
Bruna BAJRAMOVIC, PhD candidate A  Yuichiro KODAMA, PhD B

[KOBE DESIGN UNIVERSITY]  [KOBE DESIGN UNIVERSITY]

Email address of corresponding author: bruna.baj@gmail.com

ABSTRACT

Bosnia-Herzegovina, a country going through the process of development, has many challenges to overcome in order to achieve satisfactory energy efficiency of its built structures. In the last couple of years, activities to increase energy efficiency of residential buildings have gained momentum in order to align with the European Union energy efficiency legislature. The majority of those activities consist of building stock refurbishment by simply adding thermal insulation onto existing architecture.

Considering the climatic conditions, of warm summers and cold winters, decreasing heat loss is important aspect in striving to achieve thermal comfort and energy efficiency of the buildings in Bosnia-Herzegovina. Other means to achieving thermal comfort could be found in Bosnian vernacular architecture, especially when considering thermal comfort in the summertime. Vernacular architecture offers original passive architectural design solutions that are waiting to be utilized in contemporary design.

Although comprehensive research on many of the aspects of the traditional Bosnian town house have been done in the past, its passive-design elements have not been recognized as such nor systematically studied. This paper aims to introduce passive architectural elements, passive cooling and ventilation techniques to a broader public.

Excellent house performance could potentially be achieved by the integration of the vernacular design traditions, of the Bosnian town house, into contemporary passive-house designs.

Thermal performance of a traditional Bosnian town house is tested through computer aided simulations and site measurements. The results of the study should provide convincing arguments, for the local architects and policy makers, to steer the often misguided and overly provisional trends in house designs, to the sustainable path.

INTRODUCTION

In efforts to achieve sustainability it is up to each country to select solutions suitable for their specific conditions and environment. In Bosnia-Herzegovina, where privately owned, individual housing represents a popular lodging solution, finding a sustainable solution for this particular architectural category is already overdue. Some of the housing that was already built inadequately is now going through refurbishment process of adding thermal insulation, to increase thermal performance. Domestic
households take up 52% of final consumption of energy (ESSBIH 2008) and in general buildings mainly have a poor thermal insulation which causes energy loses of up 30% (CPU 2010).

The study of vernacular housing solutions in a particular environment is an excellent venue for revealing design solutions that can be replicated in the same environment but in a contemporary context. This is particularly suited to passive architecture, which makes use of its surrounding natural environment as much as possible. Beside the natural environment, a significant part of passive housing efficiency is based on the occupants’ behaviour. One can argue that vernacular architecture is the original passive architecture. Making the contemporary passive architecture possible are several inseparable elements: the natural environment, the lifestyle and the architecture design itself. This paper aims to explore specific passive-architecture elements of a traditional town house in Sarajevo, Bosnia-Herzegovina through the case study of Svrzo’s House in Sarajevo.

2. THE TRADITIONAL BOSNIAN TOWN HOUSE - BACKGROUND

The house chosen for the study is a two-storey house with elaborate ground and upper floor plans. It is known as “Svrzo’s house” and is located on the hills of the old part of the town overlooking the city of Sarajevo. It dates back to the 18th century when it was owned by a wealthy local family. It was later donated to Sarajevo City Museum to be converted into a museum itself during the 20th century. This house is particularly suitable for study since it contains a variety of the typical architectural design elements of Bosnian town house and is kept close to its original state.

Figure 1 a) Svrzo’s house (2014), view on the front courtyard and open terrace space - divanhana on the upper floor clearly distinguished in wood works (Bajramovic, 2014) b) Typical configuration of Bosnian town house, cantilever architecture: ground floor masonry, and upper floor’s timber framework with brick infill (Grabrijan & Neidhardt 1957)

Figure 2 The Ground and Upper Floor plans of traditional Bosnian town house: Svrzo’s House in Sarajevo, Bosnia-Herzegovina, renovated to original form and turned into a museum. (Grabrijan & Neidhardt 1957, graphic editing by author)
2.1. Lifestyle and occupants’ behaviour

Traditionally, parts of the house were classified according to their functions, into four groups: habitation, recreation, domestic activities, circulation (Grabrijan & Neidhardt 1957), but the rooms themselves were used very flexibly. The furniture is also flexible, there is the sofa encircling the room on 3 sides and Musandra (a walk in closet consisting of a stove, a shower space and a closet), while the rest of the space of the room is free to be used in different ways.

The number and use of the rooms is set according to the needs of the family, flexibility being the key. The same room can be used as living - dining room that transforms into bedroom during the night, other rooms can be children, study or guest rooms. The house is typically a two-story where the ground floor is used as winter quarters, and the upper floor is used as summer quarter. Depending on the house configuration the upper floor is sometime used additionally for winter quarters (Grabrijan & Neidhardt 1957). Such use of the house is a result of a the climate, hot summers and cold winters. Winter quarters are connected to the outside through verandah (Figure 2), and summer quarters open to outside through divanhana (open terrace space – Figure 1&2). Common use of the house by its tenants could be categorized in the following way: 1. Summer and winter use and 2. Private and semi-private use. Front part of the house, adjacent to the main gate courtyard, is considered semi-private, since the guests are greeted there, but second part of the house is completely private.

Several unique architectural elements allow for comfortable summer and winter habitation. The occupants’ behavior is adjusted based on the season.

2.2. Passive-architecture features of the house

![Figure 3](image)

**Figure 3** a) Divanhana – open-air terrace space, under deep eaves  b)mushebak , c)doksat (photos by author)

*Divanhana* (Figure 3.a) an open-air terrace on the first floor settled under deep eaves which provides a comfortable place to reside in hot summer days. All of the rooms adjacent to it have a direct access through massive wooden doors, and with windows looking onto it. Divanhana, together with narrow open hallway, connects pavilions of the house and enhances the airflow throughout the first floor of the house. It is accessible from the ground floor courtyard directly by stairs allowing for quick access to the rest of the house. With its built-in bench and attractive views it is mainly used for recreational activities such as reading, talking, enjoying the scenery, as an outside summer living room. It is even used even as sleeping space in warm summer nights (Grabrijan & Neidhardt 1957).

*Mushebak* crossing wood lattices in the windows providing enormously valued privacy. It enables cross ventilation of divanhana and hallways (Figure 3.b)

*Doksat*, a prism with window jutting out in the height of the upper floor of the house, overhanging the street (Figure 3. c). It is a standard architectural element that appears on all typical town houses. Since it provides 180 degree view, it is primarily used to overlook over the surrounding neighbourhood. It additionally plays an important role in house’s cross ventilation; windows on all 3
sides which gives room for creating draft and ventilating the room more efficiently (Grabrijan & Neidhardt 1957).

The Garden and courtyards (Figure 1&2) are places where one enjoys nature, where decorative and edible plants were planted and taken care of. Summer quarters of the house are oriented onto the garden, which increases the cooling off effect in the hot summer days.

The construction of the house is favourable in terms of thermal mass. The ground floor consists of massive walls, made out of unbaked brick or stone, while the Upper floor consists of wood frame filled in with unbaked brick. The timber frame is resting on the masonry wall. Ceilings are supported by the wood frames and the roof is a heavy wood construction protected by roof tiles.

3. PASSIVE COOLING, VENTILATION, AND HEATING FEATURES

A traditional Bosnian town house (further in the text referred as a TBT house) is, among the locals, recognized as comfortable dwelling in the summer, while at the same time having an adequate thermal mass to sustain the heat in winter months. This study aims to test those qualities on one of the TBT house’s pavilions, which is a representative of typical volumes, materials, and layout.

3.1 CLIMATE CONDITIONS

According to The Köppen Climate Classification the subtype for Sarajevo’s climate is "Dfb" (Warm Summer Continental Climate) or a medium continental climate with average winter temperatures of -1.3°C in January, and average summer temperature of 19.1°C in July. The average annual temperature is 9.5°C. The coldest month is January with the lowest recorded temperature of -26.1°C and the highest in July with 37.2°C (Weather Base 2014).

Summertime temperatures fluctuate drastically during the day where the average temperature difference between the early morning, afternoon, and evening can reach up to 10 to 15°C, with even more drastic differences between maximum and minimum temperatures. On average winter temperatures are fairly steady throughout the day, with slight decrease during the night, but with drastic maximum and minimum temperature differences across days (FHMI 2013). Humidity is also changing during the day, going from high in the morning (up to 80% yearly average in the morning), going down to 50% around midday and again getting higher in the evening hours. Prevailing winds are a result of complex geographical features, so there is a huge variety of wind directions and speeds. Prevailing directions are ESE and WNW. Dominant winds are SSW and ESE (FHMI 2013).

Although humidity rises during the night, these kind of climate conditions allow for effective night-time cooling because of the large drop in temperature during the night. The traditional lifestyle comprises night-time cooling as a part of the daily routine in summer period. The prevailing wind directions suggest that the orientation of the house openings towards South and West is indeed favourable for natural ventilation. The selected TBT house has the optimal South and West facing openings.

3.2 CROSS-VENTILATION AND VERTICAL VENTILATION

In addition to acting as an outdoor living room in the hot summer days, aforementioned divanhana settled under the deep eaves, is a structure that represents a buffer zone, “a layer of air between the hot outer and cool inner spaces which gives rise to air circulation. The rooms behind the divanhana are connected to it by windows and doors and open into the side facades so that the ventilation around the corners is also possible” (Grabrijan & Neidhardt 1957).
a).

**Figure 4.** a): GROUND FLOOR: Cross ventilation through the ground floor openings enabled by the openings’ positioning and the difference between the interior temperature and exterior temperature of the courtyard and the garden. B.: UPPER FLOOR: Openings on the both sides of the rooms allow for cross ventilation. *Divanhana* plays an important role in the summer months, creating a buffer zone between outside and inside spaces. (Grabrijan& Neidhardt 1957, graphic editing by author)

The rooms that are placed in the central parts of the house, with no horizontal ventilation possible, are ventilated vertically through other rooms and the opening in the roof, as shown in the sketch (Figure 3.). It is clear why the house has been given an attribute of an “airy house” (Grabrijan& Neidhardt 1957) since it is ventilated in both the horizontal and vertical direction.

**Figure 5.** The airy house, an archetype layout and section of BTB house (Grabrijan& Neidhardt 1957)

### 3.3. Indoor thermal comfort – A computer simulation analysis

The thermal comfort of the TBT house was examined Using SolarDesigner simulation software (validation of software demonstrated in the article done by authors; see references: Kodama&Takemasa 1991). The pavilion of the house chosen for the computer simulation, represents a typical two-storey architecture of the area. The Ground floor is constructed through massive stone masonry, while the lighter Upper floor is constructed using the *bondruk system* – a timber framework with unbaked clay brick infill. The performance of the house pavilion Ground floor and Upper floor volumes (Figure 4. a&b) were examined according to different simulation scenarios: summer daytime and nighttime ventilation scenario, and winter all day closed mode ventilation scenario. Simulation was conducted for three consecutive days, in winter time, as well as the summertime. *Day 1* is considers as sunny with bright skies, *day 2* as partly cloudy and *day 3* as cloudy. The temperature values represent the maximum and minimum amplitudes recorded in July and January (consecutively the warmest and coldest month of the year).

#### 3.3.1. Summertime ventilation and passive cooling effects

The TBT house, with ample thermal mass, is expected to benefit from the passive nighttime cooling effect in the summer. The computer simulation tested this on the Ground and Upper floor quarters (Figure 4 a&b). Room air fluctuation during July, the warmest month in this climate, is shown in Figure 7. There are noticeable differences between the Ground floor, and the Upper floor air temperature fluctuation. Traditionally utilized the most in the summertime, the Upper floor quarters, if kept closed all day, can provide a fairly steady temperature throughout the day. At this time of the year nighttime ventilation is the optimal ventilation mode. The optimal passive cooling effects are attained in the nighttime ventilation mode from 7 am to 9pm, (Shown in Figure 4) with indoor temperatures dropping...
up to 15°C, and which allowing the interiors to stay significantly cooler than the outside temperature. Similarly, summer nighttime ventilation on the Ground floor is the optimal ventilation mode, with temperature values going from 12°C up to 21°C in the interior spaces. All day closed mode is providing good thermal comfort, with steady temperatures up to just 19-21°C even when the outside temperatures are around 34°C.

<table>
<thead>
<tr>
<th>ventilation mode</th>
<th>day (8-18)</th>
<th>night (18-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>daytime ventilation</td>
<td>30 times/h</td>
<td>2 times/h</td>
</tr>
<tr>
<td>nighttime ventilation</td>
<td>2 times/h</td>
<td>30 times/h</td>
</tr>
<tr>
<td>all day open</td>
<td>30 times/h</td>
<td>30 times/h</td>
</tr>
<tr>
<td>all day closed</td>
<td>2 times/h</td>
<td>2 times/h</td>
</tr>
</tbody>
</table>

Table 1 Ventilation modes (room air changes per hour)

![Figure 6. Nighttime ventilation effects on a clear sunny day in July](image)

![Figure 7. a) Ground floor, summertime room air temperature fluctuations according to different ventilation modes b) Upper floor, summertime room air temperature fluctuations according to different ventilation modes](image)

3.3.2. Winter heating mode

The winter outdoor temperature fluctuations between possible maximum and minimum temperatures values can be significant (Figure 8). Ground floor’s high thermal mass, as well as the First floor’s, provided heating throughout the day (at 21°C), secures the constant comfortable temperature of the interior spaces.

Comparing the thermal performance of the Ground floor and First floor, better performance in winter months has been observed on the Ground floor. Very thick masonry walls, from 44 to 65cm, with significant thermal mass, unsurprisingly, provide good insulation quality. When kept closed all day, without heating, Ground floor quarters keep the temperature between 2°C and 8°C even when the outside temperatures are at extremes (Figure 8.a).

![Figure 8. a) Ground floor heating modes b) Upper floor heating modes](image)
Since the thermal performance of the house in its original state provides relative thermal comfort only in the case of constant heating regime, there was a need to test possible thermal performance improvements of the house by adding thermal insulation. Two additional performance scenarios have been simulated for both of the floors. These scenarios include adding insulation on the outside or inside of the existing wall structure, consecutively (Figure 9&10).

Thermal performance simulation for either of the floors, as well as comparative analysis of the results, showed that the most favorable scenario, among multiple combinations of heating hours and insulation positioning, is the case where the thermal insulation has been installed on the outside of the existing structure (Figure 9). In afore mentioned case the drop of room temperature, in the non-heating hours, is not as drastic as in the case of non-insulated (Figure 8) or inside insulated existing structure (Figure 10). Better thermal performance, due to high thermal mass, also implies decrease in heating load. This study can be used as a reference in efforts to improve energy efficiency and thermal comfort of the existing housing.

Figure 9. Ground floor: Winter heating mode with additional thermal insulation outside of the existing structure

Figure 10. Ground floor: Winter heating mode with additional thermal insulation inside of the existing structure

3.4. Site measurements

A field survey was conducted throughout the TBT house the using Mother Tool-LM-8000 measuring device. Measurements of indoor and outdoor temperature, humidity and wind speed were taken on two winter days, with extremely different conditions: 23rd of January, an unusually warm day with partly cloudy skies and observed outside temperature of 12°C and 25th of January, cloudy skies with snow and the outside temperature slightly below 0°C.

Since the house is used as a museum, some of the rooms are kept open and some are kept closed during most of the day (during working hours) so that the effects of all day closed or all day open ventilation modes could be observed. On a warm day, inside recorded temperatures in all day closed - no heating mode were slightly lower (8,7 to 10,7°C ) than the outside 12°C, and on the cold, snowy day the opposite was true, with inside recorded temperatures (4,5 to 8,5°C) were higher than the outside temperatures (-0,7 to 0,2°C) by 4 to 8°C.

Although similarities between site measurements and software simulations are evident, the site measurements conducted are not to be considered as a final and cogent evidence of the house’s thermal performance since they were executed in an only limited time frame. They can instead be taken as an encouragement for future filed measurements and studies.

4. CONCLUSION

The analysis of the architectural elements of the traditional Bosnian town house as well at the computer-aided simulation of possible scenarios in terms of achieving optimal thermal performance, showed positive results. The house indeed demonstrates good performance in the wintertime, similar to that of appropriately insulated contemporary housing. It was discovered that in the summertime, the
combination of different architectural elements (divanhana, deep eaves, pavilion type of layout, gardens and courtyards, massive walls) and techniques (cross ventilation, night-time cooling) contribute to the thermal comfort of the house. These architectural elements and techniques have the potential to change the face of contemporary Bosnian architecture, if utilized properly. Seeking the lost connection with vernacular architecture means re-establishing the most natural way of living, the one in tune with the natural environment. Including vernacular passive elements into contemporary designs is expected to contribute in achieving more energy efficient and comfortable lifestyle while paving a new way to sustainable architecture in Bosnia and Herzegovina.

5. ACKNOWLEDGMENTS

Conducted research and study wouldn’t have been possible without the advice, support, and kindness of professors and other professionals that have provided essential advice and made the access to much needed data possible. Many thanks go to friends and family for all the encouragement of efforts made by authors while conducting this and other research. The authors would like to thank to all the staff of Svrzo’s House Museum, Federal Meteorological Institute in Sarajevo and Commission to Preserve National Monuments of Bosnia-Herzegovina that facilitated their time and efforts in order to provide much needed information and access to facilities.

6. REFERENCES


