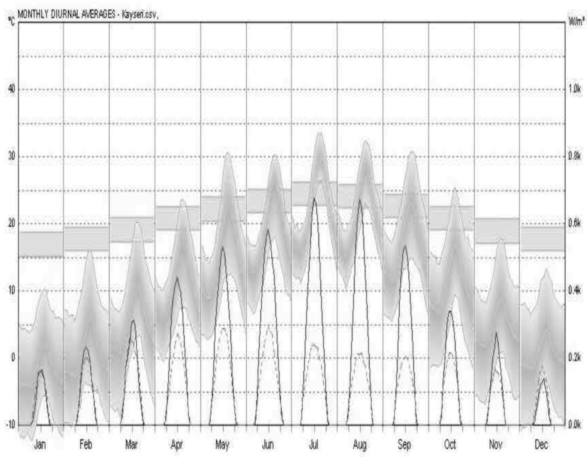

Figure 1: Diurnal range of outdoor air temperature and solar radiation (values of direct radiation shown by solid lines and diffuse by broken lines) for Kayseri plotted against thermal neutrality bands.

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 so as to prevent indoor temperatures rising to discomfort levels. At night the outdoor air temperature drops to low values suggesting that it can offer an effective sink for heat dissipation from buildings by night-time ventilation. In winter, for indoor temperatures to rise to values in the range of 15-20°C for occupant comfort, a high level of thermal insulation will be required to cope with the very large indoor-outdoor temperature differences (typically, in the region of 20K and, in the coldest months, higher than 30K) that will result. Sunshine levels on south-facing vertical surfaces are high throughout the winter (averaging some 3.0 kWh/m^2 per day throughout the heating season) suggesting that passive solar gains can make an important contribution to space heating loads.

3 MEASUREMENTS

3.1 Building Selection

Four, single-storey, detached dwellings were selected for the study in the village of Sahmuratli in Yozgat (latitude 40°N), Central Anatolia. All four buildings had relatively small, single glazed windows distributed evenly on their elevations. The buildings differed, however, in their levels of thermal insulation and thermal capacity that were the main aspects investigated by the study.

Air temperature readings were taken with “Tinytag” dataloggers over periods of up to two weeks between August 2002 and May 2003. Owing to shortage of dataloggers the measurements could not be taken synchronously in all four buildings. Figure 2 shows plans, sections and external views of the buildings and identifies the rooms where dataloggers were placed for the measurements.

3.2 The Babayigit house

This is a traditional single-storey village house built of load-bearing sandstone external walls with mud brick walls internally. The floor is of compacted earth. The roof structure is of timber beams and rafters covered with reeds and a thick layer of mud. The first set of readings was taken in this house in the period 23-25 August 2002. Further readings were taken during March, April and May 2003. The house was occupied by a single occupant who used a stove for heating in winter. The room where the data logger was placed was unheated.

The results of the measurements are shown in Fig. 3. The indoor temperature readings in August (left hand graph on top row from top in Fig. 3) are remarkably stable at around 21-22.5°C despite outdoor air temperature fluctuations of some 12K and peaks of 30°C. In the March measurements with outdoor air temperature between 2 and 12°C, the indoor temperature was again stable at between 16 and 18°C, reflecting the use of the stove and the convective coupling between rooms in the house through open internal doors. The latest set of measurements of April-May 2003 (Fig. 3 top row right hand graph) illustrate clearly the building’s thermal inertia as it responds very slowly to a spell of rising daily outdoor temperatures.

3.3 The Bastürk House

The Bastürk House is of recent construction with pitched roof and 190mm hollow brick external walls. Internal walls are of 130mm brick plastered both sides and floor is 150mm concrete slab with mosaic finish. There is no thermal insulation.

The first set of readings was recorded during 2-13 October 2002. A second set of readings was taken in the period 5-17 March 2003. The building was occupied by a family of six adults. However, the data loggers were located in an unoccupied and unheated room with doors and windows kept closed. In October with the outdoor air temperature averaging 16-17°C and peaking at around 25°C, the indoor temperature averaged 17°C with a small fluctuation (Fig. 3 left hand graph on second row from top). In the March measurements (Fig. 3 right hand graph on second row from top) the room temperature is shown to drop to freezing level and then rise again to around 5°C forllowing the variation of the outdoor temperature.

3.4 Blue House

The Blue House is also of recent construction with uninsulated, loadbearing brick walls, reinforced concrete floors and pitched, clay tile roof. The first set of readings was taken during 18-28 September 2002 with further readings in April-May 2003 (same period as for Babayigit house). During readings the building was occupied by a family of seven. The data loggers were placed in an unused and unheated room. In September (Fig. 3 left hand graph on third row from top) with the outdoor temperature varying from below 10°C to 30°C, indoor temperature varied from 14 to 22° C.

In the later period of readings the rise in room temperature in response to the outdoor temperature is much faster than in the Babayigit house and the daily fluctuations larger, suggesting that the Blue house has a lower thermal inertia (Fig. 3 right hand graph on third row from top). In both periods the mean room temperature was approximately equal to the mean outdoor temperature which is as would be expected for an unoccupied and unheated room. The effect of solar gains can be seen in the April-May readings in the form of small peaks in room temperature in the morning owing to the room’s two windows that face north-east and south-east.

3.5 The Kerkenes Depot House

The Depot House has a reinforced concrete structure with insulated cavity brick external walls and single leaf brick internal walls, insulated pitched roof, and 150mm concrete floor slab with mosaic covering. The first readings were taken in the period 20-22 August 2002. The data loggers were placed in an unoccupied

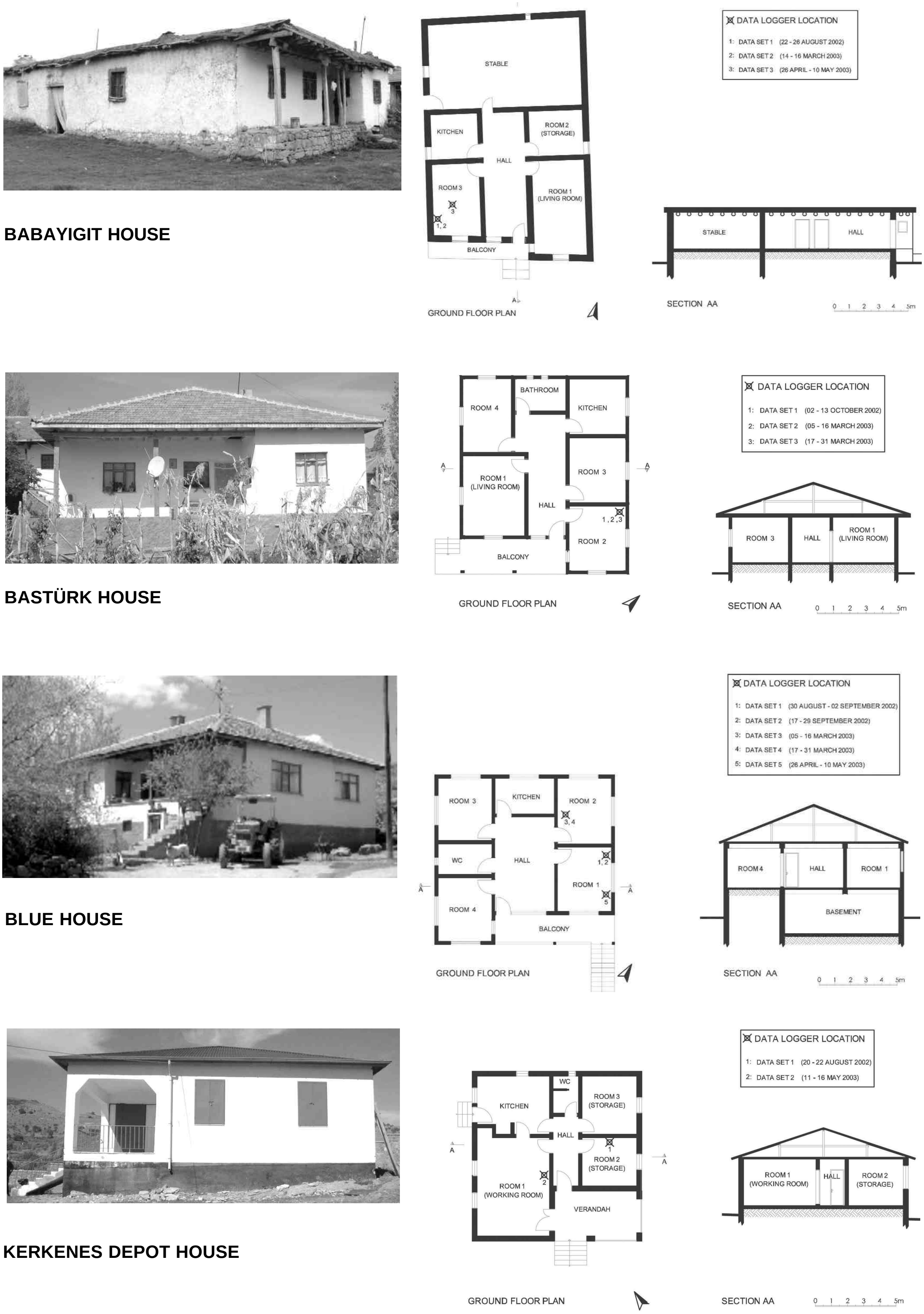

Figure 1: The four residential buildings studied at Sahmuratli Village, Central Anatolia

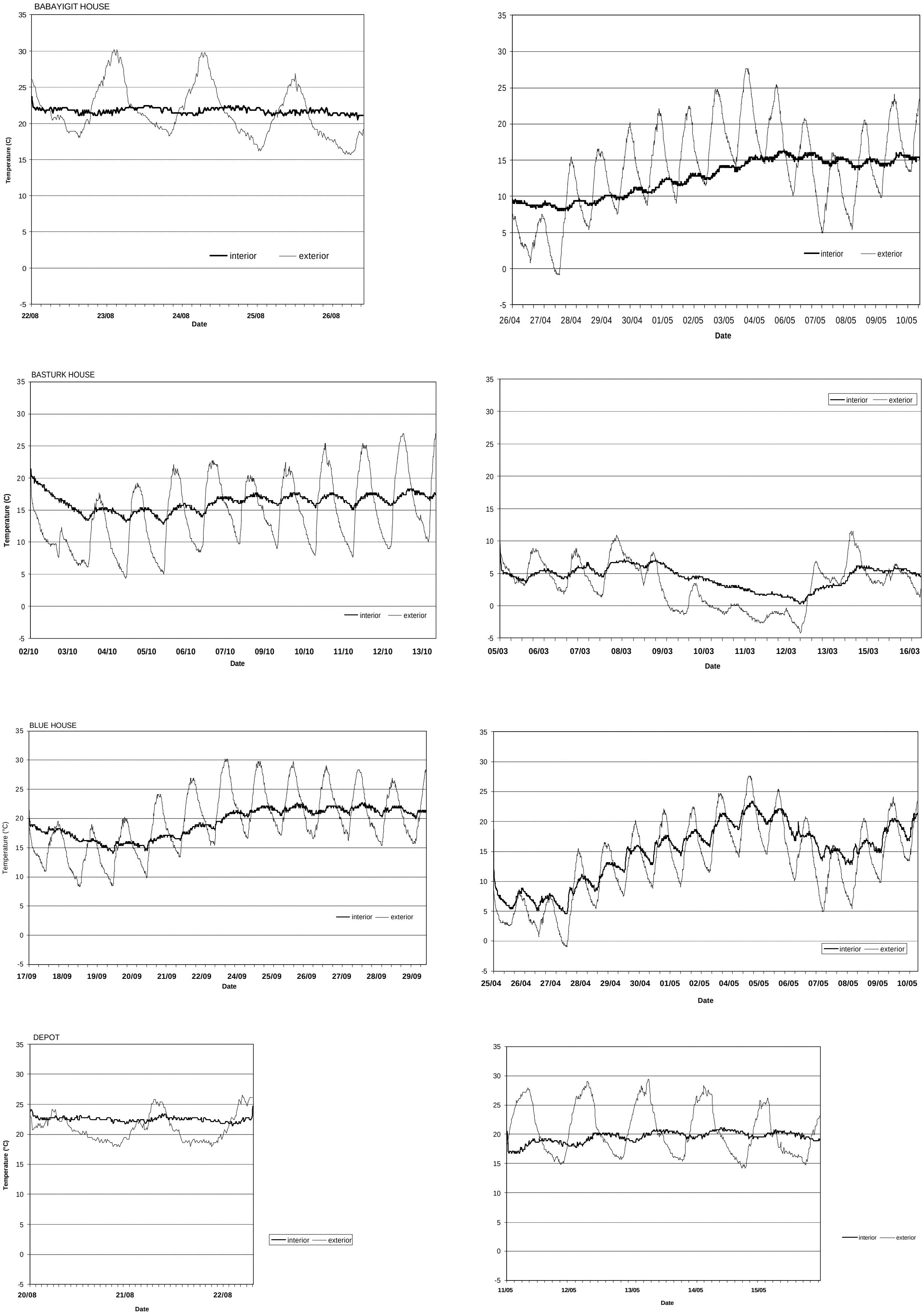

Figure 3: Air temperature readings from the four houses at different periods between August 2002 and May 2003.

room with closed shutters. In the brief period of the first readings the temperature measured indoors varied little around 22ºC with the outdoor ranging between 17 and 26ºC (Fig. 3 left hand graph on bottom row). The second set of readings was taken in May 2003. The outdoor temperature varied between 15 and 29ºC whereas the room temperature varied much less keeping a mean of some 19ºC. The profiles of the indoor temperature are more akin to those of the Babayigit house than the other two. This seems to highlight the effect of the building's thermal insulation.

3.6 Comparisons

Although the degree of measured room temperature fluctuations varied between the four houses, in all the readings these fluctuations were considerably lower than those of the outdoor temperature suggesting that all four houses have a relatively high thermal inertia. The mean values of the measured room temperatures were close to the mean daily values of the outdoor temperature confirming that the rooms in which the readings were taken were not affected by solar or internal heat gains.

The differences in the profiles of the measured room temperatures reflect differences in the constructional characteristics of the building envelopes, and since there is no internal heat input in the rooms, primarily in the thermal capacity of their internal surfaces. The higher internal thermal capacity of the Babayigit house is reflected in a flatter profile of summer temperatures and a slower warming up curve in the transitional period of the April-May 2003 sequence. The two uninsulated dwellings, Basturk and Blue, display a very similar thermal resp;onse as would be expected from the similarity in their construction.

Unfortunately, the measurements do not show how occupied rooms in these houses respond to warmer weather or when heated by a stove and occupants go about their activities. The low temperatures measured in the Blue house in March 2003 highlight the problem of achieving and maintaining thermal comfort in winter in this climate. The Depot building which combines high thermal inertia with thermal insulation should provide a better gains-to-loss ratio allowing solar and internal heat gains to produce a meaningful temperature rise in winter.

4 SIMULATIONS

Preliminary thermal modelling was performed with the Ecotect software [2]. This outputs hourly heating and cooling loads and zone temperatures that are calculated by the admittance method. The short-term measurements presented above were used to calibrate the models of the buildings created with the Ecotect software. Hourly weather data were obtained as described in [1]. Thermal and solar-optical properties were calculated from material properties assessed in the course of site surveys. Inputs on occupancy schedules, internal gains and air exchange rates were also based on site observations. A good correspondence was found between measured and simulated results. A series of simulations were performed to assess the effect of the different wall constructions. The hollow brick wall construction was estimated to have a thermal transmittance (U-value) of 1.63 W/m^{2}K and thermal admittance (Y-value) of 4.54 W/m^{2}K. The mud-brick wall was calculated to have a U-Value of 1.24 W/m^{2}K and Y-Value of 4.32 W/m^{2}K. The insulated walls were modelled as having two layers of hollow bricks with 100mm thermal insulation in the cavity giving a U-Value of 0.30 W/m^{2}K and Y-Value of 3.52 W/m^{2}K.

Notional heating and cooling loads were simulated for comparison using set temperatures of 18ºC and

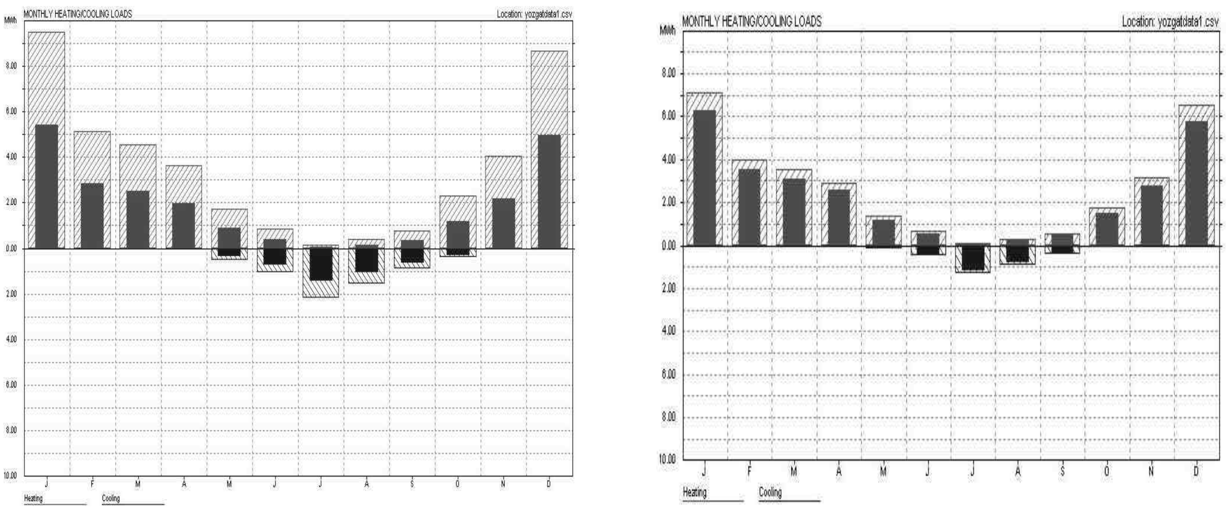

Figure 4: Simulated heating and cooling loads for setpoints of 18 and 26ºC respectively for the Babayigit (left) and Basturk (right) houses. The solid areas represent the loads for the mudbrick wall construction; hatched areas are the results for the unisulated hollow brick construction.

26ºC for winter and summer respectively. Comparison of the results shows that the mud-brick wall configuration provides a considerable decrease in heating loads compared to the uninsulated hollow brick wall, but has a lesser effect on cooling loads. The reduction in heating load is presumably because of its lower U-value, whereas the lesser effect on cooling loads relates to the closer admittance values calculated for these materials. The results are shown in more detail in Fig. 4 which summarises the simulated monthly heating and cooling loads for two of the case study houses (Babayigit and Basturk). The solid bars on the graphs represent the results for mudbrick construction whereas the hatched area shows the increase in loads for the uninsulated hollow brick construction. 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. In further comparisons, the effect of thermal insulation applied to a cavity wall construction was shown to lead to a considerable reduction in space heating loads.

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; these could be one of the tasks for the next stage of this project.

CONCLUSION

These preliminary comparative studies provided information on the thermal performance of the different constructional configurations that are common to the villages and towns across the Anatolian region of Turkey. The results suggest that it should be possible to provide a low-cost combination of thermal capacity and thermal insulation capable to achieve improved conditions of indoor thermal comfort using less fuel for the winter stove whilst keeping the houses cool in summer.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of the British Council under its Britain-Turkey Partnerships Programme.

REFERENCES

[1] Weather data for Kayseri were generated using the Meteonorm v4.0 software (Meteotest 1999); the data were then processed using the Wea Tool software (Square One 2003) to produce the graph and the input data for the Ecotect simulations.

[2] Ecotect v5.0 (2002). Square One Ltd.