

## SETHI HAVELI, AN INDIGENOUS MODEL FOR 21ST CENTURY 'GREEN ARCHITECTURE'

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### Abstract

In the 21st century, there has been a growing concern for the degradation of the environment from large quantities of CO<sub>2</sub> and green house gases, produced by the building industry. This led to the concept of 'Green Architecture', which aims to reduce the environmental impact of buildings through energy efficient designs and healthy indoor environment. In the context of Pakistan, our current practices in architecture are based on Western standards, leading to a growing dependence on fossil fuels and resulting in rapid environmental degradation. Rapoport (Rapoport, 1969) states that, modern solutions to climatic problems often do not work, and homes are made bearable by means of mechanical means whose cost sometimes exceeds that of the building shell. Before the import of the Western model for architecture, vernacular architecture provided energy efficient and sustainable spaces. Pearson states that, the new importance of vernacular building is that it has vital ecological lessons for today (Pearson, 1994). In the current scenario, the study and analysis of indigenous architecture can help in developing a home-grown and workable model for 'Green Architecture' of 21st century Pakistan. In this paper the climate responsiveness and appropriateness of the Sethi haveli, Peshawar, are analyzed in order to understand the indigenous responses to the issues of environmental comfort. The focus of the study will be the courtyard and how it provides thermal comfort and day-lighting to the building.

### Keywords

Green architecture, Sethi haveli, indigenous architecture, environmental comfort.

### Introduction

Today, the building sector uses up to 30-40% of the world's total energy consumption (I.E.A., 2008). In developing countries (World Energy Outlook, 2007) it accounts for a much higher percentage. A large portion of the energy used in buildings is used for achieving thermal comfort for the inhabitants through cooling, heating and lighting. This energy is produced by burning of fossil fuels, which result in the production of CO<sub>2</sub> and green house gases. Developing countries like Pakistan will make a substantial contribution to the CO<sub>2</sub> emissions from its commercial and domestic (21% of total energy consumption) energy usage (ENERCON, 2006).

The concept of green architecture took shape when the usage of fossil fuels began to do irreparable damage to our environment. Green architecture involves a holistic approach to the design of buildings so that the many conflicting issues and requirements; of ecology, economy

and human wellbeing are integrated. Modern buildings are increasingly unable to adapt to a warming climate and are inherently energy intensive. In contrast, vernacular architecture is more adaptable to the environment, according to principles evolved over many generations. Evolution in the paradigm of traditional housing took place from the 18th century onwards due to socio-political and socio-economic reasons (Salama, 2006). This resulted in a complete disregard of vernacular technologies, many of which were energy efficient as they worked with natural forces (sun-light, wind etc.) to create buildings that minimize consumption of natural resources and their subsequent depletion. As our climate heats up and changes, the need to study and understand vernacular buildings in the context of green architecture increases.

This research explores the havelis of Sethi Mohalla, Peshawar, Pakistan, with a view to address the benefits of the vernacular courtyard form of design and speculate its appropriateness in the modern architectural arena of Pakistan. The seven Sethi havelis are located on Bazaar Bolan Road near Gor Khuttree. They were constructed without any mechanical means, and thermal comfort was achieved through climatic modifying strategies like internal courtyards, orientation, thermal mass, solar gain and evaporative cooling. Rapoport (1969b) observed that vernacular solutions are a response to climate and culture.

### Green Architecture and the Haveli Form

The Haveli is a courtyard house, a predominant form used in the Indian sub-continent since the cities of Mohenjo-Daro and Harappa. The courtyard form developed as a response

to climatic and cultural factors in regions as wide spread as Europe, Middle East, and Asia. Bahadori (1978) states that the courtyard inverts space to fulfil several functions, including the creation of an outdoor yet sheltered space, the potential to use indigenous passive cooling techniques, protection against dust storms, and the mitigation of thermal heat from the sun. Courtyards represent an attempt to bring the forces of nature under partial control (Reynolds, 2002a). European, Middle Eastern and Asian courtyard forms share similar properties of modifying climatic conditions both cold (Mänty, 1988) and hot. Edward (2006) notes that Western and Eastern types adjusted their orientation and designs to balance the benefits of wind and the sun. The courtyard typology is a more sustainable form of housing as it allows constant contact with the natural world; sun, fresh air and water (Sibley, 2006). Revivalist architects like Fathay have advocated for and successfully incorporated courtyards in their design for modern housing.

The environmental performance of the courtyard form in relation to the pavilion form was studied at Cambridge University (Martin & March, 1972). Results confirmed that courtyards performed better than pavilions in terms of efficiency in built potential and day-lighting. Raydan et al (2006) re-evaluated the original study and concluded that the best form in environmental terms (without sacrificing floor space for a given plot of land) for hot arid climates is the courtyard form.

### Climatic Conditions

The Peshawar district lies between North latitude 30°40' and 32°31' and East longitude 71°25'

and 72°47'. The city of Peshawar, experiences longer summer spells; May to September and shorter winters; December to February, the moderate weather is in October, November, March and April. During the summers, the mean maximum temperature is over 40 °C (104 °F) and the mean minimum temperature is 25 °C (77 °F). In winters, the mean minimum temperature is 4 °C (39 °F) and maximum is 18.35 °C (65.03 °F) (Weatherbase: Historical Weather for Peshawar, Pakistan). The architectural design of buildings must address the problems of both weathers and provide relief accordingly.

The mohallas of the city employ various passive design measures to combat the extremes of weather including the use of narrow and winding streets, the huddling of the various havelis together to protect against excessive heat and cold. By avoiding exposing individual external walls, an optimum indoor temperature is achieved in both summers and winters. The courtyard form is dominant in the tightly packed traditional architecture of Peshawar city.

### Methodology of the Research

A case study research method has been adopted for analyzing a representative sample of the havelis of Sethi Mohalla, in order to understand their inherent bioclimatic responsiveness and use of natural and renewable energy sources.

The research tools include:

- extensive surveys of the courtyard houses observed,
- interviews with the residents of the havelis,
- on-site photography,
- analytical sketches.

The Allah Buksh Sethi haveli was chosen as the final choice for the case study based on the following factors:

1. *All the Sethi havelis are similar in their use of high thermal mass construction externally and lightweight construction on the inside facade.*
2. *The size of the courtyards in relation to the total volume of the havelis and their aspect ratios were similar.*
3. *The Allah Buksh haveli was accessible for data collection and detailed study.*

The analysis of the Allah Buksh Sethi haveli was done with respect to the comfort of the courtyard and the surrounding rooms. To understand the bioclimatic significance of these havelis, the analysis is based on courtyard thermal performance with respect to both solar shading and day-lighting.

### The Allah Buksh Sethi Haveli

The Karim Buksh haveli, constructed in 1898, was the largest haveli of the Sethi Mohalla (and possibly of the area), which consisted of separate courtyards and spaces for the mardana (men's area), zenana (women's area) and servants' areas. The zenana quarters were turned into an independent haveli by Allah Buksh Sethi in 1930.

The haveli has a central courtyard measuring 40' x 40' with a water fountain in the center. There are wooden arcades on all four sides, housing the balakhanas (reception rooms) on the ground floor. The balakhanas are elevated five feet above the courtyard and three balakhanas (NE, NW & SW) have large tehkhanas (basements) underneath them. The

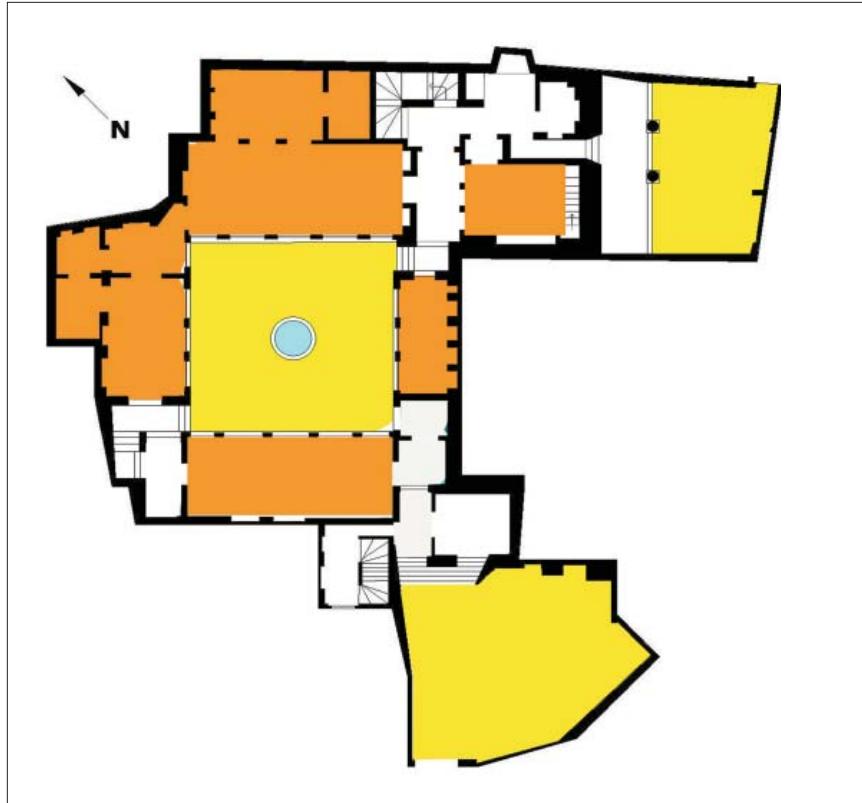


Figure 1: Ground Floor Plan of the Allah Buksh Haveli (Source: Author).

balakhanas, the rooms behind them and the tehkhanas all receive sunlight, air and ventilation through the courtyard.

### Courtyard and Climatic Comfort

The placement of the central courtyard, its size and orientation are important aspects of the design. The courtyard plays a major role in the modification of the harsh summer and winter

environment by providing a comfortable micro-climate for the haveli.

### Form and Orientation of the Courtyard

The courtyard forms a perfect square and occupies nearly 30% of the total haveli area. The surrounding walls rise to 19' and there are overhangs of 6' wide on three sides, whereas the NW side is covered by a thakht, protecting that side from excessive solar exposure. The



Figure 2: Sunlight on NE façade: Taken by author on October 21st 2008 at 12 am. (Source: Author).

courtyard is laid in a SE- NW orientation. This is about 40° off the cardinal points, which exposes the NW wall to morning sun. The NE wall also gets the sunlight from early morning until midday, after which the sun penetration is largely controlled by the takht on the NW side (fig. 2). The lower winter sun is able to penetrate the courtyard (NW, NE & SE sides) until mid-afternoon i.e. 4 pm (Personal observation on site 15th Nov. 2008).

### Courtyard and Thermal Comfort

The intense heat and glare from the sun, especially in the summer months can easily cause overheating, discomfort and glare if the courtyard is not designed and protected

properly. The Sethi haveli employs multiple devices to avoid heat gain through the courtyard, through a variety of permanent and temporary shading devices; wooden arcades, roof overhangs, lattice-work screens, stain glass windows etc.

### Roof Overhangs of the Courtyard

The courtyard is protected by 6' overhangs on all four sides (figure 3). On the NW side there is a takht (fig. 4) for sitting and eating meals on the first floor. This blocks excessive sunlight into the courtyard and provides vital shade. Early morning, late afternoon and a lower sun path in winter are the only time that direct sunlight may fall on the internal walls of the courtyard.



Figure 3: Overhangs of the courtyard. Taken by author on November 15th 2008. (Source: Author).

### Open-able Shading Devices

There are iron loops and hooks on the sides of the overhang of the courtyard indicating the use of a large covering which was tied to cover the opening of the courtyard. This was closed in the day to reduce direct sun penetration and glare. During mid-day (the hottest part of the day) of the hottest summer months, the amount of light and heat are greatly reduced. The cover was folded away in the early evening, when water is sprinkled on the floor of the courtyard to facilitate evaporative cooling, ventilation and cold-sky radiation.

### Large Fabric Fans in Courtyard to Promote Air Flow

A steel rope was hung across the opening of the courtyard; this had large loops which held a large fan. The fan was moved manually to increase the air flow within the courtyard and into the balakhanas.

### Water Fountain in Centre of Courtyard

There is a water fountain in the courtyard, which inducts water into the air. This cools and moistens the hot dry air inside the courtyard and the balakhanas providing relief from the hot dry conditions.



Figure 4: Takht on first floor; covering the courtyard. Taken by author on October 21st 2008. (Source: Author).

### Sprinkling Water on the Floor

Water was sprayed on the brick floor of the courtyard in the mornings and evenings and this encouraged cooling of the area through evaporation.

### Analysis of Thermal Comfort of Courtyard

Exposure of the Courtyard: Aspect Ratio

The courtyard's effectiveness in terms of environmental response may be measured by studying its aspect ratio (Reynolds, 2002b). The aspect ratio is a measure of the degree of the courtyard's openness to the sky; a greater aspect ratio indicates that the courtyard is more

exposed to the sky.

The Allah Buksh Sethi haveli's courtyard has an Aspect Ratio of 2.11. This indicates that this is a relatively shallow courtyard and thus has good exposure to the sky. This exposure allows winter sunlight to warm the courtyard and the rooms on the N, NE and S sides. The summer sun will also heat up the courtyard floor but most of the balakhanas are protected by the overhangs and the takht on the NW side. The courtyard floor which is heated during the day is quickly cooled by evaporative cooling (wetting of the floor) in the early evenings and radiation to the cold sky at night time. This aspect ratio allows direct and diffused light into the courtyard and

facilitates entry of the wind.

### Solar Shadow Index and Winter Solar Penetration

Another aspect of comfort is the solar shadow index, which deals with winter sun exposure in the courtyard. In the context of the Sethi haveli, the solar shadow index was calculated as 0.575. This value shows that the courtyard well is not very deep and allows more winter sun on the Sethi haveli's courtyard's sunny (NE) face at noon. The haveli's living rooms on the SW sides are used in the summer and the main NE balakhana is predominantly used in the winters as this side gets the maximum winter sun all day (figure 5).

### Courtyard's Role in Modifying Extreme Temperatures

The hottest summer month is June when the temperature swings between an average high of 81°F/27.2°C - 101°F/38.33°C. In order to test the assumption that the courtyard forms modify the external temperature extremes, the temperature of the Sethi courtyard in relation to the outside temperature (taken as 38°C) was calculated;

$$14(1 - 0.759)^{\circ}\text{C} = 3.374^{\circ}\text{C} \text{ (Reynolds, 2002c)}$$

The calculated temperature difference that the courtyard offers from the outside is 3.374°C. Thus, for an external temperature of 38°C the Sethi courtyard will maintain a temperature of about 34.62°C.

### Daily Temperature Range (Summer)

Discomfort in the hot-dry summer is also caused by the extreme diurnal swings in temperature. In order to understand the courtyard's response to the diurnal temperature swings, its response

to the daily temperature range was calculated. The average temperature range of Peshawar is 11.13° (between 27.2°C - 38.33° C).

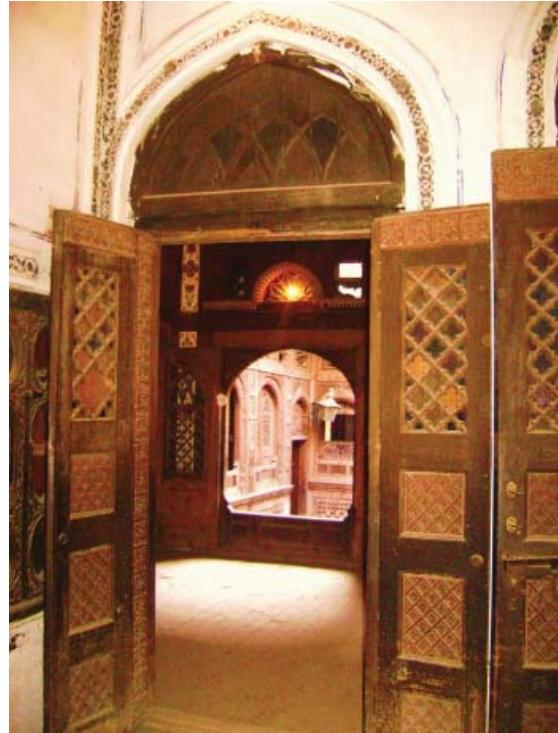


Figure 5: Light in NE balakhana, Taken by author, November 20th 2008. (Source: Author).

The calculated range that the courtyard offers is between 29.5°C - 34.62° C; a variation of 5.12°C. The courtyard form avoids large heating and cooling ranges and is effective against the extremes of the diurnal swings in temperature during the day. Thus the temperature within the house is more stable and thus more comfortable.

## The Courtyard and Daylight

To fulfil the needs for adequate day-lighting, there is the need to maximize light through ample window area, yet protection and shading must be provided to prevent solar gain. In the context of daylight, various factors influence the amount of daylight available in rooms; these include the path of direct sunlight on the facades, the ratio of room sizes and the proportion of window size to floor size.

### Solar Angles of Summer and Winter Sun

To calculate how much of direct sunlight penetrates the courtyard and into the

balakhanas in summer and winter, the angle of the summer and winter sun into the courtyard were calculated. The noon solar angle for summer solstice was  $79.5^\circ$ , this is almost a straight angle of the sun. The height of the balakhanas (raised  $5'$  off the courtyard floor) and the overhang of the courtyard ( $6'$ ) protect them from direct solar penetration in the summers. Thus direct sunlight into the balakhanas is averted in summer by design. The winter solstice angle of sun is  $32.5^\circ$ , this much lower angle of the sun. It is facilitated by the design of the haveli, and sunlight penetrates the courtyard floor and all rooms on the N, NE and NW sides, during the day. A graphic representation is given in figure 6.

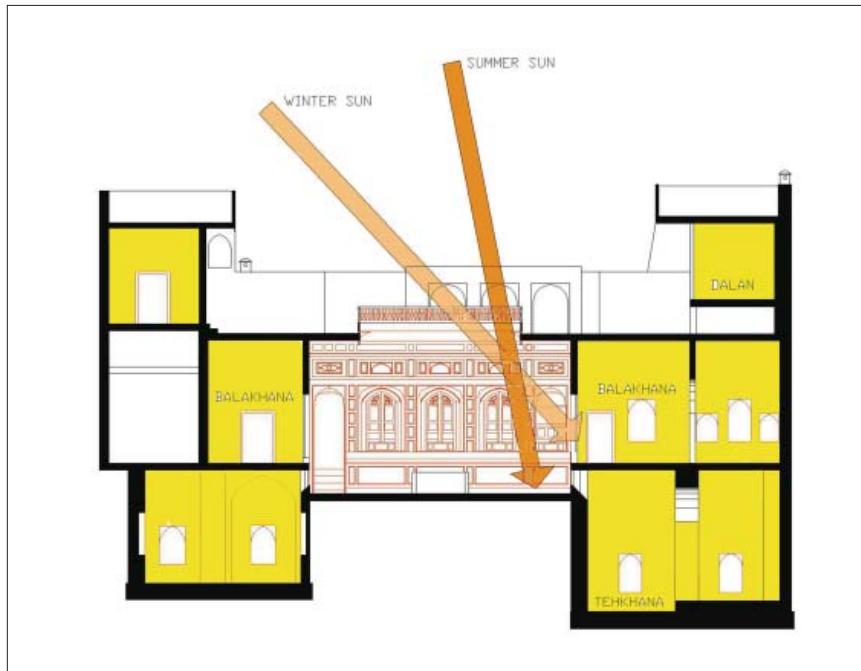


Figure 6: Section (SW-NE) showing the path of summer and winter sunlight. (Source: Author).

The importance of the solar path during the summer and winter months has played an integral part in the design and layout of the balakhanas and dalans of the first floor. All windows are placed within the internal courtyard and are protected by the overhangs of the courtyard roof. The NE side of the haveli is deeper than the other sides of the haveli due to maximum amount of sunlight in this direction. The largest tehkhanas (basement) is also located on the NE side, its ventilators face the courtyard, and provide ample amount of light in the daytime.

### Ratio of Room Size

In the Allah Buksh haveli, all rooms on the ground, basement and first floors face inwards and are dependent on the courtyard for daylight. As a consequent the layout of the balakhanas are adjusted in such a way that the longer side of the room lies along the courtyard and the depths of the rooms are shallow in comparison. For even distribution of daylight, Reynolds (2002d) specifies the preferred proportion of a room adjacent to a courtyard should be 3 : 1 (length along courtyard to rear wall of room). The proportions of the balakhanas of the haveli also show a longer length to width ratio (Table 1).

The NE balakhana receives the maximum amount of direct and reflected sunlight in both summer and winter and thus has the lowest length to width ratio (2.4:1). The three other balakhanas have greater proportions (2.7:1), their size allows maximum amount of direct and defused light to enter the rooms (figure 7).

### Proportion of Window Size to Floor

The relationship of the window size to the total floor area of a room also determines the amount

of daylight in a room. According to Reynolds (2002e) the larger the window relative to the floor area, the higher the daylight factor (DF). This relationship is calculated for the balakhanas surrounding the courtyard and presented in table 2:

The above table shows that there is a high percentage of window area to the floor area of the balakhanas. The three balakhanas (SE, SW and NW ) have 40%- 66% of window area to floor area, as these are facing away from the sun, there is a need for larger percentage of window area. The NE balakhana has the lowest percentage of the window area to floor area (33%), and by virtue of its location on the sunniest side of the courtyard, this is a deliberate design element to control the amount of light and the resultant heat.

### Elements to Control Glare

Although there are continuous windows along the internal arcades, yet they have multiple operable parts which facilitate the amount of daylight admitted to the rooms. The balakhana window shutters may be opened to create an arcade along the courtyard and this allows maximum amount of light and ventilation to reach the rooms (fig 9). The windows are made of multiple components so that they may be opened and closed in parts to control the amount of daylight admitted inside. Stain-glass windows in these shutters also diffuse the bright sunlight (fig 10). The use of ventilators on top of the windows also are a controlling elements, as they may be opened up and tilted to adjust light in the room.

Orientation of Balakhana	Length along the courtyard	Width	Ratio of room, length : width
NE balakhana	35' 2"	14' 7"	2.4 : 1
SE balakhana	21' 8"	8' 2"	2.7 : 1
SW balakhana	34'	12' 3"	2.7 : 1
NW balakhana	32' 6"	11' 8"	2.7 : 1

Table 1: Ratio of balakhanas length and width (Source: Author).

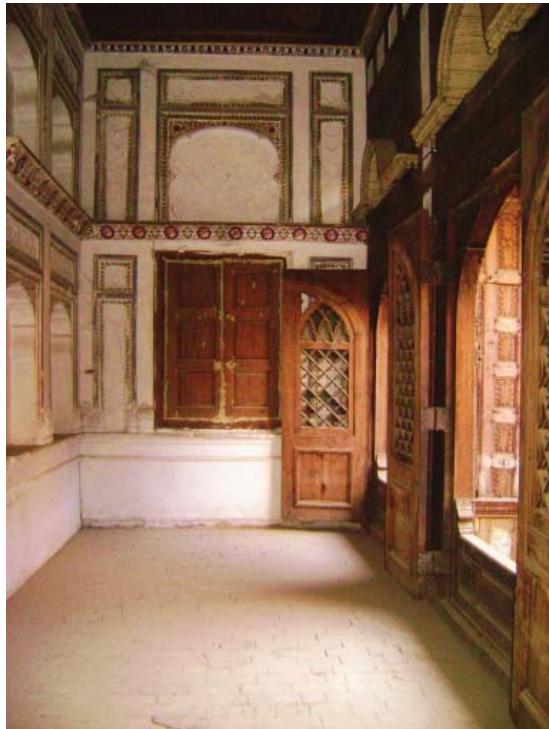


Figure 7: SE Balakhana. Taken by author on January 15th 2009. (Source: Author).

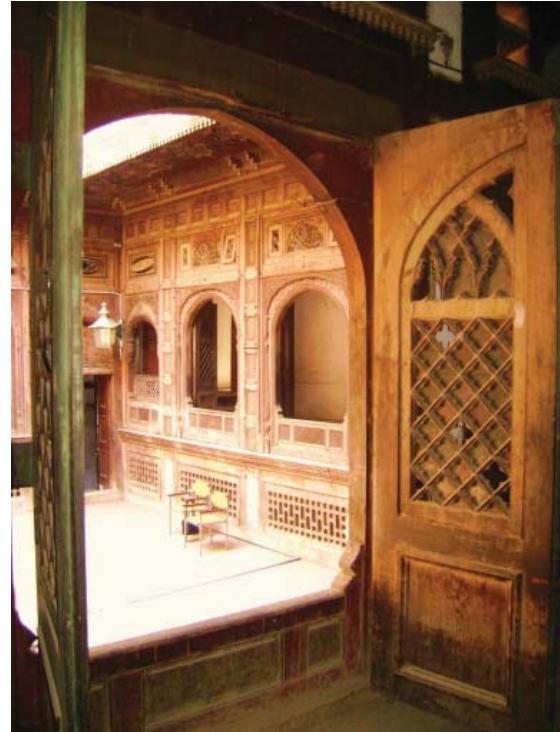


Figure 8: Windows of the internal arcades. Taken by Author, October 2008 (Source: Author).

Room	Area of window	Floor area of room	%age of window area to floor area
NE balakhana	170.5	508	33.5 %
SE balakhana	115.5	174	66.4 %
SW balakhana	170.5	408	41.8 %
NW balakhana	115.5	258	44.8%

Table 2: Ratio of Window to Floor Area. (Source: Author).

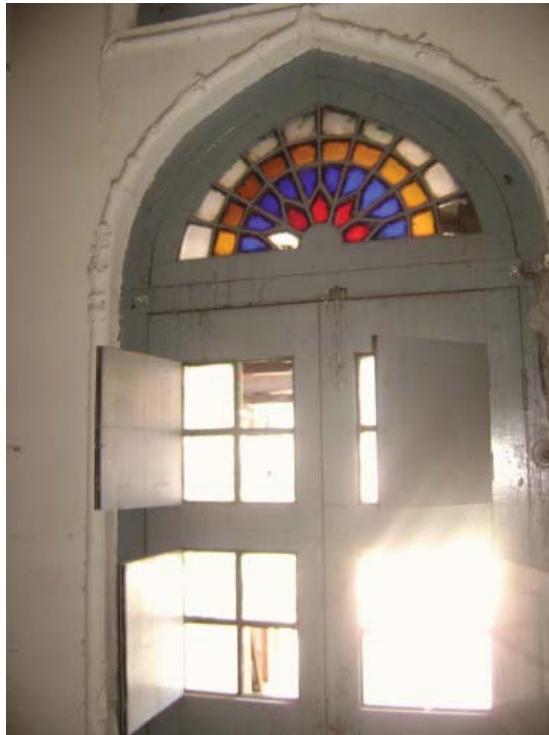


Figure 8: Windows of the internal arcades. Taken by Author, October 2008 (Source: Author).

## Conclusions

Today the typical architectural solution to global warming concentrates on making buildings more efficient by enclosing them with glass and increasing the use of mechanized cooling and heating systems. There is a need to look at courtyard buildings not just as remnants of the past, but rather as lessons for our future. Fathy (1986) states that traditional solutions in vernacular architecture should be evaluated, and then adopted or modified and developed to make them compatible with modern requirements. This research concludes that by opening up the house around a courtyard form creates more thermally comfortable conditions inside the house and also improves the amount of daylight in the house, thus reducing dependence on mechanical energy.

In the analysis of the Allah Buksh Sethi haveli we observe that the factors of shape and size configuration and orientation of the courtyard has an impact on its environmental performance. Reinvesting in the successful vernacular courtyard house by updating its features and amenities to provide for contemporary needs is the answer to our quest for green architecture.

A number of general design guidelines can be deduced from this study:

- Reintroduction of the courtyard form in homes as a garden or parking area; the size of the courtyard to be calculated so that the square of average height of the surrounding walls should be less than area of the courtyard. An aspect Ratio that is not too shallow (increases summer heat gain) and not too deep (decreases daylight penetration) is important. A balance between the two is ideal for winter solar penetration, adequate daylight and ventilation benefits.
- Orientation of the house to avoid solar gain in summer and utilize prevailing winds on site. In the context of Pakistan, a N-S orientation is best as it reduces lengths of South facing facades.
- Opening majority of windows within the courtyard to benefit from its micro-climate. Calculation of summer/winter sun angles for designing window overhangs to maximise daylighting and minimise glare in the summers and allow winter sun penetration. Providing multiple open-able components within windows to increase the ability of the occupant to control the level of light and heat in the room.

The need for making today's architecture green may well be served by employing climate responsive designs based on vernacular architecture. Modern interpretations of these principles can be energy conserving and culturally responsive.

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