Courtyards Houses of Kolkata: Bioclimatic, Typological and Socio-Cultural Study

by

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ABSTRACT

This research explores the bioclimatic and socio-cultural benefits of Kolkata's courtyard houses. A typological and historical analysis of courtyard houses from around the world, as well as in Kolkata, provides a context for the field research.

The main intention of this study is to explore the roles of solar shading and natural ventilation in courtyard houses located in the hot-humid climatic region. For this purpose interviews with the heads of household of ten courtyard houses in Kolkata were conducted in January 2005, to finally choose three houses for detailed experimental analysis. All three houses have high thermal construction and similar socio-economic conditions. This helped in comparing the results of the temperature (both ambient and surface temperatures) and air speed measurements among the three houses referred to as House A, House B and House C houses. House A and House C houses have shallow courtyards (high aspect ratios which in both cases equal 0.95), while House B house has a deep courtyard (low aspect ratio equal to 0.21). Further, ventilation analysis has been done with the help of Computational Fluid Dynamics (CFD) software. The simulation study and the experimental data measurements focused on the comfort conditions generated within the house based on their differences in proportion of form and massing. The effects of solar shading and natural ventilation on activity patterns and uses of a space are also examined through occupant surveys.

Finally, this research explores the historic courtyard houses in Kolkata, with a view to address the benefits of the universal courtyard form of design and speculate the appropriateness of the vernacular courtyard form in the modern architectural arena of Kolkata.

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I am really grateful to Subrata Kaku for helping me in gathering and assimilating the data about the different courtyard houses in Kolkata. I would also like to take this

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PREFACE

In this world of inequalities of wealth, power and opportunities the only binding factor leading us towards the concept of globalization is perhaps the human struggle for survival. The increasing global environmental degradation has perhaps unified the human race on the need to find a way to sustain human existence that is compatible with nature. Today our worldviews are greatly influenced by the fact that to live on Earth, humans need to learn and respect their environment. Global environmental concern is perhaps the cause of evolution of ideas such as 'sustainable design, ecological planning, bioclimatically adapted architecture; which have begun influencing the theories of architectural practice in the beginning of the 21st century. With the advance of science and technology, and as an effect of rapid urbanization globally, we as designers have gradually shifted away from our traditional architectural intelligence. Ironically our present studies of a sustainable future also point at the richness and relevance of our traditional culture and vernacular architecture.

It is generally accepted that vernacular architecture is the living proof of natural progression of the field of architecture through the past centuries. However, in much of the developing world, historical building types are endangered by rampant inner-city construction and the indifference of younger generations, which opt for high rise Westernized home types. Kolkata (Calcutta), India, often referred to as "the City of Palaces," is a victim of such rapid urbanization and globalization. The skyline of Kolkata is changing at an exponential rate, with its heritage buildings being rapidly replaced by modern day skyscrapers. This research intends to explore the passive cooling

techniques embedded within the courtyard form of dwelling popular nearly 100- 150 years ago in the city. Evolving from a small village to one of the world's largest global metropolitan cities, Kolkata has acquired her unique hybrid identity by accepting socio-cultural aspects from diverse cultures, such as the Dutch, French, Portuguese, British and various ethnic groups in India like the Marwaris, Oriya, Biharis etc. that have settled in the city. Historically, Kolkata has been perhaps most characterized by British Colonial influences, as evident in the architecture and planning of the city. Anthony D. King remarks in The Bungalow that the primitive form of courtyard type dwelling was originally an indigenous mode of shelter, modified by the British as bungalows to suit their social and cultural lifestyles. On the other hand, the wealthy Hindu families continued to build one to two storey courtyard dwellings for their extended families. The Kolkata courtyard form was largely determined by the intense heat, light, torrential rains, wind and dust typical of the tropical climate. The Kolkata courtyard form was also a product of the social and cultural norms of the residents – who preferred a private and religious family life.

The intent of this research is to study examples of these historical courtyard architectural forms with regard to their ability to achieve human comfort in a hot humid climate. Another primary aim of this study is to gain a better understanding of the role of courtyard housing in providing appropriate setting for household activities and creating a sense of place. These studies have also pointed toward the importance of the relation between the importance of the relation between the individual building scale and the larger urban fabric. This expected connection between the individual houses and their neighborhood design has helped me to formulate ideas about the ideal

patterns for the design of hot-humid climate "courtyard types" that can be appropriately adapted to contemporary design.

STRUCTURE OF THESIS

This thesis can be divided into three main components. The first component is the descriptive element of the research. Part one has been further sub-divided into three chapters. Chapter 1 deals with the identification of the courtyard type as has existed in the different parts of the world, their historical evolution, the basic courtyard forms, along with the benefits and liabilities associated with the courtyard form. Chapter 2 briefly introduces India and Indian Architecture and discusses the different Indian courtyard houses. The discussion includes the regional variants of courtyard types, emphasizing on their meanings and symbolism with respect to the diverse religion, culture and climate prevalent in India. Chapter 3 focuses on the courtyard houses in Kolkata, trying to define a typology of these dwellings, while discussing their origin and adaptation, and socio-cultural-economic appropriateness.

The second component of this report is the main research and analysis section. This section is again subdivided into two chapters. Chapter 5 is based on research about the hot-humid climate prevalent in Kolkata, the elements of this climate type and how the courtyard type design is adapted to the hot-humid climate. Chapter 6 presents the main research work detailing the case studies performed during a site visit to Kolkata, India in January 2005, analyzing them both experientially and bioclimatically.

The third and final component of the report is the normative element of the thesis. Chapter 6 speculates on the appropriateness of the courtyard type based on the case study findings. The main debate in this chapter focuses on whether there is any appropriate application of courtyard design in modern architecture of a tropical city, such as Kolkata. It further speculates about some design considerations that are ideally suited for the Kolkata climate, architecture and social structure.

CHAPTER 1: COURTYARD AS A RESIDENTIAL TYPE

Set in the midst of the universe, man needs a place of peace, seclusion, as part of the greater, hostile, amorphous world outside, a space which all the same, receives its share of day and night, sun and moon, heat and cold and rain.

- Johannes Spalt[1]

As one of the most primordial forms of architecture, "courtyard styles" may be relevant for any type of building be it residential, commercial, institutional or industrial. Reynolds refers to courtyards as, "… special places that are outside yet almost inside, open to sky, usually in contact with the earth, but surrounded by rooms".[2] Historically these "special places" have been most popular in residential architecture all over the world and in all climatic regions. However, the courtyard type has been and can be beneficially used for other building types, too. For example, shaded courtyards may be used as: outdoor eating areas in restaurants; flowering atria in hotel lobbies; quiet, arcaded but cheerful waiting areas in hospitals; formal and informal meeting places in schools and colleges; and relaxing areas for industrial workers.[3]

It is the residential courtyard form that is of interest to this study. Regardless of geographic barriers, religious-cultural traditions and political differences the courtyard form has emerged and disappeared in practically all the civilizations of the world.

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[1] Blaser, Werner. 1985. *Atrium: Five Thousand Years of Open Courtyards*. Wepf & Co. AG Verlag, Basel. Johannes Spalt wrote the introduction to this book.

[2] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight*.2002. New York: John Wiley

[3] Ibid 1

Bagneid observes that, "Geographically, courtyard houses are today spread mainly in North Africa, the Middle East, and periphery regions (Mediterranean: Spain, Greece, etc.; India, Pakistan, Iran, etc) as the predominant form in indigenous cities with hot-dry, moderate and/or warm humid climates" (p.42).[4]

Based on a review of the literature and analytical sketches, this chapter focuses on the historical evolution and transmutation of courtyard dwellings across the world, discusses and maps the typical courtyard types and forms and, speculates on the benefits and liabilities of the basic courtyard form.

HISTORIC EVOLUTION OF COURTYARD FORM

Paul Oliver wrote in his book Dwellings: The House Across the World that, "Courtyard houses have an ancient history: examples have been excavated at Kahun, in Egypt, that are believed to be 5000 years old, while the Chaldean City of Ur, dating from before 2000 BC, was also comprised houses of this form".[5] Over the past decades, architectural historians and theorists have constantly debated about the origin of the courtyard form but the precise evolutionary path of the courtyard house still remains undetermined. Generally, the basic courtyard house type may be described as one which has rooms surrounding an open-to-sky court and may be essentially associated with the arid climates of Middle Eastern countries. However, the form remains equally prevalent in all the countries and climatic regions of the world. Supporting the theory

[4] Bagneid, Amr. " Indigenous Residential Courtyards: Typology, Morphology and Bioclimates". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley.

[5] Oliver, Paul. 2003. Dwellings: The House across the world. Oxford:Phaidon Press Ltd.

put forward by Hinrichs[6] and Schoenauer[7], it may be logical to believe that this universal type, which responds to the human need for enclosure and defensible, private space may have been derived from very basic human instincts for shelter that can be traced back to the prehistoric cave dwellers. However, Hinrichs observes that, "Time, civilizations and even climatic conditions seem to have very little effect on the courtyard style house as evidenced by history" (Hinrichs, p. 4). The dwellings of the four ancient urban civilizations of Mesopotamia, the Indus Valley, Egypt and China, along with the dwellings of the Classical Roman and Greek periods, all bear evidence to the fact that the "courtyard form" is rather timeless in the history of architecture. Based on accounts of the historic evolution of courtyards compiled by Hinrichs, Oliver, Schoenauer and Sullivan[8] it may be said that the earliest form of courtyard architecture has either evolved from the encampments of the nomadic tribes or the fenced compound dwellings of the first agrarian communities.

ANCIENT CIVILIZATIONS

Schoenauer and Seeman suggest in The Court-Garden House that the most primitive and homogeneous society to build court houses was probably that which built the Troglodyte villages in the Matmatas of Southern Tunisia. "Each dwelling-unit is built around a crater open to the sky, having sloping walls and a flat bottom, which is the court" (p.13). This primitive prototype was preceded by the "douars" in North Africa, the encampments of nomadic tribes in West Africa, the "Kraals of Bechuanaland" in South

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[6] Hinrichs, Craig. "The Courtyard Housing Form as Traditional Dwelling". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 2-38).

[7] Schoenauer, Nobert and S.Seeman. 1962. *The Court Garden House*. Montreal McGill University Press.

[8] Sullivan, Chip. 2002. *Garden and Climate.* New York: McGraw-Hill.

Africa and the first rectangular dwellings in Morocco. Schoenauer and Seeman consider that the "noualas", the rectangular compound dwellings of Morocco mark the transition between the primitive douars and the later conventional court-houses.

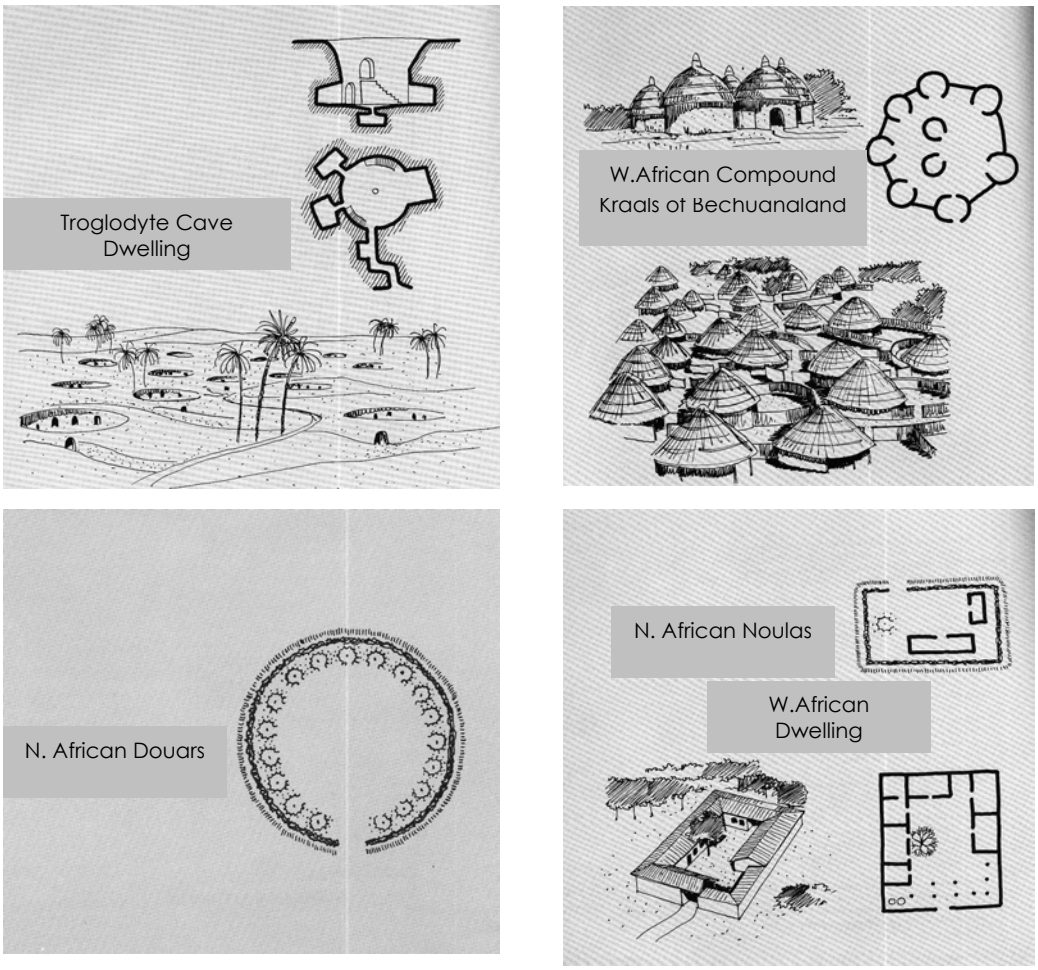

Figure 1.1: Different types of courtyard plans in Africa

Around 2000 – 1500 B.C., houses were being built in Indus valley apparently built on the same philosophy. The houses were planned as a series of rooms opening on to a central courtyard. The courtyard served the multiple functions of lighting the rooms, acting as a heat absorber in summer and radiator in winter, as well as providing an open space inside for community activities.[9] Tadgell[10] supports this fact in his book, The History of

[9] Nangia, Ashish. 2000. *Architecture of India: Indus Valley Civilization*. Downloaded on September 16, 2005.

Architecture of India, while mentioning that a major population in the Indus Valley community used to live in "well-drained courtyard houses" (p.1). Even after the demise of the Indus Valley Civilization around 900 B.C., courtyard dwelling has continued in the Indian subcontinent to the present day. The climatic and regional variances of the archetype will be discussed in detail in Chapter two.

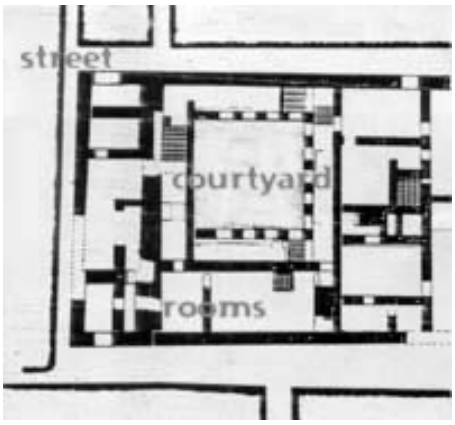

Figure 1.2: Typical plan of Indus Valley dwelling.

Figure 1.3: Typical subterranean dwelling in China

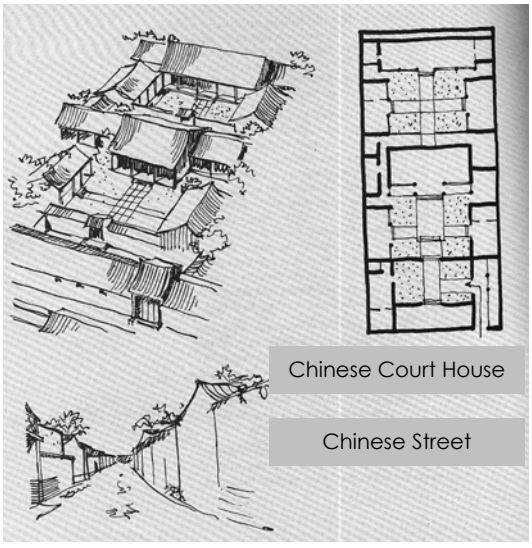

Figure 1.4: Typical layout of Chinese courtyard houses and street

(Source: *The Court Garden House.* Schoenauer and Seeman)

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http://www.boloji.com/architecture/00002a.htm . India Nest.

[10] Tadgell, Christopher. 1990. *The History of Architecture in India*. London, Phaidon Press Limited.

The early Chinese houses were highly influenced by the religious and fundamental principles of Yin and Yang. The use of local building materials and Chinese sense of economics as well as socio-cultural response culminated into similar courtyard principles as popular in the Indus Valley. Schoenauer and Seeman observe the similarity between the simplest form of Chinese subterranean settlements in Honan and the Troglodyte villages. However, they verified that, "The typical Chinese court house is a compound dwelling which consists of a several buildings surrounding a court" (Schoenauer,p.43). Blaser [11] also observed that the concept of yin and yang is reflected in planning the court houses according the north-south orientation following "a strictly axial kind, symmetrically disposed in all-embracing harmony" (p.9). Even today the innate value of these archetypes has not been forgotten and many old houses have been reused and readapted in modern China.

The Japanese dwelling has also evolved from a deep sense of religion and culture. The Shintoist and Buddhist reverence for Mother Nature has been judiciously expressed in the Japanese dwelling design, which gives great importance to the landscape architecture of their court houses. Further south in Asia, the courtyard houses in Bali bear resemblance to the Chinese houses. Similar to their Chinese counterparts these houses also contain all the different functions of the house in separate units within the four-side fenced courtyard (pekaranga).

[11]Blaser, Werner.1979. *Courtyard House in China.* Basel, Boston: Birkhauser.

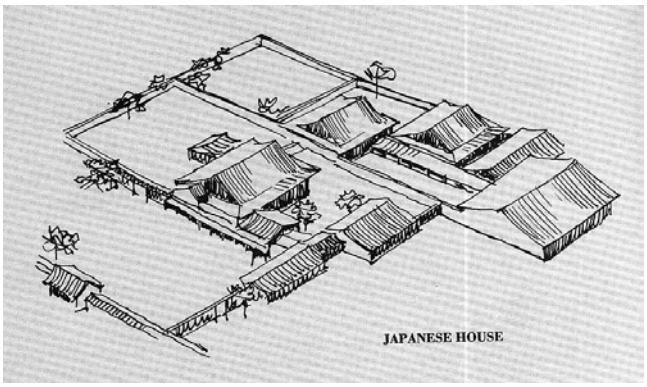


Figure 1.5: Typical layout of Japanese traditional house. (Source: *The Court Garden House.* Schoenauer and Seeman)

CLASSICAL CIVILIZATIONS

The Classical Age of architecture, marked by sophisticated Greek and Roman design and planning, bears evidence to the universal appeal of courtyard dwellings. The Greeks recognized the thermal quality of courtyard houses and therefore designed their homes in a manner to allow low winter sun in the courtyard, while blocking the high summer sun angles by the overhanging eaves on the portico (Hinrichs, p.4). The Romans were later inspired by the light and airiness of Greek peristyle houses and the atrium houses of the Etruscans. This is how the Roman atrium house with two interior courts, the peristyle and atrium, evolved. "The remains of Pompeian houses suggest that the Roman domus was usually one-storey high, and that all rooms were lit by relatively small openings facing the interior courts…the interior was sumptuous; the floors were patterned mosaic or marble, the walls were painted in fresco, and the ceiling timbers were often gilded" (Schoenauer and Seeman, p.23).

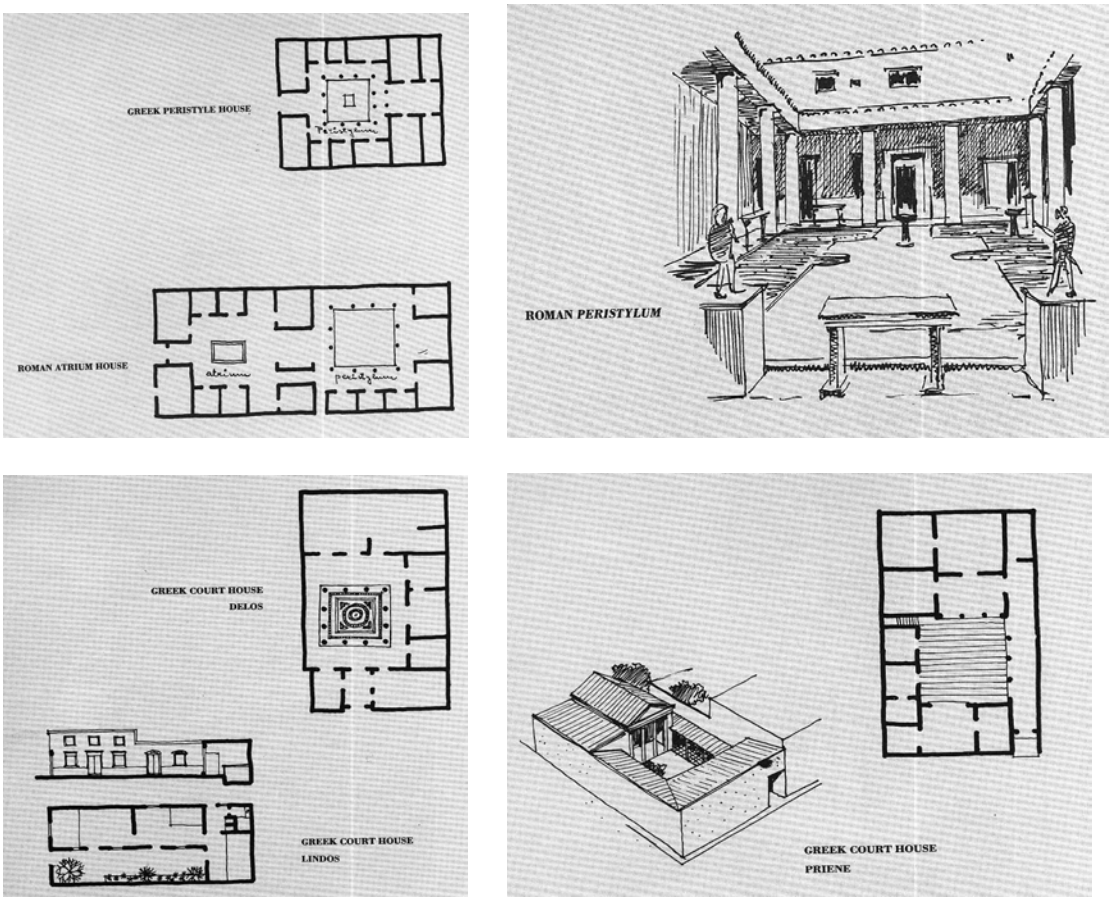


Figure 1.6: Typical courtyard dwellings prevalent during Classical Civilization

(Source: *The Court Garden House.* Schoenauer and Seeman)

THE MIDDLE AGES AND RENAISSANCE CIVILIZATIONS

By A.D. 476, after the fall of the Roman Empire, the courtyard-type dwelling suffered a setback. In fact, during the Middle Ages the only traces of courtyard houses were found in Italian cortile houses and monastic cloisters. As Christianity gained popularity the courtyard form started being adopted by the monasteries. Sullivan observes that the "Benedictine monastery life typically revolved around a central, enclosed, four sided space with a roofed walk about which the monks came to study and to meditate" (p.102). Even during the Renaissance the courtyard type remained rather suppressed

with some rare presence in cities like Florence. Here, Brunelleschi, Manetti and Michelangelo designed bold and charming courtyards within the historic center, transforming Florence into a city of great courtyards (Sullivan, p.102).

"Court houses survived, however, as a more humble dwelling-type in other regions bordering on the Mediterranean…" (Schoenauer and Seeman, p.25), namely in the Muslim countries of North Africa and the Middle East. The paved courtyard in the dar houses, the more refined riads with interior gardens, the simple Arab houses, the unpretentious exterior with interior splendor of the Syrian (Damascus) houses all adhere to the basic Islamic dwelling philosophy of "privacy and seclusion with a minimal display of the occupant's social status to the outside world" (Schoenauer and Seeman, p.29). The courtyard form in the countries in the Mesopotamian region adapted to the very hot climate by adding a cellar below the level of the courtyard called the serdab. This room is always kept damp to provide a cool retreat to the residents. Hinrichs rightly describes the Islamic adaptation of the courtyard houses as an "oasis concept". The proportions of these buildings maintained a beautiful responsiveness to the hot-arid climate in most of the Muslim countries – "where there exists an intentional contrast between the stark, bright, heat of the outside and the intimate confinement, shade, and coolness of the dar's interior" (p.3).

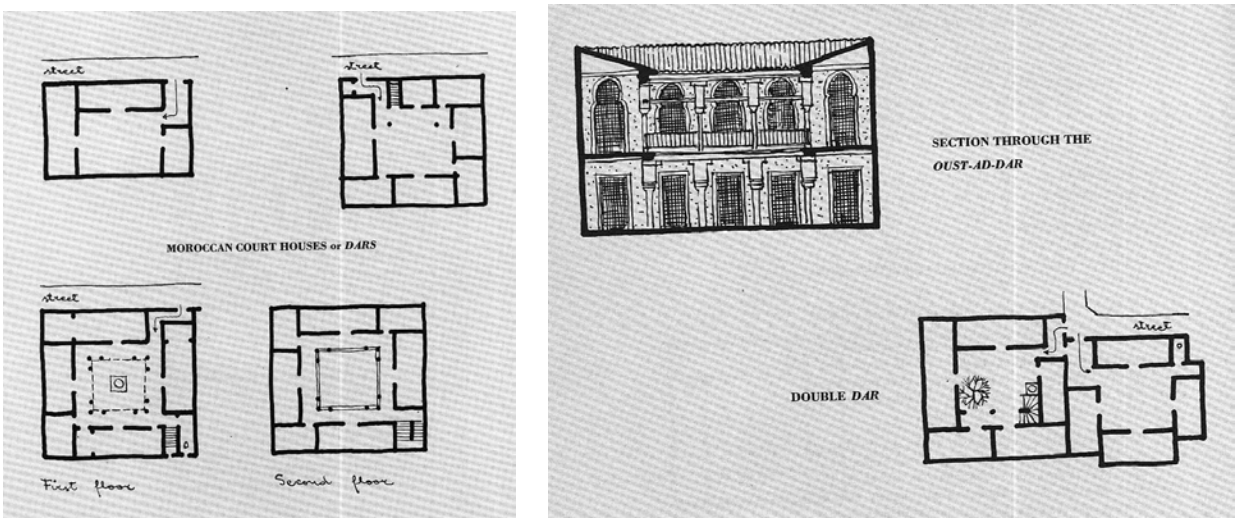
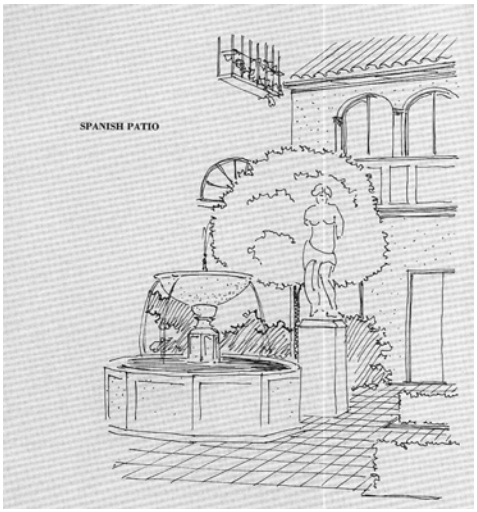


Figure 1.7: Courtyard houses in Morrocco, typical during Middle Ages

(Source: *The Court Garden House*. Schoenauer and Seeman)

Courtyard houses were also popular in northern areas around the Mediterranean Sea, especially southern Spain. There were mainly two dwelling types in Spain inspired by the Roman atrium houses. In Northern Spain the houses were more solid. However, the climate in Southern areas favored outdoor activity, which helped in the evolution of the courtyard dwelling type. The court houses in Spain extending between southern Catalonia and Andalusia were characterized by patio houses. Later the Spanish colonists exported this building construction method to Latin America, where it survives till the present date as a predominant dwelling type.12 "The typical court house in Mexico is entered through a monumental doorway, leading into a passageway known as the zaguan…From the zaguan one enters the patio. This is the center of Mexican family life, around which the home is built" (Schoenauer and Seeman, p.37).

[12] Hinrichs, Craig. "The Courtyard Housing Form as Traditional Dwelling". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 2-38).



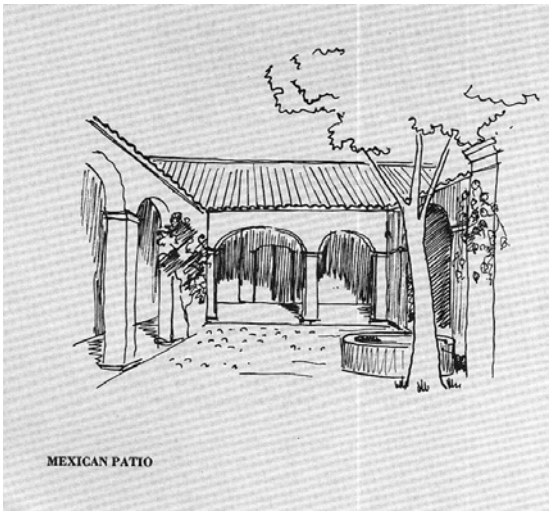


Figure 1.8: Typical Spanish patio

Figure 1.9: Typical Mexican patio

(Source: *The Court Garden House.* Schoenauer and Seeman)

MODERN CIVILIZATIONS

In the modern age, the courtyard form first reached the West Coast of North America mainly due to the influence of the Spanish Colonial Revival movement in Southern California in the late 19th century. Many critics have suggested that, with the absence of any established academic architectural tradition on the West Coast, Los Angeles became an experimental ground for all kinds of theatrical architecture. Many others have argued that the film industry, and especially movie set design, had an immense influence on the evolution of Los Angeles buildings into a wide variety of styles. However, in reality the most logical explanation has been put forward by Polyzoids et.al in Courtyard Housing in Los Angeles: A Typological Analysis. These authors argue that the huge influx of immigrants between 1880 – 1930, created an intense pressure for housing. "Even the availability of land and easy mobility, however, could not deter denser clusters in the form of courtyard housing forms appearing within the city" (p. 12).

Polyzoids et.al 13 further explain that, "The fact that a great many tourists returned to retire in southern California must have encouraged builders to provide permanent high-density accommodations in the original form of the temporary tourist court; and that activity in turn helped to canonize the type and generated a wide range of specific and novel buildings" (p.16). The courtyard type moved across the United States to the East Coast only after the Depression, when Marcel Breuer first conceived the idea of separating living and sleeping areas by use of courtyards.14 Macintosh writes in The Modern Courtyard House that by 1956 the binuclear patio house had evolved into the long, narrow, terraced house with several patios.

Courtyard houses, especially mass courtyard housing, became a popular form in Europe though, Macintosh warns that these dwellings had nothing to do with the earlier precedents in architecture. He observes that the "…symmetrical quadrangular plan has been reworked" (p.8) since the early twentieth century. The single storey mass courtyard housing in Europe was mainly a social response to the housing demand for the low income working class. In Europe, Macintosh observes that the first modern detached court house overlooking a garden on the south was built by Hugo Haring in 1928. This style was later adopted into an L-shaped plan by two Bauhaus architects, Hannes Meyer and Ludwig Hilberseimer. This L-shaped modification of the quadrangular court-house became popular in both Germany and England by the 1950's and 1960's.

[13] Polyzoides, Stefanos, Roger Sherwood and James Tice. 1996. *Courtyard Housing in Los Angeles: A Typological Analysis*. Princeton Architectural Press.

[14] Macintosh, Duncan. 1973. The Modern Courtyard House. Architectural Association, London.

Finally, courtyard architecture still survives today in almost all countries of the world, either in its pure rectangular form or in modified shapes. Macintosh writes that, "Social surveys have shown that people who live in courtyard houses do appreciate their qualities" (p.8). The question remains, what is so universal about this historic form that it has survived through the ravages of time and across so many varied climates and civilizations? The interesting point to note here is that there seem to be similarities between the different stages in the evolution of this housing type. This may be explained by what Schoenauer and Seeman mention as traits evolving from human ecology. "The need for privacy, climatic conditions, and the requirements for adjustment to available land area limitations, find their solution in a general and widespread housing form: the court-house" (p.46).

COURTYARD FORMS AND ELEMENTS

The courtyard plan is not fixed. Though the basic courtyard form of dwelling is rectangular or cubic in shape, it may be round or curvilinear too. A block with a punctured hole in the middle as a breathing space within the confined box is the general courtyard type. However, this form may be and has been modified to adapt to the topography, site restrictions, building orientation and functions to create new formal shapes such as the L, U, H, T, V or Y.

Sullivan observes that "The size and scale of a courtyard can vary from very intimate to quite spacious. In every case, the courtyard creates a wonderful frame of light and air" (p.101). Based on the literature survey done it may be said that, historically most

courtyard houses worldwide have been restricted to one to five floors. However, the modern variants of courts like atria, terrace gardens and so on allow the heights of the building to soar higher, provided that proportion and scale are maintained to allow the courtyard feeling of light and airiness.

Finally, to understand the different parts of the courtyard house type the following elements of a "basic court house" are analyzed. Though it must be understood that these elements have been modified and adapted in different regions and cultures, they are usually continuously present in all court houses across the globe.

- The court
- The arcade or verandah
- The rooms
- The roof

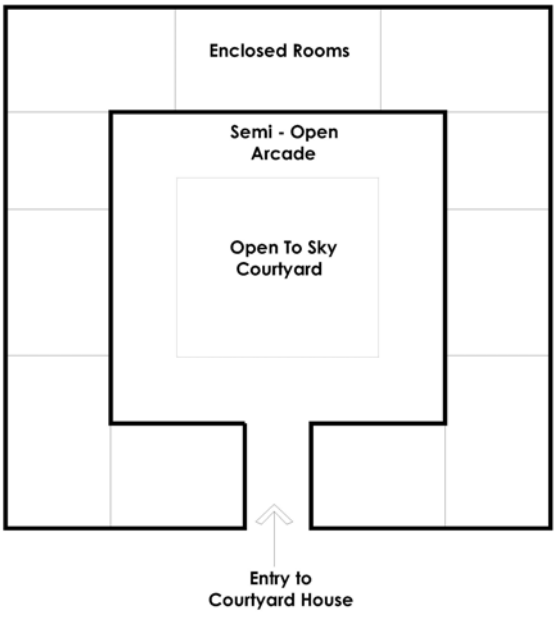


Figure 1.10: Basic Courtyard Form

COURTYARD BENEFITS AND LIABILITIES

Some advantages and disadvantages are inbuilt to the courtyard form. As Hinrichs puts it, "…vernacular dwellings are the distillation of centuries of basic experiments of trial and error" (p.6).

BENEFITS –

The benefits of a court in the house may be described by the following list:

PSYCHO-SOCIAL BENEFITS – The primary benefit of the courtyard is a result of its inward form, which provides a sense of enclosure and privacy to the residents of the house. The court is the heart of the house, where different functions can take place during different parts of the day. This "outdoor room" can be used as an extension of the kitchen during mornings or as an extension of the living room during evenings to entertain guests. As Reynolds observes, "Everyday repetitious acts benefit from the change of scene" (p.57).15 The courtyard can provide a safe place for the children in the family to play under the visual supervision of elders. The court acts also as a space for interaction for all family members. Generally, all the rooms face the courtyard, creating a direct relationship between the inside and outside. This arrangement encourages family members to use the courtyard as a group.

Privacy is the main concern of courtyard type dwellings. Therefore, in most of the courtyard houses the court is visually secluded by screened or walled entrances. In places where the climate is conducive to outdoor activity, the parapet walls on the

[15] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*2002. New York: John Wiley

roofs are high enough to provide a private sleeping area during the night. The inherent private quality of these houses provides privacy from the neighbors or the outside world while bringing in the elements of nature like sun and wind. Besides the visual privacy provided by the courtyard form, it also provides acoustical privacy. The courtyard house absorbs the noise of the house within itself. Also the surrounding rooms provide a noise barrier between the inner heart of the house and the street outside. This prevents the residents from being disturbed by the outside humdrum and provides a quieter and private outdoor space to enjoy.

CULTURAL BENEFITS - Often we find the use of more than one courtyard in both occidental and oriental cultures. This is usually to segregate the public and private spaces within the house. The public domain is mainly for the guests and is mostly used by the male members of the family. The inner court is more restricted to the family and is usually an outdoor space enjoyed by the female members of the house.

Hinrichs[16] observes that there are some basic differences between the oriental and occidental courtyard houses. He notes that, unlike the occidental houses, the family sections in the oriental houses are more lavish and spacious. In the occidental houses there seems to be a tendency to reflect social values, wealth and status by consciously decorating the exterior of the house and outer courtyards. The oriental houses seem to be more flexible and compact than their Western counterparts. This is mainly because

[16] Hinrichs, Craig. "The Courtyard Housing Form as Traditional Dwelling". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 2-38).

in oriental homes each family member has a room to himself/herself, which could be used for a number of different functions like eating, sleeping and entertaining friends.

CLIMATIC BENEFITS – Courtyards have been generally referred to as a microclimate modifier in the house due to their ability to mitigate high temperatures, channel breezes and adjust the degree of humidity. Sullivan observes that, "The courtyard integrates a wide variety of passive devices into its design, each creating its own thermal environment" (p.104). The properties of self-shading and thermal lag may be used to reduce heat gain in courtyard houses by using the right proportions and building materials. The right courtyard proportions may block higher summer sun angles while allowing lower winter sun angles. The courtyard floor and surrounding walls are usually a good radiator of heat depending on the material used. Thus, the courtyard acts like a cool air reservoir especially in hot-arid climates where clear sky conditions favor the heat radiation property of surface materials. This helps in maintaining lower temperatures in the court and especially ground floor rooms. However night sky radiation, depending on the amount of heat dissipated from any surface via long wave radiation, increases and decreases by the number of exposed surfaces.[17] In his article "Climatic Issues Concerning Open Courts" Doell[18] describes how courtyards can modify and adapt to both cold and hot climates. Use of low albedo, light-colored highly reflective surface materials in courts help to bring more sunlight into surrounding rooms in cold climates. Wide, open courts, allowing maximum exposure to solar radiation is

[17] Hanna, R and P.Simpson. "The Climate and the Social Climate of a Design Stereotype: The Courtyard Paradigm ". *Environmental Factors in Traditional Environments.* AlSayyad, Nezar.ed. 1996. Traditional Dwellings and Settlements Working Paper Series, Volume eighty-eight, IASTE 88-89. Center for Environmental Design Research, University of California, Berkeley. (p. 75-99).

[18] Doell, Bryan. "Climatic Issues Concerning Open Courts". *Perspectives on Courtyards*. 1989. University of Manitoba.

also beneficial to cold climate housing types. Again, using plants and water elements in courtyards helps to add moisture to the air and enhance comfort conditions in hot-dry climates. Natural ventilation in the courts may be increased by either adding wind-traps or by using shaded and open-to-sky courts alternately.[19]

The courtyard is a space in the house that is subservient to the annual, seasonal and diurnal weather changes. Therefore, if appropriately designed the court may provide a 360 degree opportunity of orientation of the house.[20] Schoenauer and Seeman observe that "…the inward directed nature (of courts) enables the architect to orientate (them) in relation to sunlight" (p.117). This freedom in orientation and control over the solar sky helps in modifying the amount of daylight entering the courtyard house. As mentioned earlier, highly reflective surface materials may allow greater light penetration in rooms; similarly use of proper shading devices and massing of the building may help in filtering the daylight which enters into spaces. The envelope mass of the court house helps in both acoustically isolating the court from outside noisy streets, while amplifying the sound of nature within the enclosed environment – for example that of birds, water falling from fountains.[21]

ACCESSIBILITY AND CIRCULATION BENEFITS – Courtyards generally function as loci in the house, connecting the different areas and functions within the house, assuming the primary

[19] Ibid.

[20] Bagneid, Amr. " Indigenous Residential Courtyards: Typology, Morphology and Bioclimates". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley.

[21] Ibid.

role in building circulation.[22] The compact nature of the form reduces circulation space within house so that corridors may be eliminated by accessing different rooms directly from the court.[23] This emphasis on the use of the ground plane minimizes the requirements for stairs, which helps in making the different parts of the house easily accessible by even those with limited mobility. Polyzoides et.al mention in their typological study of courtyard housing in Los Angeles that courts function successfully for the older generations in the house. The practical solution of courtyard design combines the advantages of compact design and easily maintained living quarters. Furthermore, the courtyard design accommodates communal outdoor places for public contact, encouraging those with mobility disabilities to enjoy the outdoors.

SYMBOLICAL – RELIGIOUS BENEFITS – The courtyard is both symbolically and religiously significant. This open-to-sky yet enclosed space within the surrounding walls of a house has been considered as a spatial symbol of inwardness and femininity in the house. The courtyard may symbolize many things: an oasis in the desert; a fragment of nature inside the house; the central focus of interest in the house; a concentration of light, wind, sound and water; a private, safe and life-sustaining refuge.[24] The courtyard may also symbolize the life-cycle of nature and humans with respect to the social values of the times.

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[22] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*2002. New York: John Wiley (p.53)

[23] Sinha, Amita. "The Traditional Rural Settlements and Dwellings in Northern India". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 117-140).

[24] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*2002. New York: John Wiley (p.25)

Courtyards have been accepted as a secular form in almost all the religions of the world. The oasis concept is a valid analogy of the courtyard space in Islamic regions of the world, which is located within hot -arid regions. The use of courtyards offers an intentional contrast between the stark, bright heat of the outside and the intimate confinement, shade, and coolness of the court inside which provides relief like an oasis in the desert. The courtyard houses in the Hindu regions of the world follow the cosmic square of Hindu theology. Hindu courtyards are used for daily religious rituals. Most Hindu courtyards are distinguished by the placement of a Tulasi (basil) plant which is watered and worshipped every morning by the ladies of the house. The most universal religious application of the open courtyard is perhaps congregation, whether as prayer halls in Christian or Buddhist monasteries, or as areas for religious festivals in Hindu houses and temples, or for offering namaz in Muslim mosques or houses.

ECONOMICAL BENEFITS – Some financial benefits are closely associated with the courtyard form and construction. Courtyard house designs show efficiency in land use. Especially when adjoining courtyard houses share walls, the cost of both construction and maintenance is significantly reduced. With an interior open space, the setbacks usually required for front and sides around buildings may be nullified, thus allowing usage of more floor area. Schoenauer and Seeman observe in The Court-Garden House that, "Efficiency of land use may, on the other hand, justify the employment of court houses in central urban renewal areas in conjunction with high-rise multiple housing developments. These two dwelling-types complement one another, provided that the masses of the low and high-rise buildings are well balanced" (p.115).

The minimization of walls also leads to fewer surfaces for either heat gain or heat loss, which may help in economizing the air-conditioning load inside the house. Hinrichs[25] observes that the inherently austere visual quality of the street façade of most courtyard houses leads to simple, unpretentious design solutions, which help create savings in construction costs. Another financially beneficial aspect of the courtyard form is its generally flexible interior spaces. It is common to find examples of court houses all over the world where each room can be modified into serving multiple purposes. This helps the easy adaptability of new functions for the courtyard house once the old use is no longer appropriate or relevant.

LIABILITIES –

Inspite of the many benefits of the court house as described above, Hinrichs[26] has also highlighted certain disadvantages of this form.

The usual low storey open-to-sky structure may attract burglary. Burglars may enter the house by climbing on the roof from the street side and then climbing down into the courtyard to access the inner rooms. Also if the adjacent courtyard houses share walls, the continuous roofs/terraces may provide an easy escape path for burglars.

The open court brings nature into the periphery of the house. This may also mean different insects can come into the house easily. Again, if the courtyard has water

[25] Hinrichs, Craig. "The Courtyard Housing Form as Traditional Dwelling". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 2-38).

[26] Hinrichs, Craig. "The Courtyard Housing Form as Traditional Dwelling". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 2-38).

features, care should be taken to see there is no still water which may be conducive to mosquito breeding.

While the families enjoy a private life secluded from their neighbors and the children get an inner playground, it may also lead to seclusion especially for the children who may not meet other children easily.

Being outdoors the space has a propensity for collecting dust and therefore needs to be regularly cleaned and maintained.

The affordable economics of courtyard construction has unfortunately also added a stigma of poverty to this house form. Today, there is a general trend of associating courtyard houses with low-cost construction methods, and locations in rural or economically weaker neighborhoods. Generally, the difficulty of incorporating modern amenities like mechanical ventilation in this traditionally naturally ventilated form has been a setback in the popularity of the form. Hanna and Simpson[27] also observe this fact in their extensive comparative analysis of traditional court houses and modern non-courtyard houses in the Middle East. In their article, "The Climate and the Social Climate of the Design Stereotype: The Courtyard Paradigm", Hanna and Simpson report that, "The main reasons for dissatisfaction with the forms, given by 70% of traditional house occupants, were the environmental disturbances in summer and winter when they moved from one room to another across the open-to-sky courtyard, and the difficulty in controlling the indoor environment that this form of planning creates" (p.86).

[27] Hanna, R and P.Simpson. "The Climate and the Social Climate of a Design Stereotype: The Courtyard Paradigm ". *Environmental Factors in Traditional Environments.* AlSayyad, Nezar.ed. 1996. Traditional Dwellings and Settlements Working Paper Series, Volume eighty-eight, IASTE 88-89. Center for Environmental Design Research, University of California, Berkeley. (p. 75-99).

In places where compact planning of traditional courtyard houses has been created, there are chances that the low pressure differences between opposite sides may discourage natural cross ventilation.

These may be some of the reasons why, even after surviving for 5000 years, the courtyard form is suddenly being threatened by the development of high-rise apartments. However, if we look closely we will be able to see that most of the disadvantages of the courtyard form may be compensated for by appropriate design and construction methods. My interest in studying this universal form is that I believe that the basic advantages of the form still surpass the liabilities.

CHAPTER 2: INDIA AND INDIAN COURTYARD HOUSES

INTRODUCTION TO INDIA AND INDIAN ARCHITECTURE

Figure 2.1: Political Map of India

(Source:http://www.mapsofindia.com/maps/india/india-political-map.htm)

Geographic coordinates: Situated between latitudes 8° 4' and 37o 6' N and longitude 68°7' E and 97° 25'E

Area: total: 3,287,590 sq km

land: 2,973,190 sq km

water: 314,400 sq km

Climate: varies from tropical monsoon in south to temperate in north

Population: 1,049,700,118 (July 2003 estimated)

GDP: purchasing power parity - $2.664 trillion (2002 estimated)

GDP per capita: purchasing power parity - $2,600 (2002 estimated)

Climatic zones: 4 distinct climatic zones- hot arid, hot-humid, warm-humid, cold.

(Source: http://www.cia.gov/cia/publications/factbook/geos/in.html)

INDIAN ARCHITECTURE

The vast tapestry of Indian architecture is comprised of a multitude of expressions over time and space, transforming under the forces of history – which may have been destructive sometimes but remained mainly absorptive.[28] Therefore, even in this process of metamorphosis and hybridization of architecture and society, there has remained continuity in the vernacular buildings and cities in the sub-continent. In the evolving and pluralistic range of architectural styles in India, (namely - Indus / Vedic architecture; Buddhist and Jain architecture; the Hindu temple; Islamic architecture; secular architecture; architecture under the colonial rule; post-independence architecture of India [29]) one architectural form has continued to be expressed repeatedly – the courtyard type. The courtyard forms may be dormant now replaced mainly by Westernized-box architectural types; however, as Randhawa [30] suggests courtyard types have historically been not just an architectural style but a "way of life" especially with reference to residential architecture in India.

[28] World IQ.com. Indian Architecture. Downloaded on September 14th, 2005. Weblink: http://www.wordiq.com/definition/indian_architecture

[29] Ibid.

[30] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

INDIAN COURTYARD TYPES

> *Courtyard house architecture reflected the style and culture of its time. It was indicative of the owner's self-image and aspirations, with a distillation of the historical influences. It manifested itself in degrees of solidity to extreme ornamentation.*
>
> *- T.S. Randhawa, The Indian Courtyard House,p.32*

India has some splendid design examples of courtyard houses, called by various regional names like the – haveli(s) of Gujrat of northern India, wada(s) of Maharashtra, deori(s) of Hyderabad, rajbari(s) of Bengal and nalukettu(s) in Kerala.[31] Research on the genesis and significance of Indian courtyards seems rather recent as previously it has been overshadowed by the architectural importance and preference given to its Western counterparts (mainly Greek, Roman etc). Even in their extensive historic accounts of courtyard evolution by Schoenauer and Seeman, Hinrichs and Blaser and many other architectural historians, it is difficult to trace the origins of Indian courtyard houses. Randhawa points out that, "The courtyard house form in India was not based on blind conformity and there was tremendous innovation in the design of such homes…" (p.32). He observes in The Indian Courtyard House that these designs were not only indigenous but also conformed to the climatic requirements of the different regions. "The spatial and formal elements fell into a wonderful introverted blueprint. It reflected the society of its times. Even the simplest homes have an air of elegant character" (p. 29). This air of elegance is visible across the country with regional

[31] In his study about the patterns and relationships among the Indian vernacular housing, Allen G. Noble observed that the English word "courtyard" has at least twelve major Indian language terms: *angan, muttram, uthan, sehan, chowk, mittam, nadumittam, manduva, nalukettu, chawk-milan, agana, gothiyara.*

Noble, Allen G. "Patterns and Relationships of Indian Houses". *Asia's Old Dwellings: Tradition, Resilience, and Change*. Knapp, Ronald G. 2003. Oxford University Press.

variations accentuated by use of different design and craft techniques, building materials (like brick or stone) and mortar joints. Schoenauer and Seeman also observe this fact about the Indian courtyard house in The Court-Garden House:

> *It is obvious that in a large country like India one must encounter many regional differences in court-house building traditions. However, there is one characteristic which applies to the Indian builder in all regions: he has an excellent sense of proportion and is highly skilled, despite his simple tools, producing buildings with a distinctive dignity and beauty. (p.43).*

In India, where the greater part of the population lives in villages, the courtyard form of dwelling is a very common residential type. Generally, four oblong one-storey huts enclosing a square court is a common way of rural massing of housing.32 There are differences in the urban and rural courtyard form, though the general oriental concept of dividing the courtyard house into public and private sections remains similar in both types. Today, as we witness the gradual transition of the urban courtyard house into oblivion, being replaced by the Western construction models, the rural courtyard form still persists in India. In this thesis I am more concerned with this dying and disappearing variant of the courtyard house in India's rapidly urbanizing skylines.

HISTORICAL BACKGROUND

Historically, the courtyard dwellings in India can be traced back to the ancient Indus civilization of the 3rd millennium B.C. Tadgell[33] observes in his historic account of Indian architecture that the civic planning in the Mohenjodaro - Harappan civilization was

[32]Schoenauer, Nobert and S.Seeman. 1962. *The Court Garden House*. Montreal McGill University Press.
[33] Tadgell, Christopher. 1990. *The History of Architecture in India*. London, Phaidon Press Limited.

based on a rectangular grid oriented to the cardinal points, with the blocks built by well drained brick courtyard houses. Later the Vedic architecture (1500 B.C.) was also influenced by the native adoptions of court houses by the Aryan invaders. According to Tadgell, the typical Aryan village community consisted "…of several families each with its own house (griha), cowshed and granary in its own compound on a courtyard" (p.7). Later, the Muslim invaders who were already aware of this type of residential architecture in the Middle East embraced the form which was once described as – "a great vaulted space wholly or partially closed on three sides but entirely open to a court…"[34] – to supplant the Hindu apadana as the dominant element in Iranian secular architecture (Persian invasion around 500 B.C). Courtyard houses continued throughout the Hindu, Buddhist and Jain ages as a popular housing type. The religious institutions also adapted the courtyard form as is evidenced from the temples throughout India, or the Buddhist monastic clusters. Alexander's invasion in 326 B.C. brought a Greek influence to Indian architecture especially in the form of Buddhist sculptures and monasteries. The courtyard architecture survived and persisted through the ravages of time in different forms (mainly monumental, such as temples, palaces, monasteries) till the early 16th century and then gained prominence under the Mughals in India.

As described by Randhawa, the courtyard house that we are familiar with today in India has undergone mainly two design phases. The first phase is associated with the Mughal period between the 16th and early 18th centuries and the second phase, which is marked by the colonization of the subcontinent between the late 18th to 20th centuries (Randhawa, p.33). Courtyard architecture remained significant throughout

[34] Tadgell, Christopher. 1990. *The History of Architecture in India*. London, Phaidon Press Limited.

the different religious movements in India. The adaptation and transformation of the courtyard form and the different religions in secular India will be discussed in detail later in the chapter.

At this point, I have concentrated on identifying a typology of courtyard examples seen across the country using references from different literary sources.

Figure 2.2: Akbar's Fatehpur Sikri shows a culmination of two phases in courtyard design, combining the Muslim Arches with Hindu Traebate style.
(Source: mikespub.net/pictures/ India/page31.html, downloaded October 30th, 2005)

Randhawa suggests that the first stage of courtyard design evolution started with the introduction of the Islamic arch and ended with its fusion with the Hindu Traebate style exemplified in Akbar's Fatehpur Sikri. During this time there was also evidence of cross-regional influence as the bangaldar roof, derived from the village huts in Bengal was imported to northern parts of India. According to Randhawa, the second stage was marked by the rise of palatial architecture in India. He noted that the magnificence and splendor of the palace-like houses became related to social status and power, "…ironically only when the British subjugation provided comparative peace for such

building activity, and also provided European models" (p.33). This created hybrid courtyard architecture in India, blending the Indo-Saracenic (Baroda and Gwalior) to other Louis XIV and Italian imitations (Randhawa, p.33).

SOCIAL AND FORMAL ANALYSIS OF THE COURTYARD TYPE IN INDIA

SOCIAL RESPONSE

Courtyards in India are the direct expression of the socio-cultural values of the times and society. These social values are demonstrated in the belief in the cardinal directions which guide the location and orientation of the building and its different functions. The organization of space within the household reflect the social relations between men and women, elders and young in the family and also, most importantly, the social structure.[35] The Indian courtyard house type is basically very loosely defined in relation to the interior spaces. In fact, as Randhawa has rightly observed, the kitchen and the puja rooms are the only rigidly defined spaces. Otherwise most other rooms are multipurpose, which reflects the adaptable social structure, respecting the utility of spaces even after their primary use is over.

In India, like in most other cultures, the courtyard form was a direct response to the social preference for privacy and seclusion in family life. The Indian affinity for a family life-world separated from the world outside favored the inward courtyard form. Indian courtyard houses were highlighted by two courtyards, the outer court or baithak which

[35] Sinha, Amita. "The Traditional Rural Settlements and Dwellings in Northern India". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 117-140).

served as the visitors' sitting area or public space; and the inner court which was mainly the women's area or for specific to the family members.

FORMAL RESPONSE

Noble writes that, "A courtyard – centered dwelling is the climax structure in the middle of the Ganges valley, in the Chota Nagpur plateau, in the Dehra Dun valley at the foothills of the Himalayas, in West Bengal, along the Malabar coast, the east coast of Andhra Pradesh, throughout Tamil Nadu, and in the canal irrigated district of Rajasthan. There have been many theories behind the evolution of courtyard houses in the Indian subcontinent. A formal genesis of the courtyard house type as proposed by Mitra [36] has been generally widely accepted. According to this theory, the evolution of the courtyard dwelling may be traced through four different phases. In the first stage, a single room, either square or rectangular, is built. In the second stage, verandahs are added to this structure, allowing the idea of intermediate or transitory or semi-outdoor spaces. The third stage begins with the intention of expansion of the rudimentary house form. The original house is then expanded by construction of smaller structures, at right angles to form two sides of a fenced or shrub enclosed compound. Alternatively, in this stage a second building may be placed opposite the original house, separated by the open but fenced compound. In both these instances the main theme is the generation of the open yet partially enclosed, unroofed compound or courtyard. In the final stage, the remaining two open sides of the compound are filled by rooms effectively enclosing a space to form the courtyard. Noble further adds to this theory by

[36] Mitra, Ashok. 1982. "Rural House Types and Village Settlement Patterns". In Allen G.Noble and Ashok K.Dutt, eds. *India: Cultural Patterns and Processes*,pp. 105- 24. Boulder, Co.: Westview Press.
Noble in his article on the "Patterns and Relationships of Indian Houses" mentions this theory of formal genesis of courtyard dwellings in India.

suggesting that houses with two or more courtyards were further developed from this basic form to accommodate joint or extended families.

BASIC COURTYARD SOCIAL- FORM

Street level – The courtyard dwelling stands in direct harmony with its surroundings and the street. Unlike the palaces in India, which somewhat followed the occidental model of solidity and rigidity on the exterior, most of the Indian court houses have an interactive relationship with the streets. Randhawa notes that in most of these houses, there is a platform or sitting space next to the main entrance door (p.33). It is essentially this space that acts as a transitory space between the exterior and the interior of the house – a space where the house activities spill out. This space is especially the domain of the men and the children in the family who are allowed in traditional societies to maintain social interactions with the outside world and be part of the street life. Usually the number of openings on the street side is limited since the private life of the interior court, which is the female domain of the house, is highly guarded. Therefore, the daily peddlers, weavers, dyers, traveling artisans, barbers and so on are usually restricted to this platform outside the house. Only traders selling items specific to the ladies use like different dress materials, fashion accessories, tailors, utensil vendors and so on were allowed to enter the inner courtyard of the house. Jugglers, acrobats, snake charmers, musicians and theatre groups were also admitted into the courtyard to perform. This was mainly the only form of entertainment for the household ladies. However, they could watch these shows only from areas where they could be visually hidden from these showmen, which are usually spaces located behind curtains, or railings on the first floor of the house.

Building level – The building is designed with rooms enclosing the courtyard. The court itself symbolizes the female space in the house. The general square or rectangular plan is functionally divided into outer spaces where males dominate and inner spaces where the females live. The usual height of the building is two to five floors, with an inward looking plan to ensure privacy from neighbors. The courtyard is the central focus of the house which is enlivened by different daily activities. The rooms around the court are used for various functions. Randhawa explains that, "The courtyard ordered other spaces by context in an abode where space was not rigidly fixed but could be adaptable depending on the time of day, season and exigency…It was the spatial, social and environmental control center of the home" (p.31). Towards the exterior are living rooms where friends, neighbors or guests may be entertained without giving them total access to the interiors. The kitchen or bedrooms are placed towards the interior, in such a way that the females can use the space on a daily basis without any hesitation or male intervention. The inner court is an extension of the kitchen, prayer room, bedroom and living area for the females in the house. They sit in and around the courtyard and the arcades from morning to evening, cooking, washing, preparing, gossiping, knitting, taking naps, and supervising servants in the house. Randhawa points out that even in the loosely defined functional spaces there exists a kind of informal code specifying such things such as which terraces in the house can be used for sleeping in summer afternoons. There is also a demarcation of levels providing privacy for newly-weds. Generally, the terraces also have an open shelter at one end to provide protection if it suddenly starts raining in the night.

Building element level – Doors and windows in the courtyard house are important architectural elements which complete the aesthetics and socio-climatic order and significance of the courtyard houses in India. The doors are elaborate decorative elements in practically all courtyard houses in India, irrespective of the regional variation. Noble observes that in general the main door in all courtyard houses is usually offset in the home façade and opens into an anteroom from which a largely unornamented doorway leads into the courtyard or house interior. Thus the main entrance is located in a manner that does not allow the outsider to directly gaze into the courtyard. A similar philosophy guides the placement of windows in a courtyard house. Window openings of a room face towards the courtyard or toward the street outside, though the number of such openings in the ground floor is restricted. This inward view helps to provide privacy within the house with each opening behaving like a one-way mirror that is screened from the exterior by the strategic positioning of curtains, *jalis*, bay windows and cradle balconies called *jharokhas* or *mashrabiyya*. Especially in the western Indian *havelis* the *jharokhas* are very prominent features. Randhawa observes that these *jharokhas* provide private sitting areas above the street, catching the summer breezes and winter sun. The *jharokhas* help in filtering diffused light into the room and effectively ventilating it. The rows of cantilevered *jharokhas* also provide shade to the street below.[37]

[37] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

REGIONAL VARIATION IN COURTYARD FORM

Courtyard houses in India can be found in every part of the country, from the Himalayas to the south; however, the typical planned form was more essentially a feature of the plains, starting from the foothills of the Himalaya. The next section discusses the different regional forms of the courtyard house in India.

HAVELI - The havelis of northern and north-western India are perhaps the most popular types of courtyard houses in India whether in Gujarat, Rajasthan or Punjab. The Gujarat havelis are known for their rich interior and exterior wood carvings and decorations. As Cooper and Dawson remark, "These buildings evolved from local timber resources but during the nineteenth century, as the forests fell, teak was brought from Western Ghats" (p.104) or imported from the Malabar coast or Burma. Typically the Gujarat haveli is elongated but narrow in plan which is ideal for conserving space in the dense khadki[38]. Noble suggests that the Gujrati haveli essentially may be divided into three subparts. First there is the roofed but open verandah in the front of the house facing the street. Next there is a room, called baithak, occupied by males and used for gathering, entertaining guests or as sleeping space during the monsoon. The number of courtyards varies from a single small one to a number of larger ones. When there is more than one courtyard, the outer courtyard is used to park trolleys and tractors, keep cows or buffaloes. The inner courtyard has a series of rooms devoted to cooking, food preparation and water storage. Rainwater is also stored underneath the courtyard. The

[38] Khadki is a collection of havelis in Gujarat opening onto a cul-de-sac with a single outlet usually controlled by a massive gateway. Khadki are grouped in larger sections called *pol* that are closed settlements.
Noble, Allen G. "Patterns and Relationships of Indian Houses". *Asia's Old Dwellings: Tradition, Resilience, and Change*. Knapp, Ronald G. 2003. Oxford University Press. (p.67).

complex gable roof structure of the front and rear sections facilitate the gathering of rainwater towards the courtyard (Randhawa, p.39). The architectural features like doors and windows are intricately ornamented in the *havelis*. The main door is usually fabricated from solid wood and is divided into rectangular planes or engraved panels. The window openings are smaller near the street level but expand as one move to higher levels. At the upper levels, windows become centers for socialization and places to observe street activities. Such windows are typically intricately designed bay windows or cradle windows visually separated from the exterior by rich latticework in wood. A unique characteristic of the Gujrat *haveli* is the inclusion of the swing-seat or *hinchko*, the gentle motion of which in warm-humid climate creates a breeze with minimal effort allowing one can take a rest, a nap or just to sit and relax (Cooper and Dawson, p.107).

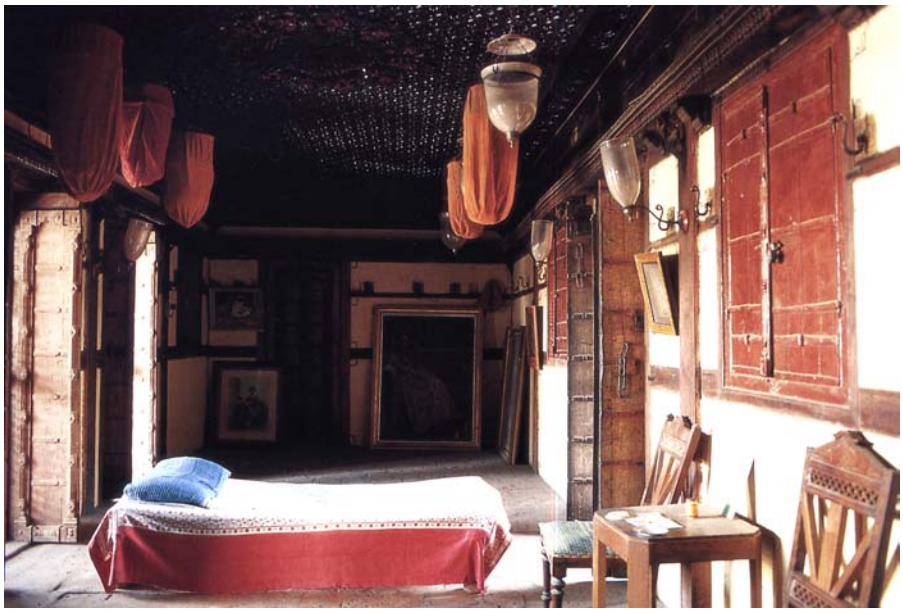

Figure 2.3: Typical interiors of a Gujrat Haveli showing richly carved wooden ceiling (Source: *Indian Courtyard House*. T.S. Randhwa)

The *havelis* in Rajasthan were distinguished from the Gujrat *havelis* mainly in their extensive use of locally available stone (sandstone, limestone, marble, etc) as a building material. Noble describes the Rajasthani *havelis* as devices for the, "Enforced seclusion of women, solid stonewalls, and at the same time the need for admittance of sunlight, combined to favor the adoption of multiple alcoves (*jharokha*), balconies, porches, and oriel windows projecting from the façade" (p.49). Randhawa points out that Rajasthan has the greatest diversity in courtyard house styles ranging from the exquisitely embellished and ornamented honey colored sandstone *havelis* of Jaisalmer to the pink houses in Jaipur, to the light blue colored houses of Jodhpur to the white splendors signifying purity in Udaipur. Though most of the *havelis* have been partially influenced by the Mughals the Udaipur *havelis* reflect the pure amorphousness of earlier Rajput palaces. Randhawa observes that though in the layout of the city the *havelis* look congested, they become "surprisingly airy the moment one steps across the threshold into the courtyard and the noise of the street is blocked by high walls" (p.36). The Rajasthani havelis generally rose higher than two stories and many are five to six stories high. As one moves to the higher floors, day light penetration into the space increases creating an illusion of spaciousness. Raised platforms on the exterior of the house provide a physical transition from the exterior to the interior, while a visual transition is provided through indirect views into the house created by screening and right-angled entryways. Though the stone foundations rise from basements to form elegant columns, usually the exteriors of the house are rather bare with ornamented windows and balconies on the higher levels overlooking the street. Cooper and Dawson observe the significant Mughal influence on these *havelis*, which regularly had upper floor rooms capped with bangla arches, domes or four-slope penthouse roofs.

Nearly all the floors had balconies and window openings into the courtyard which helped in air circulation. There are also ventilation air wells at different levels connected to the central courtyard. The rooms are gilded with floral patterns and inlaid with mirrors which reflect light multiple times to increase the feeling of spaciousness within the rooms.

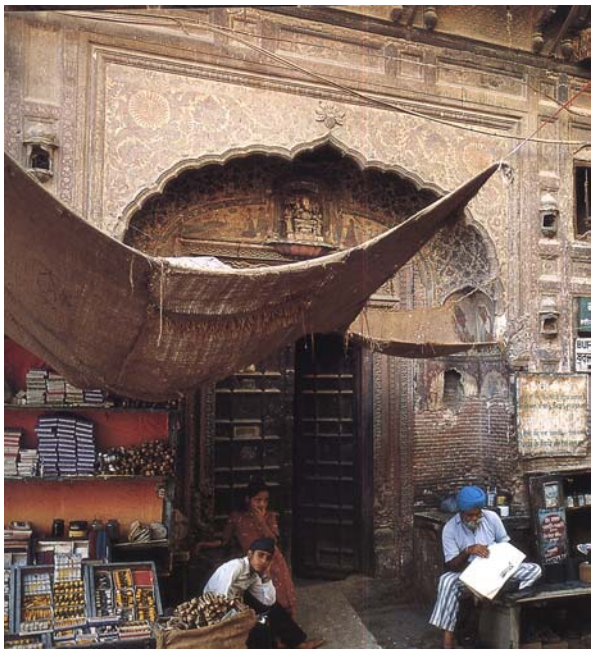

Figure 2.4: Typical Punjab haveli, emphasizing on protective entry gate.
(Source: *Indian Courtyard House*. T.S. Randhwa)

The *havelis* is Punjab reflect the psychology of the society that built them which relied primarily on security and robustness to safeguard the families from the Muslim invaders. This is reflected in the rather bare façades as compared to the ornamental *havelis* of Gujarat and Rajasthan. Randhawa notes that, "The solid *haveli* gates, studded with nails, were bolted at dusk and were not opened till the morning" (p.35). The bangla roofs are also prevalent in the Punjabi *havelis*. Cooper and Dawson observe that even

the otherwise fort-like appearance of the *haveli* was softened by the Mughal influenced decorative domestic architecture in the form of double-cusped arched brackets or *chhajjas* for shading and the use of stucco and other decorative floral patterns. Though the rather high walls provided an air of privacy and defense, like most other courtyard houses, the courtyard inside the house remained the central focus. Typically the western section of the house is more open to the exterior and therefore is predominantly a men's area or *mardana*, while the eastern section which is carefully set away from the entrance is the women's area or *zenana*.

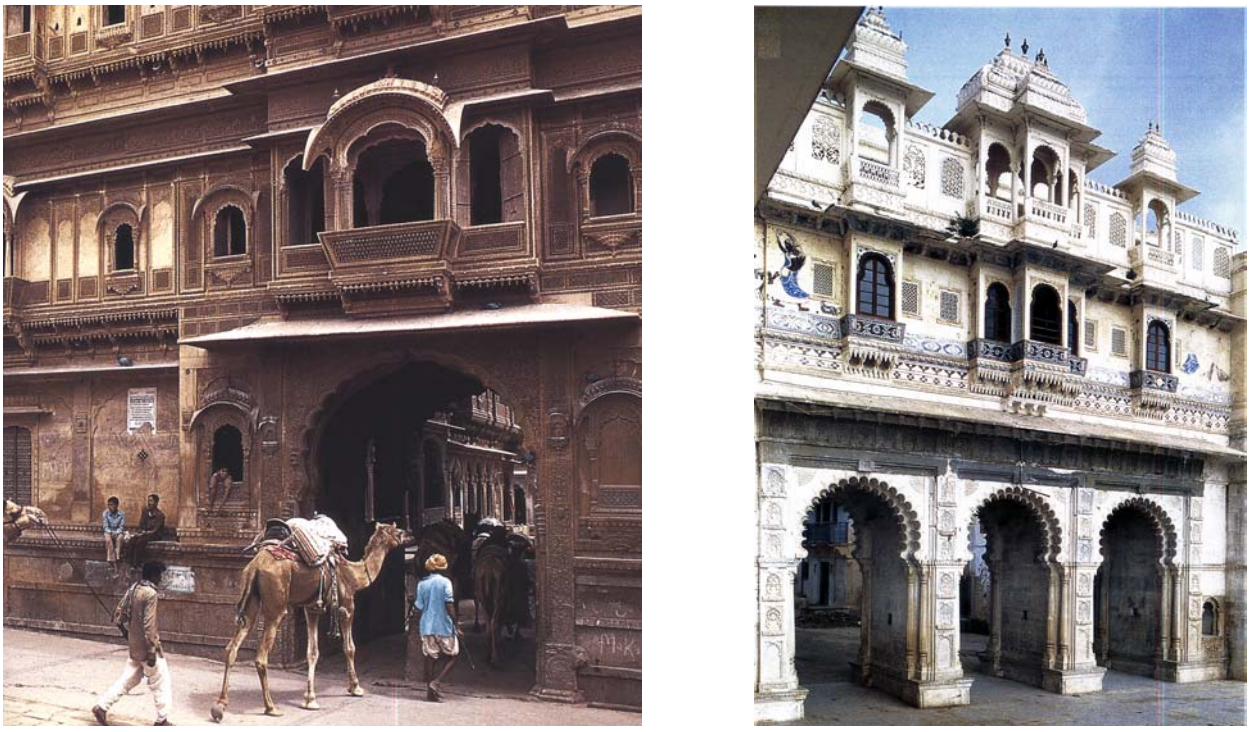

Figure 2.5: Different types of building materials used for Rajasthan havelis.

(Source: *Indian Courtyard House*. T.S. Randhwa)

WADA – The *wadas* which were popularized as a form of residential architecture by the Marathas under the patronage of *Peshwas*, were built from Nasik to Pune to Sholapur. Interestingly, though the *wadas* housed the Brahmin Maratha aristocracy the buildings show a significant Mughal influence in their design and the inclusion of courtyards with fountains, pools, terraces, pillared aisles, arches, latticed windows or balconies. Symmetry is an important aspect of these houses. Generally the *wada* rose to three or more floors. Situated in mainly urban areas of Maharashtra, due to shortage of space the courtyards were many times smaller in size. However, most houses have one court in front to receive visitors or accommodate business and administrative activities of the master of the house, and a series of family-oriented inner courts (Noble, 66). External ornamentation in the *wadas* is minimal and basically restricted to carved Hindu deities (*Ganesh* or *Lakshmi*) on the center of the wooden lintel over the main entrance (Cooper and Dawson, 1998; Randhawa, 1999). Cooper and Dawson mention the location of guardrooms on both sides of the main entrance to regulate access to the house. The interiors are lavishly decorated with paintings and other embellishments. Randhawa observes that nearly all the *wadas* had either a room dedicated for religious ceremonies or the corner of the hall would be partitioned to house the image of the family deity. Cooper and Dawson observe that most *wadas* have a sitting platform or *otla* in front of the house providing a semi-private space in which to socialize with neighbors in the evenings. They also observe that in large wadas, two extra floors are present which function as the diwankhana.[39] Access to upper floors is typically by a open flight of wooden staircase at one side of the courtyard.

[39] Diwankhana – on the first floor the *diwankhana* acts like the house's showpiece, used for formal entertainment and religious ceremonies. "A rectangular hall with ornate pillars supporting arches, it is well lit by arched windows…Although there may be a place from which womenfolk can view proceedings this is

Figure 2.6: Showing a typical Wada of Maharashtra.

(Source: *Indian Courtyard House*. T.S. Randhwa)

NALUKETTU – This typical residence form of Kerala is also known as tarawad. Nalukettu means a single courtyard with four sides. The compact structure which is comprised of four blocks around a courtyard with sloping tiled roofs on all sides, protecting an interior and exterior verandah from rain and sun, is housed in a larger compound next to a bathing tank or kullam. When the house needs to expand to accommodate an expanding family, similar modules are added to the original house. Like most northern houses the nalukettu also has a decorated main entrance (see figure 2.8) on the east side, with a semi-private raised verandah with built-in platforms for visitors to sit on. Though the court is usually smaller in dimension than northern *havelis*[40] they also include rainwater cisterns. These typical houses of the elite Nair Brahmins of Kerala are guided

essentially a male, semi-public room. The women have a similar, but smaller and less ornate *diwankhana* sometimes decorated with religious murals" (p.130).

Cooper, Ilay and Barry Dawson. 1998. *Traditional Buildings of India*. Thames and Hudson Ltd., London.

[40] The opening in the roof of the courtyard is also small to allow a moderate amount of light into the space (p.40).

Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

by strong *Vastushastram*[41] principles of orientation, location and functions of rooms; for example, the *vadakkina* or kitchen is in the north while a room in the south called *tekkina* is devoted to household activities. Cooper and Dawson observe that even though the "Scriptures advice which rooms should be in which wing; but in general Muslim, Christian and Jewish houses" (p.149), in the region follow a similar plan. They also observe that local domestic architecture is based on various treatises; for example, if a man wanted to build a *tarawad*, he had to first choose another person of equal or superior caste as his master, who would then select the plot and perform initiation rituals. An important difference of this southern courtyard house from its northern counterparts was the matrilineal family that housed them. Due to the lack of seclusion of women, the *nalukettu* did not have a segregated women's area (Cooper and Dawson, 1998; Randhawa, 1999). The upper floors in these houses are mainly used as storerooms which are ventilated by the screens on the gable roofs. Wooden stairs lead to the upper level storerooms. The basic structural element is laterite blocks and wood, though most of the ornamentation is wood carvings in geometrical patterns. Characteristically the religious residents include deities near the courtyard and in a small temple, typically a serpent shrine or *sarpu kavu*, at the rear end of the house.

Figure 2.7: Typical courtyard inside a Nalukettu

[41] Vastushastram is the ancient Hindu scripture for building a house, guided by the theological concepts of cardinal directions and the Cosmic Mandala.

CHETTINAD – This is the typical residence of the Chettiar Brahmins of Tamil Nadu, who are also a community of traders and businessmen that once had extensive mercantile links with Southeast Asia. The primary plan of this house is elongated and rectangular in shape, similar to the *havelis* in the north. However, a basic difference in the plans is the transparency in design of *chettinads* which allows uninterrupted views from front to the back door. The main door is ornamented with rich wood carved figurines along the door panel. The front door is accessed by steps leading through a two tiered verandah which is used for receiving guests during marriages and other social functions, when musicians are seated on them.[42] The primary courtyard in the house is rectangular in shape. The characteristic two tier spacious front verandah is covered by a sloping tiled roof supported by two rows of lathe-turned wooden pillars (bulging in the lower section) which is unique to the *chettinads*. Covered verandah surrounds the main courtyard. The verandah closer to the rear end of the house is used for formal meals. This is also in two levels, the higher level being used by men and the lower one by women. Behind the main structure there is a smaller court or '*kattu*' associated with the kitchen and cooking activities, therefore generally a women's domain. Noble also observe that the toilet and menses room is also physically separated from the house, guided by the Hindu philosophy of keeping the impure separated from the pure. Small rooms surrounding the main courtyard are used by the heads of the sub-families within the joint family residing in the house. The *Chettiars* emphasized on security of home and storage areas for their goods, since they were traders by profession. Most of the upper storey is used for storage rooms except one room which is reserved for newly-weds. Cooper and Dawson observe that though today most of the *chettinads* have been

[42] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

deserted by their original families and entrusted to caretakers or the elderly, the family still comes back to these ancestral homes during ceremonial occasions like marriages which need to take place within the courtyard at a point marked by *kollam* (a painted design).

Figure 2.8: Showing the shaded courtyard inside Chettiar mansion and the exterior space near the main entrance. (Source: *Indian Courtyard House*. T.S. Randhwa)

RAJBARI – In Bengal two basic types of courtyard forms can be found – one the houses built by the *Marwari* tradesmen who came into the city and to familiarize the new land and local conditions, built replicas of their ancestral homes; second the *Rajbaris* built by wealthy *Begali babus* who were influenced by the Western architectural styles and tastes of the British and who built these mansions with a Western touch of classy furniture and sculpture but retained the traditional inward courtyard form and puja room. According to Randhawa, "The courtyard houses of Calcutta have eclectic blends within western style facades, marble statues, imported tiles, as well as traditional design elements" (p.123). The Bengali love for culture and performing arts is evident in the design of these *Rajbaris* which have a raised platform at one side of the main courtyard which acted as stage for theatrical, music and dance performances. There is usually a *pujamandap* or *thakurdalan* (room for worship) on one side of the courtyard where the

family offers daily worship. Randhawa further noted that since many reformation and women liberation movements started in Bengal most of these houses did not have an essentially sequestered *zenana*, as in the case of northern *havelis*. Randhawa also notes that these practically modern courtyard houses have a diverse mix of western exteriors and vernacular interiors. For example, while the traditional *pujamandap* may be supported by Doric columns, a western façade may include a guardroom at the entrance with a roof in the form of a *bangladar* (traditional Bengal roof)[43] hut. It is essentially this second type of building or *Rajbari* that is the primary focus of this thesis and will be later discussed in further detail in Chapter 3.

Figure 2.9: Rajbari in Kolkata showing inner courtyard.

Figure 2.10: Western façade treatment with bangaldar roof on top of guard room.

(Source: *Indian Courtyard House*. T.S. Randhwa)

[43] Anthony D. King observes in *The Bungalow* that, two types of roof forms originated in Bengal – (i)dochala or a sloping roof having two sides with gable ends and central curved ridge; (ii) charchala – a roof covering on four sides which are more or less curved, but never make a straight pyramid. Later a third variation with eight sides or atchala was adopted from the previous basic forms. The Mughals were highly influenced by these roof types and popularized them in other parts of India. Therefore, we find *bangla* roof or these traditional styles being included in Shekhawati havelis.

King, Anthony D. 1995. *The Bungalow: the production of a global culture*. New York: Oxford University Press.

MEANINGS AND SYMBOLISM

COSMOS

The cosmic significance and symbolism of the courtyard is relevant in all the different cultures and religions which have adopted the universal form of the courtyard. In this discussion, I will be using the cardinal principles of five elements, or *Panchbhuta* in Hindu philosophy, to describe the courtyard form and architecture. However, it may be said here that these phenomenological discussions on the five elements namely – earth, fire, water, air and space are equally relevant to the ideologies of Divine Order in Islam. In all cultures, perhaps the courtyard dwelling symbolizes stability and defensibility based on the square universal form. One of the most unique qualities of this space is even in its enclosed and confined nature it combines an earthly and sensual imagery to create an abstract yet mystical symbolism. In Earthly Paradise, Jonas Lehrman[44] suggests that,

> *The courtyard provides a private, protected space, symbolizing the inner life of the individual. In practice it supplies light and cool air to the rooms that form it. Even the simplest courtyard often contains a potted aromatic or flowering plant. Fountain, pool, shade and occasional tree are also a symbolic reflection of paradise" (p.31).*

The courtyard and its landscape integrate the earth and sky at once, bringing in the unpredictability of nature within the predictable form. The earth below and the sky above form the floor and ceiling of this outdoor room, while sharing the walls of the surrounding rooms and arcades. The texture of the floor surface guides the life-activity within the courtyard. While soft textures with use of grass and plants may lead to its use

[44] Lehrman, Jonas. 1980. *Earthly Paradise: Garden and Courtyard in Islam*. Thames and Hudson, London.

as a kind of garden space, the hard texture of brick, mosaic or other building materials allow the different functions of the surrounding rooms to spill into the courtyard. Most of the courtyards in the Indian houses are below the level of the floor of the arcades. This also helps in emphasizing the proximity to the earth or soil below. Different paving materials used for the courtyard floor may lead to the increase of the sensation of warmth or coolth in the courtyard. The porosity, smoothness or roughness of the surface material evokes various feelings when touched by bare feet. Reynolds observes that in Courtyards[45] with soft landscape surfacing, "The aroma of the earth is strongest just after a rain (or watering), and its surface is slow to dry compared to any pavement" (p.27). Again, on a hard paved courtyard floor the sheet of water created by rain or watering produces a mirror effect, reflecting the sky, clouds and surroundings on it as if they are all collapsing into the earth.

Water plays an important role in creating the impression of richness and life in the courtyard whether in the form of rain, watering the surface to keep it clean or by the inclusion of water features. Reflecting on the mirror property of water, Reynolds observes that when courtyards are wet and sunlight strikes water, "…it is reflected in a constantly shimmering pattern…The dancing light enlivens the surface it strikes, often the underside of an arch or shaded ceiling of an arcade. Despite its brightness, it represents coolness, because it is a product of both water and breeze…" (p.29). Though luxurious water features like fountains are rare in the usual domestic architecture which is essentially underlined by the logic of water conservation. Many houses include water in the form of wells or water storage tanks in the courtyard. Later

[45] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*1938. New York: John Wiley.

under the Mughal influence, water features started being more easily included in the courtyards across the country. According to Lehrman, the Muslims believe that water is rich in symbolism and represent at city level both material economy and spiritual force, while at the personal level it symbolizes purity and fluidity of soul. This encouraged the inclusion of water features post Mughal influence. However, the scarcity of water was recognized and therefore there was a deliberate effort to design shallow pools with murky water to represent indefinite depth or infinity.

Air movement in the courtyard is vital for comfort within the enclosed space. Air circulation within this confined space relies largely on the proportions of the surrounding walls and positioning of window openings in the surrounding rooms. The proper proportioning of the building allows a cool breeze within the courtyard. Breeze and shading in the courtyard help in creating comfortable living conditions during day and sleeping conditions during night. The air moving through potted plants, or trees or over water features brings dynamism into the otherwise still atmosphere in the space. The wind blowing the clouds over the courtyard ceiling contributes to the constant variation in the view frame.

Fire in the court may be directly related to the sun – offering heat and light to the space. The concept of fire is therefore integral to the universal form. In fact even in occidental philosophy, fire has been suggested as the generator of the courtyard form. Reynolds questions whether, "At the center of an ancient dwelling, a fire produced smoke, which was expelled through a hole in the roof. Did this hole widen over many generations, allowing light as well as relief from smoke, eventually becoming the place

open to the sky but still at the center of the dwelling?" (p.31).[46] Fire is also perhaps the most symbolic element in the Indian courtyard house. In the Indian court house, the kitchen is usually next to the courtyard and therefore, on a hot day when the conditions inside the room become uncomfortable and stuffy the activities of the kitchen spill out. In general, the climatic conditions in the country allow favorable outdoor conditions at least at one part of the day or the year. Therefore, the residents spent time in the outdoors enjoying the sun or the filtered light through appropriate shading devices. Lehrman observes that the quality of light into the courtyard has mainly three functions: first, it has a cognitive aspect defining the environment in terms of shape, color and brightness; second it has an aesthetic appeal related to sensual and emotional awareness; and finally it links the cognitive to the aesthetic symbolically by providing life within itself with meaning and unity.[47] Lehrman further explains that even "Inside the building, mood may be greatly influenced by the quality, intensity and direction of light…" (p.78) depending whether the light is filtered through *jalis* or reflected by mirror work within the interior walls. Even during night, the cool soft moonlight in the courtyard creates diffused patterns of light and shade within the outdoor area depending on the texture of materials used. Again, as Reynolds notes, "A thoroughly darkened courtyard offers a view of the stars" (p.32).

Finally, to discuss the symbolic significance of the courtyard form or the space element, the basic sense of order, balance, repose and stability must be referred to. As Lehrman observes, space is all pervading; however once it is confined as in the case of a

[46] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*1938. New York: John Wiley.

[47] Lehrman, Jonas. 1980. *Earthly Paradise: Garden and Courtyard in Islam*. Thames and Hudson, London.

courtyard, this three dimensional external space is no longer abstract but converts to a "place", possessed with its own character.[48] Again, Cooper and Dawson observe that the Hindu concept of a universe as an ordered division of space ranging from unstable to the stable, from less pure to pure, helps in ensuring that the courtyard is protected as the most sacred part of the house.49 In the Indian courtyard house, this private enclosed space within the surrounding rooms often gains sacredness by virtue of its position. This transitional space between the interior and exterior of the house, acts as a unifying link between the mortal worlds below with the heavenly abode above. Therefore, often it is found that the prayer room in the house is attached to the courtyard. This central focus of the house is usually used in all the regions across India, for different social rituals associated with marriage, life and death so as to keep the celestial gods as witnesses to the event.

RELIGION AND CULTURE

Religion and culture have been an integral part of the domestic architecture of India. According to Cooper and Dawson's study in Traditional Buildings of India[50] the constraints of religion, culture and social customs defined the evolution of traditional architecture in India. Rapoport also supports this idea of the building a house as being a cultural phenomenon. In House, Form and Culture, he observes that, if provision of shelter is the passive function of the house, then its positive purpose is the creation of an environment molded by the spaces and their relationships according to the residents' vision of an ideal life. Rapoport mentions in his book that while the form of the house is

[48] Lehrman, Jonas. 1980. *Earthly Paradise: Garden and Courtyard in Islam*. Thames and Hudson, London.
[49] Cooper, Ilay and Barry Dawson. 1998. *Traditional Buildings of India*. Thames and Hudson Ltd., London.
[50] Cooper, Ilay and Barry Dawson. 1998. *Traditional Buildings of India*. Thames and Hudson Ltd., London.

greatly influenced by the cultural milieu to which it belongs, the religious ceremonies and rituals precede the entire building process like – foundation, erection and occupation. [51]

If the social understanding of culture and religion is reflected in the house form of a place, then the courtyard form has been its product for centuries in India. While all the main religions practiced in India like Hinduism, Islam, Buddhism, Jainism, Sikhism favored the inward, defensive courtyard form in their philosophies of dwelling design, it was mainly the Hindu and Islamic houses that portrayed this inherent sense of religious principle. Sinha[52] writes in "The Traditional Rural Settlements and Dwellings in Northern India", that the vernacular courtyard form found in most parts of northern India can be associated with both Islamic and Hindu traditions. This fact is also confirmed by Randhawa in The Indian Courtyard House, where he observes that the courtyard houses in India often showed a blending of Hindu and Muslim designs within them; for example a Muslim house may be seen to have *chhajja* or brackets while the Hindu house includes the cusped arch.

THE HINDU COURTYARD HOUSE – The sense of enclosure and privacy highlight the Hindu courtyard houses in India. The cosmic-square philosophy of the Mandala guides the relationship and orientation of the different spaces in the house with the central node in the form of the open-to- sky court. The reverence for the sense of direction is the heart

[51] Rapport, Amos. 1960. *House Form and Culture*. New Jersey. Prentice- Hall, Inc.

[52] Sinha, Amita. "The Traditional Rural Settlements and Dwellings in Northern India". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 117-140).

of Hindu building construction. While the east and north sides are favored, the south and west sides are considered inauspicious.[53] Nearly all Hindu courtyard houses have their main entrance in the east. Often in Hindu houses the top of the main door would have engraved deities or religious symbols. Generally, multiple entrances are preferred to segregate the paths of men and women in the house. Based on the philosophy of "pollution-purity axis"[54], the kitchen and toilet in the house are separated by the internal court in two axially opposite directions. The Hindu courtyard is generally distinguished by a Tulasi (Basil) plant and a few curved or stone images, set in a low platform in the center, where the female members in the family offer prayers for household peace and prosperity, every morning and evening.

In the Hindu houses the courtyard is mainly a female space. The female members, who are usually separated by distance from the male members, use this outdoor space for their daily activities. Sinha observes that in many Hindu houses the activities of cooking and preparation of food spill into the courtyard allowing the kitchen to be itself quite small. The size of the courtyard and its open-to-sky characteristic allows for accommodating different Hindu communal and religious rituals and rites that need to be witnessed by heavenly bodies like, marriage, birth and death. [55]

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[53] In Hinduism, the east is regarded as auspicious because it is the direction of sunrise, and north is auspicious because it is the direction of the Himalayas, the abode of the gods. The south is associated with the God of Death (Yama) and the west is dominated by darkness(Nisha) and therefore these two directions are inauspicious.

[54] Sinha observes that, "The separation of the two areas where the activities are carried out, is based upon the cultural attitude that functions carried out in space invest it with their sacred or polluting character. Since pollution is contagious, necessitating the separation of the kitchen (which should be a 'pure' area since food is cooked there), from the latrine". (p.126)

Sinha, Amita. "The Traditional Rural Settlements and Dwellings in Northern India". *The Courtyard As Dwelling.* AlSayyad, Nezar and Jean-Paul Bourdier .ed. 1989. Traditional Dwellings and Settlements Working Paper Series, Volume six, IASTE, WP06-89. Center for Environmental Design Research, University of California, Berkeley. (p 117-140).

[55] Noble, Allen G. "Patterns and Relationships of Indian Houses". *Asia's Old Dwellings: Tradition, Resilience,*

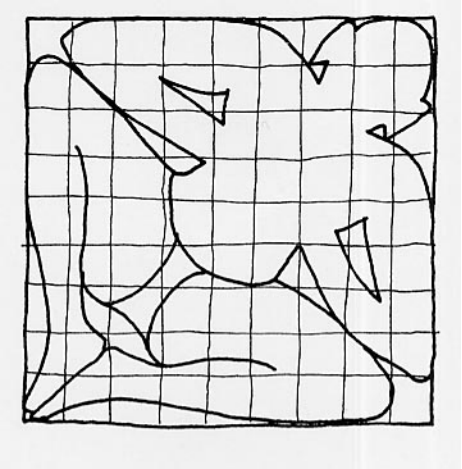

Figure 2.11: Cosmic mandala

(Source: *Traditional Buildings in India*)

THE MUSLIM COURTYARD HOUSE– The tradition of courtyards in Islamic or Muslim houses is quite long. The architectural philosophy of Islam is guided by a strong mathematical intellect that thinks abstractly to reflect the Divine Order. Lehrman[56] observes that the purity and perfection of symmetry as a constituent of man-controlled geometry is appreciated in Islamic architecture. The Islamic people knew about the advantages of courtyard houses long before they came to India. As the Muslim invaders came from the Middle-East, they brought with them the tradition of courtyard buildings which they found was adaptable to the Indian climate too. With the spread of the religion, these principles of balanced symmetry in courtyard houses became part of the Muslim architecture in India.

Though the Muslim houses bear a resemblance to the Hindu houses in the adaptation of the private and secluded courtyard form, there are some basic differences that arise

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and Change. Knapp, Ronald G. 2003. Oxford University Press. (p.54).

[56] Lehrman, Jonas. 1980. *Earthly Paradise: Garden and Courtyard in Islam*. Thames and Hudson, London.

from their religious ideologies. Unlike the Hindus, the Muslim houses are not so rigid about orientation. Usually the main entrance in the Muslim houses in on the west looking towards the Mecca for their daily prayers[57]. Most of the Muslim houses also have multiple entrances separating the female and male domains in the house. The seclusion of women in the household, the "*purdah*" or veil system influences the courtyard form in Muslim houses in India. Even in the Muslim houses, however, the court is the female domain, and the men are carefully kept out of this area by mainly visual barriers like traditional jali58. The Muslim fascination for different qualities of light within a contained space is reflected in their intricate details for windows, screens and shading devices. The basic conception of the courtyard as an oasis has also been integrated into the Indian Muslim houses. This is why most Muslim houses in India contain some kind of water feature within the court, for example a pool of still water or fountain.

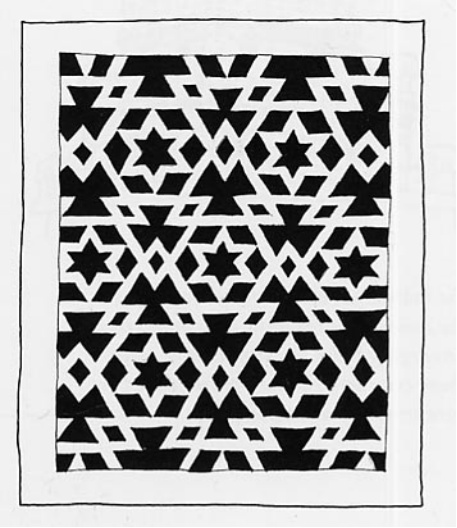

Figure 2.12: Showing a typical jali in traditional buildings in India

[57] Noble, Allen G. "Patterns and Relationships of Indian Houses". *Asia's Old Dwellings: Tradition, Resilience, and Change*. Knapp, Ronald G. 2003. Oxford University Press. (p.45).

[58] Jali has been described by Cooper and Dawson as, "…carved latticework screen. Allowing the passage of air and light in a hot climate, the distinctive decorative patterns show Mughal origins. Features of Islamic architecture became integrated with other indigeneous forms in northern India" (p.16).
Cooper, Ilay and Barry Dawson. 1998. *Traditional Buildings of India*. Thames and Hudson Ltd., London.

CLIMATE

Noble rightly remarks that, "…many customs and traditions, while couched in religious terms, may simply be cloaked in religious sanctity from an earlier period in order to gain widespread adherence for a principle which turns out to have sound scientific logic and beneficial attributes after all" (p.43). He observes that though the religion and tradition have clearly influenced many house building customs, the practical solutions also pointed towards their bioclimatic significance. The houses in the Ganga-Jamuna region, for example, made use of the moisture-laden cool winds from the north and east while preventing the hot summer winds from the west. Again in Tamil Nadu, the south facing courtyard houses took advantage of the cool, southern breezes in summer and was protected from the cold northern winds in winter. In general, the open to sky court provides a vent in the house to allow summer heat to escape from the structure.[59]

Randhawa observes that the degree of enclosure in courtyard houses in India directly depended on the local climate and the requirements of minimum light and air as much as the degree of visual interaction depended on social norms. The size and orientation of the courtyard, the height of the surrounding structures were considered in these vernacular dwellings for their importance in climate control by preventing the entry of summer sun while allowing the entry of the winter sun. Noble observes in his article "Patterns and Relationships of Indian Houses" in Asia's Old Dwellings that, "Sunlight penetrates to illuminate the darker interior areas and courtyard air circulates, reducing the dampness inside during the monsoon and other periods of high humidity" (p.54). In some arid regions the courtyards also functioned as rainwater collectors. Some houses

[59] Noble, Allen G. "Patterns and Relationships of Indian Houses". *Asia's Old Dwellings: Tradition, Resilience, and Change*. Knapp, Ronald G. 2003. Oxford University Press.

in the arid regions of India also have wind scoops for ventilation. High ceilinged rooms are another well used technique to facilitate ventilation and keep spaces cool in summer due to the lower angle subtended by roof to floor. In most courtyard houses, the window openings are kept at a minimum at the ground floor. *Jharokhas* or traditional *jalis* are used to catch summer breezes but prevent rooms from direct glare of the outside. The loosely defined functions of the rooms in the Indian courtyard houses also help in easy adaptability for different functions to a room dependant the time of the day or the year. For example: in summer the roof is preferred as a sleeping area, while in winter the room is preferred.[60]

[60] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

CHAPTER 3: COURTYARD HOUSES OF KOLKATA

KOLKATA – QUICK FACTS ABOUT THE CITY

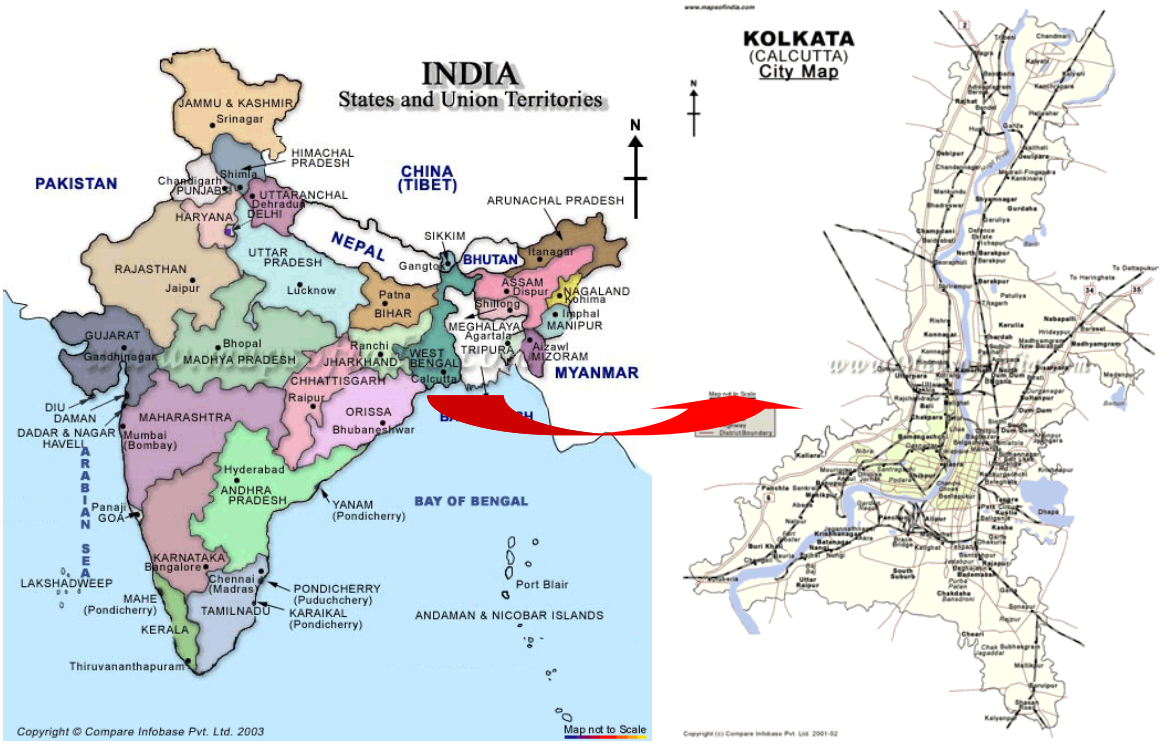

Figure 3.1: Political Map of India showing a detail map of Kolkata

Longitude : 88° 20'E

Latitude: 22° 32'N

Area : 187 sq.km (city)1380.12 sq.km (Kolkata Metropolitan area)

Population: as per 1991 census - 4.39 million(city)

9.2 million (Kolkata Metropolitan area)

Altitude: 6.4m (20 ft.) above sea level

Climate: Winter – Maximum Temperature 36.3°C

Minimum Temperature 9.6°C

Summer – Maximum Temperature 41.7°C

Minimum Temperature 38.1°C

Rainfall: 1581mm (monsoon months – June to early September)

Best season: October to March

Clothing: Cotton in summer and light woolen in winter[61]

Population Statistics			
Year	**Population** **1950 - 2015**	**Percentage of urban population (%)** **1950 - 2015**	**Percentage of total population (%)** **1950 - 2015**
1950	4 446 000	7.2	1.2
1955	4 945 000	7.1	1.3
1960	5 500 000	6.9	1.2
1965	6 162 000	6.6	1.2
1970	6 912 000	6.3	1.2
1975	7 888 000	6	1.3
1980	9 030 000	5.7	1.3
1985	9 946 000	5.3	1.3
1990	10 890 000	5	1.3
1995	11 925 000	4.8	1.3
2000	13 058 000	4.7	1.3
2005	14 299 000	4.6	1.3
2010	15 452 000	4.4	1.3
2015	16 747 000	4.2	1.3
Source: UN 2001			

Table 3.1: Showing the population statistics of Kolkata, India as per the records of United Nations.

Source: Megacity Task Force of the International Geographical Union[62]

Kolkata, the capital of West Bengal was founded by Job Charnok. He combined three villages on the banks of Hooghly to form Kolkata more than 300 hundred years ago. In

[61] http://www.westbengaltourism.com/calcutta/gen_info.htm#generalinfo (Downloaded on 30th September, 2005)

[62] http://www.megacities.uni-koeln.de/_frame.htm?http://www.megacities.uni-koeln.de/documentation/calcutta/statistics.htm (Downloaded on 30th November, 2005)

these past three hundred years Kolkata has grown as a city of sharp contrasts and contradictions. On one hand it has been referred to as the 'City of joy' while on the other as the 'Dying city' (Rajiv Gandhi, Former prime minister of India). However the truth remains that even in the most conflicting pictures of Kolkata, the city remains a thriving and alive city accepting every aspect of culture from the wide range of ethnic groups settled in the city and evolving its unique hybrid identity. This is probably the reason why it has been termed as the 'Cultural Capital of India'.

KOLKATA'S ARCHITECTURE AND URBAN PLANNING: PAST AND PRESENT

Kolkata is a relatively new town compared to the other major cities in the country.[63] Evolving from a small village to one of the world's largest global metropolitan cities[64], Kolkata has acquired her unique hybrid identity by accepting cultural aspects from the diverse ethnic groups that have settled in the city. The city was formed by the British and therefore the history and architecture of the city can perhaps not be separated from the Colonial circumstance. Historically, Kolkata's architecture may be divided into two main phases – pre-independence and post independence. In the abstract of his essay on The Unintended City, Jai Sen wrote, "This vernacular, self-made city is shaped by forces of rejection and affinity: rejection by urban centre and the affinity of

[63] In Dr.S.C. Mukerji's account on the city in *The Changing Face of Calcutta,* he mentions that "While many other cities of India, like Varanasi, Delhi, Ujjain and Kanchi can boast of origin dating back to remote antiquity, young Calcutta grew to be the first capital of the last empire in India" (p.1)

Mukerji, Dr.S.C. 1991. The Changing Face of Calcutta: An Architectural Approach. Government of West Bengal.

[64] Monidip Chatterjee reflects in his essay written in 1980s regarding the town planning of the city, how the combination of the three villages of Sutanati, Gobindapur and Kalikata comprising of merely 1,692 acres has grown phenomenally in the last three hundred year to what he refers to as a "massive conurbation" of the Calcutta Urban Agglomeration covering 210,500 acres by 1981.

Chatterjee, Monidip. 1990. "Town Planning in Calcutta: Past, Present and Future". *Calcutta: The Living City.* Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

traditions".[65] It is essentially this eternal tension between rejection and affinity that has been explicitly integrated with the urban planning and architecture of the city. From the day of her conception to this day, this dramatic contrast has been expressed visually in the buildings and urban layout of Kolkata. One of the objectives of this thesis is to research whether the traditional pre-independence domestic architecture still bears any relevance to the dwelling needs of post-independence architecture and society.

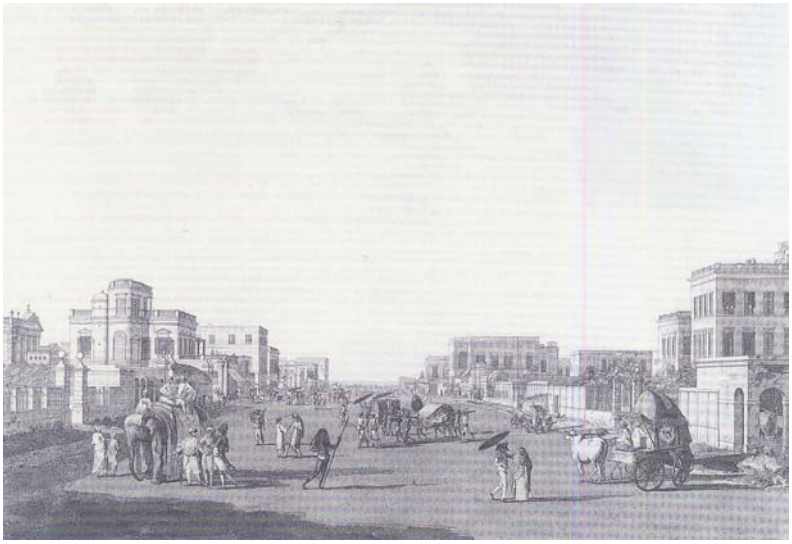

Figure 3.2: Picture showing historic urban layout of the city

(Source: *City of Palaces*)

Pre-independence architecture of the city is largely characterized by British Colonial influences, which is evident in the architecture and planning of the city. Before the Battle of Plassey66 in 1757, as per the accounts of Mukerjee, the city could be divided

[65] Sen, Jai. 1975. *The Unintended City: an essay on the city of the poor*. Cathedral Relief and Social Services, Calcutta.

[66] The Battle of Plassey was the final battle fought between Siraj-ud-daula the then Nawab of Bengal and the British. Anthony D. King remarks that, "The defeat of the Nawab of Bengal and his French allies at

into four different sub-areas – European Calcutta (Dihi Kolkata), a residential village with some sacred spots (Gobindapur), a traditional Indian market (Bazar Kalikata or Burrabazar) and a riverine mart concentrating on cloth trade (Sutanati). It was only after the decisive Battle of Plassey, that the British started rebuilding the city with the notions of making it the capital for their Empire. Under the governorship of Lord Wellesley from 1798 to 1805, the British began the making of the imperial city by the design and construction of the Governor's House or Raj Bhavan (Chatterjee, 1990; Mukherji, 1991). The British, placed emphasis on the Classical style in their architecture in an attempt to express architecturally their superiority and the authority of their historical precedents. However, Mukherji notes that these adoptions of Corinthian, Doric, Ionic or Tuscan orders were blemished and disproportioned compared to the original Greek orders. Gradually, the British also introduced the "Italian Renaissance" to the city. Mukerji notes in his account about The Changing Face of Calcutta that,

> *Inspite of the patronage afforded, no purely European style could take firm root in India. While some aristocratic and princely houses went on for neo-classical style, there was a tendency among the British architects to introduce Indian features and motifs into their so-called 'Imperial Architecture'. Soon the eastern fancies invaded the orthodox architectural vocabulary and gave rise to hybrid architectural types combining the elements of Renaissance, Saracenic and Hindu schools of building art (p.3).*

Though most of the city's growth has been haphazard, the planned growth in the old central areas mostly inhabited by Europeans is definitely noticeable. One striking aspect

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Plassey in 1757 is usually taken as symbolic beginning of the British Empire in India. Where the operations of the East India Company in the 17th century had been those of trade, though increasingly armed trade at that, after Plassey, the rapidly turned to plunder" (p.23).

King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

of the city's rectangular form is its strong north-south axial layout. Kolkata's system of streets and roads reflects the city's historical development. Local streets are narrow. The main roads form a grid pattern primarily in the old European sector, but elsewhere road planning has a haphazard character especially in the native town. By the end of the 19th century, the affluent British started to move out of the European or White town to set up garden houses. Most theorists have noted the awful condition of these houses initially which eventually evolved into the stylish bungalows. Anthony D. King[67] remarks in The Bungalow that the primitive form of bungalow type dwelling was originally an indigenous mode of shelter, adapted by the British to suit their social and cultural lifestyles. These Anglicized housing forms were later adopted by wealthy Hindu families, who built one to two storey courtyard dwellings for their extended families but added the traditional element of having central courtyards. This is what Randhawa refers to as the "eclectic blend" between the western style facades, marble statues, imported tiles and the traditional design elements.[68]

The British also tried in their own way to bring order to the chaotic city. Chatterjee notes that, "Calcutta must thank Lord Wellesley for initiating the process of government-sponsored development of the city" (p.136).[69] The Town Improvement Committee formed in early nineteenth century, the Fever Hospital and Municipal Improvement Committee formed in 1836, the Calcutta Improvement Trust (CIT) formed between 1902 and 1903 all point to the British initiatives in improving the quality of life in the city.

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[67] King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

[68] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited. (p.123)

[69] Chatterjee, Monidip. 1990. "Town Planning in Calcutta: Past, Present and Future". *Calcutta: The Living City.* Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

However, the initial negligence during the conceptualization of the Imperial Capital leading to an organic settlement pattern, still underlined all the planning efforts in the city.

Figure 3.3: Pictures showing old Kolkata streets with courtyard houses along them

Post-Independence architecture and planning in the city is witnessing yet another wave of Westernization or modernization with a flavor of International style. As in much of the developing world, historical building types are being endangered by rampant inner-city construction and the indifference of younger generations, who opt for high-rise Westernized home types. The historic "City of Palaces," is today a victim of rapid urbanization and globalization. The skyline of Kolkata is changing at an exponential rate, with its heritage buildings being rapidly replaced by modern day skyscrapers.

In the beginning of 20th Century, Bengal in general and Kolkata in particular suffered numerous hardships starting from the transfer of the capital in 1912, followed by the First World War, the Bengal Famine, the Second World War and finally the Partition of Bengal a cruel price Bengal had to pay for independence. The British policy of 'Divide and Rule' has taxed the civic facilities of the city since then. After partition in 1947, the city

endured a massive urban immigration as millions of homeless men and women encamped on the vacant plots of the city. By the 1950's, Chatterjee observes that the city's civic facilities were under "severe strain and grossly inadequate". At the same time, Calcutta was beset by cholera epidemics which drew the attention of the World Health Organization.70 Under the initiation of the WHO, in 1961 a planning organization for Greater Calcutta was created called the Calcutta Metropolitan Planning Organization (CMPO) by the West Bengal Government. Assisted by international experts the CMPO prepared and published the "Basic Development Plan for the Calcutta Metropolitan District (1966 -1986). However, in spite of all the effort, commitment and honest endeavor very little could be achieved by the plan due to the gap between planning and decision-making. In 1971, in yet another attempt to bring order to the unsettled, organic city growth, the Calcutta Metropolitan Development Authority (CMDA) was created. Then came the period of communist government which has been continuing till the present date and therefore West Bengal has been referred to as "…home to the world's longest surviving democratically elected communist government, the Left Front".[71]

The Leftists have also had their share of visions for the city expressed in the Perspective Plan of CMDA: Vision 2025, the Master Plan for Traffic and Transportation in Calcutta Metropolitan Area (2001-2025) and similar various other plans to remake the city. Roy reflects in her essay on "The Gentlemen's City" that,

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[70] Chatterjee, Monidip. 1990. "Town Planning in Calcutta: Past, Present and Future". *Calcutta: The Living City.* Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

[71] Roy, Ananya. "The Gentlemen's City: Urban Informality in the Calcutta of New Communism". *Urban Informality: Transnational Perspectives from the Middle East, Latin America and South Asia*. Al-Sayyad,Nezar and Ananya Roy. ed. 2003. Lexington Books, New York.

> *The remaking of Calcutta looks ahead to the city of the future, the bhadralok city. This is the gentlemen's city – gentlemanly in its sensibilities, and housing the gentleman and his family. But this moment also gestures to the past, as in the content of developmental projects, in the attempt to recover a lost city grace and charm (p.151).*

She further notes that today the imperatives of economic liberalization and globalization have forwarded a city management model based on economic interests. Present day Kolkata is witnessing the rise of an active group of supporters and beneficiaries especially among the business, industry and upper middle class income groups. Roy suggests that if these plans and visions are materialized successfully it will lead to an extension and improvement of quality of the formal city. However, as mentioned earlier, under this pressure of rapid economic liberalization the city history and architecture remains largely neglected. There is a general tendency of expressing development in the city by the mushrooming growth of high-rise apartments and "condoville" all over the city surface. Many of these new developments are rewriting the territorial boundaries of the city edges and recreating the skyline but at the cost of replacing the historic building from the city façade. The argument here is not just related to the preservation of these traditional structures that are often in ruins today; the main emphasis of this study is to try to learn from these traditional structures and question if there inherent socio-cultural and climatic principles that are still valuable to the modern society? The question is whether we can appropriately adopt this design intelligence (if there is any) in our present approach to urban planning and architecture?

Figure 3.4: Views of rapidly urbanizing metropolitan today

EMERGENCE OF THE COURTYARD HOUSES IN THE COLONIAL CITY

The political upheaval in 18th century Bengal demanded a high-security city for the new European settlers to realize their Colonial dreams. Amidst this political unsettlement and vision for successful trading, Job Charnock founded the city of Calcutta (now known as Kolkata) by combining the three villages of Kalikata, Sutanati and Gobindapur. Bandhopadhay[72] recollects in his book written in Bengali (the local language of Bengal) that the British bought Kalikata for only 1300 rupees from Subarna Raychouwdhury, though they had to bribe the Mughal Subedar a lump sum amount of 16,000 rupees to finalize the deal. Nair[73] observes in his account on "The Growth and Development of Old Calcutta" that, "The English portion of Calcutta was confined to the old Fort William area (today's B.B.D. Bag). The area south of Dharmatala was a jungle, while the 'native quarters' to the north consisted of a number of straggling villages" (p.11). In her account about the history and architecture of the city, Evenson quotes that the British built the city around the secured Fort William, like a "town, rising about this old Fort, like one about a baronial castle in the medieval times, was built

[72] Bandhopadhay, Debashis. 2001. *Banedi Kolkata'r Gharbari* . Ananda Publication, Kolkata.

[73] Nair, P.Thankappan. 1990. "The Growth and Development of Old Calcutta". *Calcutta: The Living City*. Sukanta Chaudhuri. ed. Volume I. Oxford University Press, Calcutta.

without order, as the builders thought most convenient for their own affairs" [74](p.17). In fact she mentions the city was greatly influenced by the taste for garden houses held by the colonizers.

Kolkata's architecture in the initial years was marked by a dramatic and distinct contrast between the British and Indian parts of the city which reflected both architectural preferences and socio-economic status. The British liking for functional zoning which was gaining popularity in Europe in the 18th century, reflected in British parts of Kolkata. Evenson noted how the British areas in the city had their residential areas dispersed beyond the compact business and administrative center in the Dalhousie region around the tank (man-made pond). On the other hand, in the Indian community the complexity of the social structure was reflected in the physical design of their parts of the city, where "…the urban fabric was generally characterized by an intermixture of manufacturing, commerce and housing, as well as a juxta position of social levels" (p.23)[75]. This kind of organic urban growth was severely criticized by those who had been educated in the 18th century school of thought of order and regularity in aesthetics. However, from this disorder there have risen many examples of splendid architectural hybrids of the Colonial Classical taste and traditional indigenous building practices.

The British, influenced by the vernacular construction, adopted many different forms of the traditional architecture and modified them to suit their Colonial living style and

[74] Evenson, Norma. 1989. *The Indian Metropolis: A View toward the West*. Yale University Press, London.
[75] Evenson, Norma. 1989. *The Indian Metropolis: A View toward the West*. Yale University Press, London.

aspirations. In The Bungalow: The Production of Global Culture, Anthony King observes, the genesis of the popular British bungalow architecture and mentions that, "The main characteristics of the developed Anglo-Indian bungalow in the late 18th century – its free standing and single storey structure, the plinth, the pitched, thatched roof and the verandah – are all characteristic features of the indigenous Bengal hut, whatever addition came from the Europeans" (p.28).[76] During the same time, there emerged a class of natives who by their skills in language and interpretation gained British favor and amassed wealth nearly overnight. While the British enjoyed the bungalow-type living, this new-found rising middle class of the Bengali society started building great houses with an eclectic blend of Colonial taste and traditional ideologies. King notes that the chief feature of this evolving architectural form was the square shape with an open to sky courtyard in the centre. King acknowledges that this evolving domestic architecture based on 'old fashioned Indian dwelling types with interior courtyards' established the social institutions and the necessities of climatic adaptation in the city, relevant to its time and place. The Kolkata courtyard form was largely determined by the intense heat, light, torrential rains, wind and dust typical of the tropical climate.

Figure 3.5: Showing a typical Indian courtyard house (above) and a typical British bungalow (below).

[76] King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

The main difference between the outwardly oriented British bungalow plan and the inwardly rich Kolkatan dwelling is marked by their differing philosophical and socio-cultural understandings of lifestyle. Both the British and the Indians believed in the importance of transitional places in their architecture. While the British expressed this in the form of front verandahs, the Indian equivalent is the courtyard. The British society had been socially much more liberal in the 18th century and did not require to physical and visual barriers to protect women. On the other hand, at that time both Hindu and Muslim traditions supported the idea of segregated spaces for the women. The courtyard's introverted plan helped the Indians to maintain this social distance between the sexes by providing an outdoor area for the women within the house, therefore minimizing the need for women to be outdoors outside the domain of the house in contact with other men in the society. Evenson rightly remarks in The Indian Metropolis that, "The courtyard form of dwelling was maintained among Indians for security and also for visual privacy, because nothing could offend a native more than the erection of an edifice overlooking the interior of that enclosure in which his family resided" (p.67). On one hand, this inwardly oriented plan in the early years of British rule helped many Indians to secretly entertain the British officers and seek their favor. Again,

on other hand, the well concealed courtyard form helped later freedom fighters and social reformers to carry out radical work secret from the British who were in control outside the house.

Figure 3.6: Showing interior courtyards and their activities during different festivals

ANALYSIS OF KOLKATA COURTYARD TYPES

This research focuses on a typological analysis of courtyard houses in Kolkata. The extensive formal analysis of the courtyard type will be done in chapter 5 based on the interpretive case-study method. In this chapter, I am discussing some basic facts of the courtyard type on the basis of literature review. Further detailed discussions will be done in later chapters.

FORM

> *The chief feature in the building is that it must be in the form of a square, with an opening to the sky in the centre. The roof slopes outward and inward, and the inner sides all converge around a rectangular open space…In large houses, this…space will form a regular courtyard, whilst in smaller buildings… it is only a few inches square.*
>
> *- J.E. Padfield, The Hindu at Home*[77]

The inward form of the courtyard houses in Kolkata are exactly opposite in their form from the British bungalows which open out towards the front verandah. Most of the courtyard houses in Kolkata are either square or rectangular in form. This form idealizes the Bengali flavor for tradition in architecture. The hollow form spotted with its Western elements in a manner symbolizes the transition from the core Indian architectural philosophy to Occidental architectural style. The traditional element of having an inner courtyard helped the owners to lead a private and secluded life within the house even though they had to imitate British lifestyles in spaces which were accessible to the rulers. Most of these courtyard houses were seldom higher than stories.

[77] Anthony D. King quoted J.E. Padfield from *The Hindu at Home* in his account about *The Bungalow*. King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

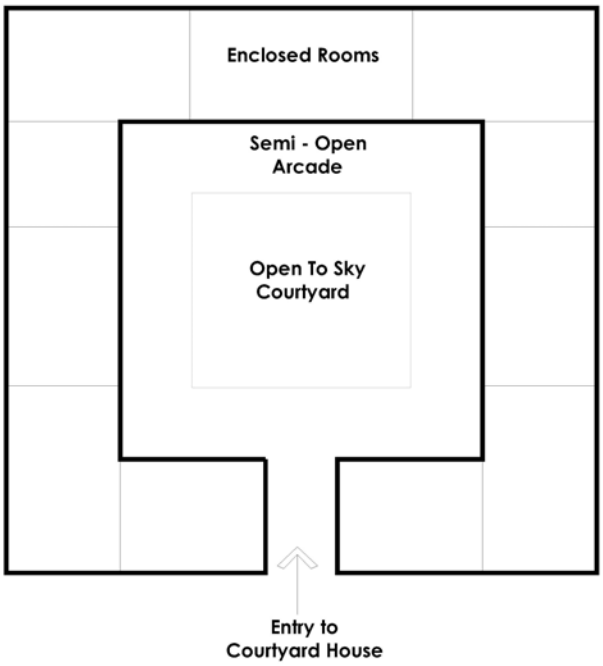

Figure 3.7: Typical form of courtyard house in Kolkata

PLAN

Similar to most other courtyard dwelling in India, the *Rajbari* or courtyard houses in Kolkata have a simple plan with rooms laid out surrounding the central courtyard. In most of these palatial buildings there is more than one courtyard – the outer being the public courtyard or *bahirmahal* while the inner courtyard is more restricted to the family or *andarmahal*. The traditional plan is symmetrical in nature. The rooms are planned according to their functions based on the cardinal directions around the courtyard. The most unique feature of these courtyard mansions in Kolkata, as differentiated from those in other parts of the country are the existence of *thakurdalan* (puja room) and

natmandir (stage for cultural performances).

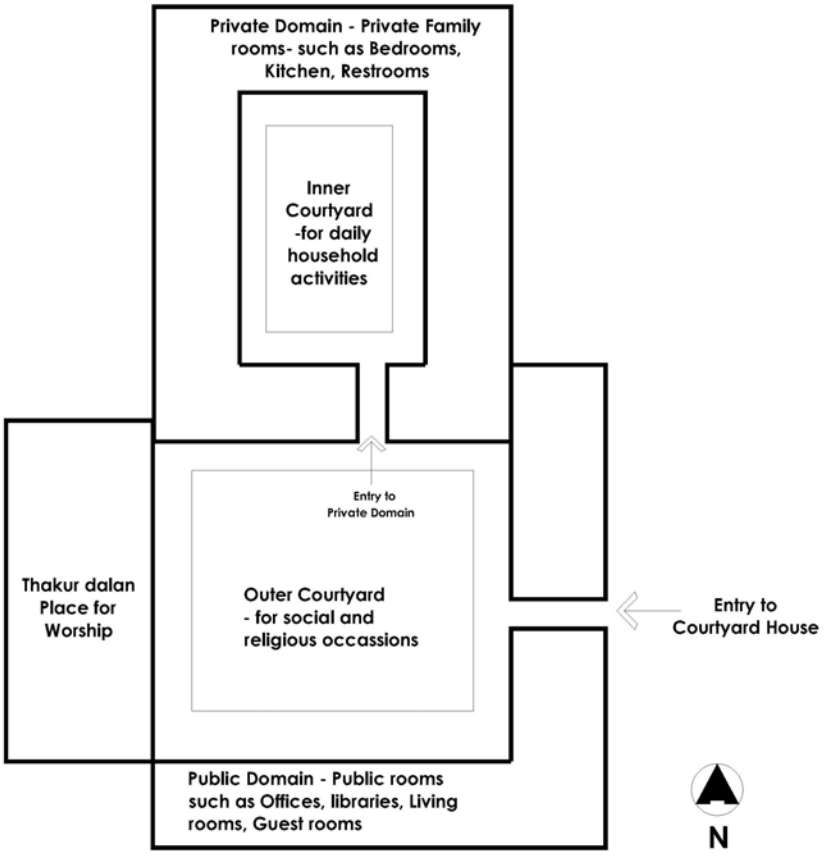

Figure 3.8: Typical plan of courtyard house in Kolkata

ENTRY

The entry of the Kolkata courtyard houses may be either directly onto the open space court or through a small passage which obstructs the direct view into the courtyard. Most of the courtyard house shows an indirect entry. This allows the court to maintain privacy in its daily activities. The entry usually gives access to the outer court which has the *thakurdalan* and *natmandir*. Festivals and social occasions celebrated in a pompous manner were an integral part of the history of these courtyard houses. Most of these religious festivals and celebrations were public events, that is to say the British

officials as well as the neighbors were invited to these lavish occasions. Since all public people and activities were restricted to the outer courtyard, the entry sequence gave access to this court. The inner court entry remained much more guarded and restricted from easy access either visually or physically.

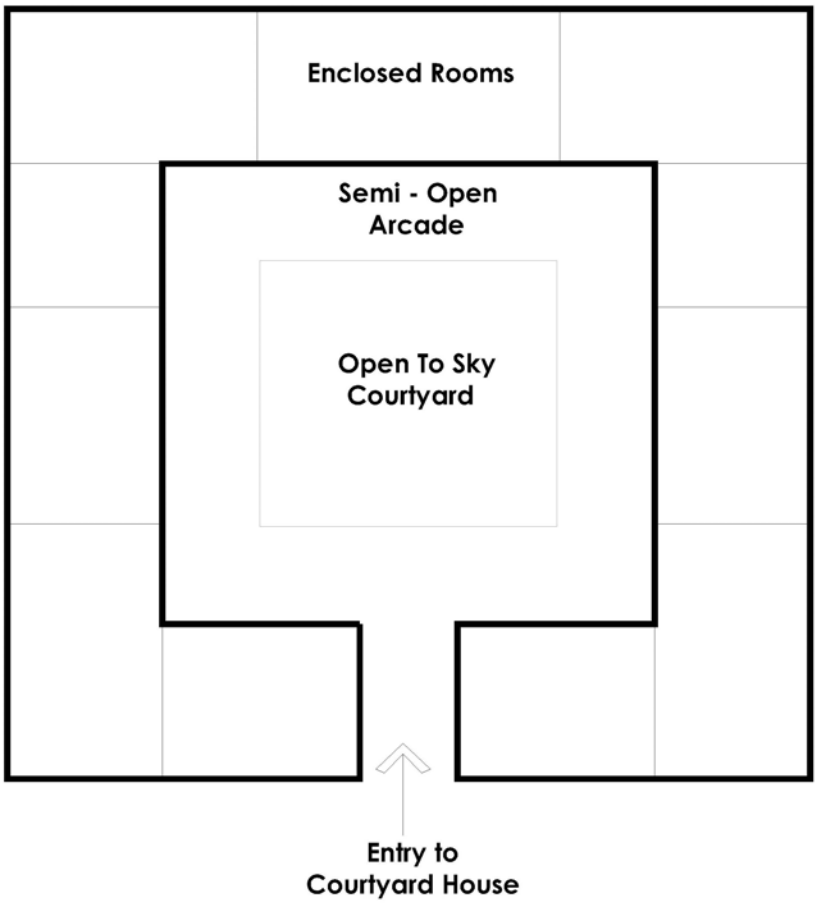

Figure 3.9: Typical entry sequence of courtyard house in Kolkata

CIRCULATION

The centripetal movement within the house is usually directed towards the courtyard. Most of the circulation in the house is through the arcaded verandahs around the courtyard. The rooms in general open to these arcades towards the courtyard side. Some houses had verandahs on the outer side of the house facing the street, but they

are visually blocked by using screens in the upper floors where the women may reside, whereas the lower floors usually remained the domain of the men in the house. Since most of the houses are two stories, there are stairs for vertical circulation at strategic corners.

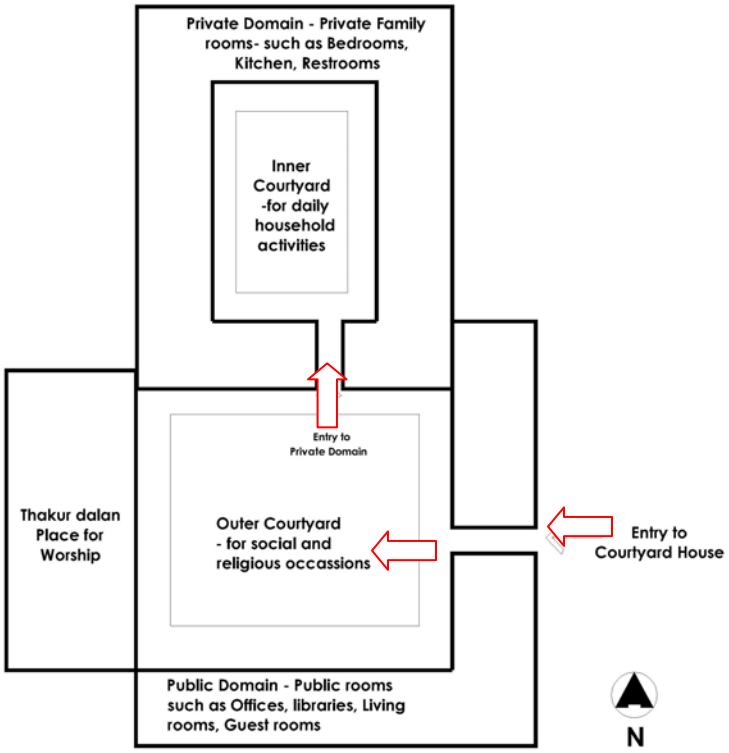

Figure 3.10: Typical circulation layout of courtyard house in Kolkata

MEANINGS AND SYMBOLISM

The courtyard houses of Kolkata are symbolic of the society in which these families emerged and their lifestyle. The courtyard houses bear witness to the development of a group of economically advantaged Bengalis due to their genius for language and business. The British favored this class to form an intermediate group of natives who

could execute their orders and facilitate communication between the rest of the natives and the colonizers. The courtyard houses bear witness to the development of this "intermediate" class from – early mere mediators who were greedy for making quick money, characteristic of the extravagant upstart '*Babu Culture*'; to the genesis of an intellectually evolved second generation of *Babus* who were Western-educated and brought Renaissance to Bengal and generated many radical social, cultural and political reforms.

SOCIETY – The history and significance of the great courtyard houses in Kolkata can be rendered meaningless if one does not understand the society and the times when they were built. In an increasingly westernized process of building the city, the courtyard houses may be considered as the product of Western influence and traditional ideologies. In fact, in The Bungalow, King aptly describes the effect of Colonial developments on the residential behavior of the rising middle class as the expression of an amalgamation of "…social institutions and the necessities of climate, both of which were expressed in the 'old-fashioned Indian dwelling', with its interior courtyards" (p.55).[78] The courtyard houses may be considered the symbol of the nouveau riche society's adoption of feudal pomp and arrogance. In his account of "The Great Houses of Old Calcutta", Chitra Deb mentions that "With minor variations, they (courtyard houses) all follow the same pattern: dwelling house, women's quarter, *thakurdalan* or god's sanctum with adjoining *natmandir* or stage for performances, office, parlor,

[78] King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

strong room, servants' quarter, stable and granary."[79] However, he noted these houses were marked by the spirit of rivalry in the way they are constructed and decorated with respect to other such houses and symbolizing the "grotesque acts of extravagance that shocked and fascinated the common man" (p.58).

In *The Bungalow* King observes that in general, westernization of the domestic architecture in India implies three inter-related changes which have affected both building forms as well as urban setting. King observes that besides the physical variation as manifested in architecture or the spatial philosophy, the new building forms obviously resulted from larger ongoing social, economic, technological and cultural processes at the time. He further describes the Westernization process as – a change in house plan, form and structure, and the addition of an enclosed compound or garden; a move from traditional indigenous city to a suburb; the adoption of Western domestic equipment, especially cutlery, tableware, utensils, furniture, sanitary equipment.[80] Architecturally this Westernization of the Bengali society is directly expressed in the western-style facades of the courtyard houses, the inclusion of different functional spaces like dining room, living room and European furnishings in the house plan, and the exclusion of sequestered *zenana* or women's area within the houses built in the later years.[81] However, the Bengali love for tradition and culture manifested in the design of

[79] Deb, Chitra. 1990. "The 'Great Houses' of Old Calcutta". *Calcutta: The Living City*. Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

[80] King, Anthony D. 1995. *The Bungalow: The Production of a Global Culture*. Oxford University Press, New York.

[81] The Bengalis who traditionally used to sitting on the ground with their legs folded, were introduced to the concept of sitting in chairs and eating from the table with use of fork and knife. Again, Bengal started many women liberation movement and therefore the Bengalis did not believe in restricting the women of the house from knowledge or outside world as emphatically as practiced elsewhere in India.

thakurdalan (a place to worship) and *natmandir* (a stage to perform cultural shows like music, dance, theatre) near the courtyard.[82]

While describing the basic plan of these traditional houses, Evenson notes, in *The Indian Metropolis*, that, the Kolkata courtyard dwelling with a Classical portico in front and colonnaded loggia surrounding the interior court resembles the Italian Palazzo more than the British prototype.[83] She further explains that,

> *"…the adoption of Western architecture coincided with a sophisticated range of intellectual interests. In some ways, the Indians who favored European design were counterparts to the Englishmen who had first employed Renaissance Classicism. The new style was associated with the cosmopolitan views of a cultural avant-garde." (p. 73)*

The courtyard houses in a manner represented the British notions of creating a class of people who Macaulay had envisaged as "interpreters between us (British) and the millions whom we (British) govern – a class of persons of Indian in blood and color, but English in tastes, in opinions, in morals and in intellect" (Roychowdhury, 1990; King, 1995).

FAMILY – The symbolism of the Kolkata Courtyard houses is incomplete without an understanding the nature of families residing in them. In the introduction of the *Banedi Kolkata'r Gharbari,* Bandhopadhay and Mitra observe that the "great courtyard houses" were popularized by the rising middle class tradesmen (referred to as 'Banedi')

[82] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited. (p.123)
[83] Evenson, Norma. 1989. *The Indian Metropolis: A View toward the West*. Yale University Press, London.

under the British. They note that the rise of these families is an integral part of the socio-political history of the city. While on one hand, many of the owners of these houses had amassed wealth by continuously torturing and exploiting the poor common men; on the other, there were some who had attained great renown and acclaim for their benevolent and philanthropic nature. The courtyard houses of Kolkata have historically housed both vain and opportunist Babus[84] and also radical and committed freedom fighters.

In general there are two widely accepted theories of how this Banedi class of families emerged in the city. Deb in his account on "The 'Great Houses' of Old Calcutta" mention that most of the great house families may trace their roots back to 1742, when the Maratha raiders or bargis attacked Bengal and their associate Mir Habib occupied the town of Hugli. At this time, many established families in the region fled to Kolkata seeking protection under the British. The second reason explained by Mitra, is attributed to the impact of massive silt accumulation on Saraswati River, which closed the prosperous trade channel between the Bengali tradesmen and the Mughals. Therefore, many of those families were compelled to move to Kolkata where they could continue their trade from the new-found trade center on the Hugli River. After migrating to Kolkata most of these tradesmen started acting as chief agents between the British and

[84] The term Babu is used to refer to the new wealthy class that formed as a product of Kolkata based families with the West essentially British. Over time the term though associated with the 18th century extravagant, pompous landlords and also late nineteenth century social reformers and philanthropists, in general the term retained a derogatory connotation. According to Raychoudhuri, the term Babu degraded "…with radical shifts in the economic power structure of Calcutta, the glamour of Babudom faded away: ultimately 'Babu' came to mean nothing but a clerk" (p.75)

RayChaudhuri, Subir. 1990. "The Lost World of Babus". *Calcutta: The Living City*. Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

the natives. Their literary and language skills (most of them were well versed in more than one language – for example Sanskrit, Bengali, English and Persian).

Most of the courtyard houses in Kolkata housed a joint family system, where the sons of the owner of the house remained in the same house after marriage. This helped to form large domestic establishments including family members and numerous servants to serve each member in their daily household activities. This huge joint family system functioned properly as long the owner lived; however these houses tended to be the bone of contention on issues of inheritance within the family. Quoting from a local literary source, Evenson remarked, "A house might be built on a grand scale with the firm conviction that seven generations would live there, yet fall into disrepair because of the succeeding generations being too busy quarrelling or making ends meet" (p.68). As most of these families had initially accrued all the wealth from what Deb refers to as "new sources allied with nascent British colonialism", retaining the new-found social and economic status always seemed to generate tensions in the expanding families.

Courtyard houses can be found all over Kolkata, but their exquisiteness is underlined by the family cultures who have historically resided in them. According to Binay Ghosh as quoted in "The Great Houses of Old Calcutta" by Deb, the family cultures adopted by the residents of these courtyard houses may be broadly divided into four basic types prevailing in various parts of the city – the Sutanati culture of north Kolkata consisted of the new urban feudal culture of the city 'Rajas'; the Kalikata culture of central Kolkata consisting of mercantile cultures propagated by the Tantubaniks or cloth merchants like the Seths and Basaks, as a the Subarnabaniks or gold traders; the Gobindapur culture

of south-central Kolkata consisting of the families influenced by new-found English culture or European riches; finally there is the Bhowanipore culture of south Kolkata consisting of the middle class culture. These differences in culture of the families was expressed architecturally in the design of the courtyard houses, where the arrogance of wealth is portrayed in the palatial mansions found mainly in north Kolkata or the rich English taste yet restrained in size as evident from the courtyard houses in south Kolkata owned mainly by bureaucrats and lawyers under the British or the amalgam of old and new elements seen in the houses of mercantile groups in central Kolkata. It is important to note here, that although all the four zones in the city interacted, the Sutanati culture gained more popularity from the 18th to 19th century. Deb note that, "…as the generations passed, it acquired a new sophistication and a new responsible interest in education and social reform" (p.61).

LIFESTYLE -

> *"If the Calcuttan appears indifferent to the daily preoccupations of life, it is because he scorns such mundane matters as bourgeois: the true Bengali is an aristocrat.*
> *This anthology attempts to show aspects of Calcutta which the doom and gloom mongers gloss over, and give some idea of why, despite the difficulties of climate and power cuts, it still inspires such affection and loyalty in the hearts of its people."*
>
> *-Laura Sykes in Calcutta Through British Eyes (p.1)*

Truly, while analyzing the lifestyle of the families in the great courtyard houses of Kolkata, one can realize the inborn aristocracy within these families, expressed in their house design, and the furniture or furnishings in the house. The courtyard houses of

Kolkata nurtured the lifestyle of *Babus* or the owners who have been aptly described by Raychaudhuri[85] as the product of Bengal's imperfect encounter with the West. Though the great courtyard houses were dominantly resided in by Hindu families, their lifestyle was greatly influenced by Persian *nawabi*[86] style. In fact, in "The Lost World of the Babus", Raychaudhuri observes that the Hindu and Muslim elite differed on their response to British rule and Western education. However, Raychaudhuri notes that in spite of their parting of ways the early exponents of *Babu* Culture did not give up their *nawabi* lifestyle. Emphasizing this fact the author observes that "Nothing illustrates better the amalgam of motives in the early 'aristocratic' *Babu*, as well as his ostentatious pride of wealth" (p.71). Deb observes that, "Under the new dispensation where wealth flowed from skillful tending of British interests, the advantages lay with the commercial and legal literati and those who could act as middlemen and manipulators" (p.57). Accordingly, most of the founders of these courtyard houses were Kayastha (traders or businessmen according to Hindu caste system), as they found it easy to adapt to the commercial and political service under the British holding different titles like *diwan, banian, vakil* etc but their chief function was to intermediate between the rulers and the ruled.

According to Raychaudhuri, "There were a number of diverse components entering into the total phenomenon of *Babu* life, in addition to the ambivalent absorption of Western life-styles and Western ideas, the two not always in conjunction" (p. 70).[87] He

[85] RayChaudhuri, Subir. 1990. "The Lost World of Babus". *Calcutta: The Living City*. Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

[86] The term nawab is used to refer to Muslim rulers.

[87] RayChaudhuri, Subir. 1990. "The Lost World of Babus". *Calcutta: The Living City*. Sukanta Chaudhuri. ed. Volume II. Oxford University Press, Calcutta.

observes the fondness of the *Babu* for *adda*. Though generally referred to as idle chit chat today, in those times this conversation sessions were more than that, and many times these informal sessions were the birthplace of noble ideas of social reform and cultural regeneration. The *adda* and interest in advanced literature and social philosophy later translated into the love for periodicals patronizing and publishing similar ideologies by the *Babu*. Raychaudhuri notes how "From Rammohan Ray (1772/4-1833) to Rabindra Thakur (1861-1941), all the stalwarts of the 19th century used periodicals as a vehicle for both polemical and creative writings" (p.71). This is perhaps why within a period of only 50 years (1818 – 1867), 219 periodicals had been published in both Bengali and English in Bengal.

This literary and philosophical genius among the Bengali Babus later reflected in its associations with different groups and societies related to academic and literary interests, socio-religious reforms and finally to the protection of the interests of landholders. Interestingly, nearly 25 of these organizations formed between the 18th to 19th centuries were organized by British and Indians jointly. Another aspect of the *Babu* culture was its interaction with caste politics. Religion and caste were a vital reality among *Babus*, both the non-Western educated and those who attained formal Western education, though the class characters were radically different. Raychaudhuri emphasizes this subtle difference by quoting Bankimchandra from his satirical Confessions of a 'Young Bengal':

> *We have cast away caste. We have outlived the absurdity of social classification based upon the accident of birth. But we are not such ultra-radicals as to adopt for our catchword the impracticable formula of 'Equality and Fraternity' (p.72).*

The Babu Culture or Babudom survived its glory so long as the Babus acted as collaborators in founding the British Empire, sometimes accruing fortunes overnight. However, the illusion was exposed when the Babus started demanding an equal share in power and administration. This led to unsettlement within the society and finally culminated in the shift of the capital from Kolkata to Delhi in 1912. With the rise in the sense of alienation between the ruled and rulers, the Babus became more and more committed to or involved in forming political organizations and freedom movements to vent their grievances.

CHAPTER 4: CLIMATE, COURTYARD AND COMFORT

Our modern solutions to climatic problems often do not work, and our houses are made bearable by means of ingenious mechanical devices whose cost sometimes exceeds that of the building shell…The poor thermal performance of many of our buildings despite this mass of mechanical equipment suggests that we underestimate its continued effect on our cities and buildings.

- Amos Rapoport, House Form and Culture

As cultural aspirations and technology are often linked with changing technologies, the form of buildings in the tropics has transformed. The curtain glass building symbolizing "corporate power" being the classic case where the hermetically sealed box pumped with air-conditioning becomes the symbol of corporate aspiration".

- Rahul Mehrotra, Architectural Responses in Tropical India

INTRODUCTION

Climate is inseparable from the history of the existence of life and humankind on this Earth. Climate's influence on the life world is as eternal a truth as life and death. In a way, it may be said that climate is responsible for creating the basic necessities of early man – food, clothing and shelter; for example the right amount of rain and weather in a place decided the type of food that could be grown there; the heat and cold of a place influenced man in deciding his clothing to feel comfortable; and finally it was the basic necessity to prevent the harshness of the weather that primitive man first learnt to take shelter. History bears evidence that climate has guided the rise and fall of many empires, cultures and economies. Long before the times of Socrates and Vitruvius,

homo sapiens had learnt that human beings need to adapt to the rules of nature and climate. Today, modern man has traveled a long way from the Stone, Bronze and Iron Age man and is now rapidly reaping the benefits of the present Hydrocarbon phase in the history of human civilization. In his arrogant belief in the supremacy of scientific progress and technical advancement modern man has started ignoring this basic rule of healthy living on the planet. While introducing his book, Tropical Architecture, Kukreja[88] wrote:

> *The twentieth century has brought new dimensions to our living conditions and environment, through successive industrial and scientific revolutions. The invention of various 'comfort gadgets', like air conditioning, and use of new materials and building techniques have altered our approach to the design of buildings. To practice architecture today one must have an understanding of the art, science, and technology of our times. For, though architectural principles may be universal, they have to be applied in a particular environment, and climate is the most important environmental factor to be considered in the design and construction of building.*

One of the main objectives of this chapter is to understand these underlying architectural principles of bioclimatic, or climate responsive design, that Kukreja refers to, with special reference to hot humid tropical climate in India. Rahul Mehrotra[89], in his article "Architectural Responses in Tropical India", points out that in the quest for a pan-Indian architectural identity, the architectural community has largely been overwhelmed by the vocabulary and approach that have emanated from the architectural spine along Chandigarh – Mumbai. Indeed, today the architecture of

[88] Kukreja, C.P. 1978. *Tropical Architecture*. McGraw-hill Book Company, New York.
[89] Tzonis. A, L.Lefaivre and b. Stagno. (ed.). 2001. *Tropical Architecture: Critical Regionalism in the Age of Globalization*. "Architectural Response in Tropical India". Wiley – Academy, Italy.

India is highly guided by the western and northern Indian architects whose design approach is more specific to hot-arid climates. In general, the needs of an architectural character for hot-humid eastern and southern India have been largely neglected by the Indian architectural community. The focus of this research is on the architectural patterns created as a response to a tropical humid climate like shading and ventilation. The case studies explore the bioclimatic and cultural adaptations to the courtyard form of dwelling in the hot humid climate of Kolkata. The research tries to explore the relevance of courtyard design in hot humid climate of Kolkata and therefore the possibility of adding courtyard design as a bioclimatic approach as a design strategy in hot humid climates.

"It seems that for courtyard comfort,…the worst climates are hot and humid, where little wind is available to relieve stuffiness…"(Reynolds, p.80)[90].

The affluent families under the Raj owned these courtyard houses, popular during the Colonial rule of Bengal. My intent is to reexamine these historical buildings to find whether the courtyard design adapts and responds to the hot humid climate. For a comprehensive understanding of the bioclimatic research it is better to operationalize some of the terms mentioned above.

OPERATIONAL DEFINITIONS

TROPICAL CLIMATE – Tropical climate may be defined as the climate prevalent between the two imaginary parallels, the Tropic of Cancer and the Tropic of Capricorn. Tropical climate is characterized by two different types – the hot dry climate and the hot humid

[90] Reynolds, J. 2000. Courtyards: Aesthetic, Social, and Thermal Delight. John Wiley & Sons, Inc., New York.

climate. Kolkata lies within the hot-humid belt of tropical climate. Hot Humid and hot dry tropics are distinguished from the extreme temperature variations of temperate zones but between themselves, their chief distinction is that due to the intervention of the cloud barrier between the sun and the ground humid tropics are less hot but much more humid.[91]

Nieuwolt mentions two very important characteristics of the tropical climatic belt – "absence of a cold season" and that economically "most tropical countries belong to the group of developing nations".[92] Another distinguishing factor probably is that nearly all of these developing nations have been British colonies historically. Therefore they have retained traces of the colonial empire. Kolkata served as the British capital of India from 1757 till 1912 and the older parts of the city which is also the research study area bears significant imprints of planning and architecture molded during that period.

BIOCLIMATIC DESIGN

> *Climate is clearly one of the prime factors in culture, and therefore built form. It is the mainspring for all the sensual qualities that add up to a vital tropical architecture*
>
> *- Beng, p13.*[93]

Bioclimatic, or climate responsive design, is "based on the way a building form and structure that moderates the climate for human good and well-being".[94] Discussing the

[91] Fry, M and J. Drew. 1964. Tropical Architecture in the Dry and Humid Zones. Reinhold Publishing Corporation, New York.
[92] Nieuwolt, S. 1977. *Tropical Climatology: An Introduction to the Climates of the Low Latitudes*. John Wiley & Sons, London.
[93] Tan Hock, Beng. 1994. *Tropical Architecture and Interiors*. Page One Book, Singapore.

term "pure climatic functionalism", Rapoport[95] notes that the need of shelter design adapts and responds to the severity of the climate in the area. It is this intuitive adaptive capability to respond to the forces of climate like sun, wind and humidity that sets apart bioclimatic architecture from senseless, arrogant, and merely style-based creation. He further notes how economic and technological constraints force man to think of climate responsiveness in design. In Kolkata, the courtyard buildings, which I am studying, were also built much before innovations in mechanically controlling interior environment. Therefore, the design attitude of these buildings does not ignore climatic considerations and adapts the limitations caused by nature to suit social needs.

BIOCLIMATIC FACTORS FOR HOT HUMID CLIMATE

> *In the humid tropics, life often takes place out of doors during the day and evening when it is not actually raining, but sleeping is of course indoors, mainly due to primitive fears of the dark and possibility of sudden rain squalls".*
>
> *- Maxwell Fry and Jane Drew, Tropical Architecture.*

Hot humid tropical climates are comprised of mainly three basic climatic elements – sun, wind and humidity. The other climatic considerations of temperature, precipitation and daylight are affected by the proportions in which these three elements work. The tropical hot humid climate is characterized by high relative humidity, heavy rainfall, and

[94] Hyde, R. 2000. Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates. E&FN SPON, London.
[95] Rapoport, A. 1969. House Form and Culture. Prentice-Hall, Inc., Englewood Cliffs, N.J.

mean annual temperature of over 64°F (17.7 °C), but may reach 100°F (37.8°C) in the hot season.[96]

Architecturally, Fry and Drew observe that there are three main considerations guiding tropical design - "first, people and their needs; second, climate and its attendant ills; and third, materials and the means of building" (p.20). Responding to these design issues tropical architecture is mainly open in nature. In this climate sun and humidity act as the main liabilities whereas wind is an asset.[97] In his summary about the hot humid climate Salmon wrote, "The tempo of life is slower in the tropics …A combination of high temperature and high humidity in built-up areas can be very unpleasant because of the lack of air movement due to breeze shadow" (p.100).[98] Therefore, the main strategies to attain comfort in the hot humid region include[99] –

1. Efficient ventilation by dissipating heat through dispersed structures.
2. Protection from sun by proper solar shading during overheated months.
3. Avoiding heat storage and promoting ventilation to dissipate humidity.
4. Expanding use of outdoor living areas during day and evening when it is not raining.
5. Using vegetative cover or non-reflective flooring materials to prevent reflected radiation and glare.
6. Flattening day and night temperature swings within the interiors.

[96] Fry, M and J. Drew. 1964. Tropical Architecture in the Dry and Humid Zones. Reinhold Publishing Corporation, New York.
[97] AIA Research Corporation. 1978. Regional Guidelines for Building Passive Energy Conserving Homes. U.S. Govt. Printing Office, Washington, D.C.
[98] Salmon, C. 1999. Architectural Design for Tropical Regions. John Wiley & Sons, New York.
[99] Coates, Gary. Bioregional Design Strategies Lecture Notes.

SUN -

The sun or solar radiation is the chief influence in controlling the global climate and weather. According to Victor Olgyay, a mean solar constant[100] of 1.94 cal/cm2 /min reaches the Earth daily. Kukreja observes in his book *Tropical Architecture*, that solar radiation is weak in the hot–humid tropics due to high water vapor content in the atmosphere. Most of the incoming solar radiation in the humid tropics is due to scattered radiation. In most cases, high albedo materials are preferred in the climate to enhance maximum reflectance of solar radiation. This fact guides the material choice and color of the buildings. However, heat intake of a building is highly affected by heat absorption from surrounding reflecting surfaces. "For instance, a white courtyard will reflect more radiation and will therefore remain relatively cool, but, at the same time, the reflected light will fall upon the surrounding walls or buildings, and part of it will get absorbed. A dark-colored courtyard may get hot because it absorbs radiation but it will reflect little heat towards the surrounding structures or walls" (Fry &Drew, p.10). In the tropical climate more than one-fifth of the radiation emitted from the surface escapes to space. The rest of the radiation is reradiated back to the cloudless sky. Since the outward radiation tends to be low, the nights in these regions are rather oppressive as one move towards equator.[101]

Architecturally, solar radiation and the movement of the sun in the sky impacts the major design decisions like – site selection, orientation of the building, shape of the building, its location of openings and sun control devices. When designing a building

[100] Solar constant – the amount of sun's energy that falls in a unit time on a unit area 93,000,000 miles from the sun and perpendicular to its rays.

[101] Fry, M and J. Drew. 1964. Tropical Architecture in the Dry and Humid Zones. Reinhold Publishing Corporation, New York.

responsive to the effects of the sun, the availability of the sun during the solar day is evaluated with the help of sun-dial and sun-path diagrams or advanced computer simulation programs. This helps in guiding the space programming in the buildings to utilize or prevent the sun as per their needs and use.

WIND -

The unequal distribution of solar radiation on the Earth leads to the imbalance in atmospheric density giving rise to winds.[102] In hot humid tropics effective use of wind is the main asset of the climate. In fact human behavior with the buildings in this climate is greatly related to the wind direction and availability. Maximizing air movement within the buildings and especially in the living zone helps to increase comfort conditions in the hot-humid climate. The high summer temperatures and lower winter temperatures induce a reversal in wind directions in tropical hot humid regions. The high summer temperatures create low pressure zones and induce heavy winds. This wind system is known as the monsoon and guides the Asian climatic pattern. [103]

Architecturally, the building design and orientation should try to take advantage of the prevailing winds in the hot humid climate. "Unlike housing in the hot and arid zones, housing layouts in the humid regions tend to be spread out so that they can take advantage of the existing air movements" (Kukreja, p.80).

[102] Olgyay, V. 1963. Design with Climate. Princeton University Press, Princeton, New Jersey.
[103] Kukreja, C.P. 1978. *Tropical Architecture*. McGraw-hill Book Company, New York.

HUMIDITY -

Humidity is the amount of water vapor content in the air. The atmosphere is always charged with a certain amount of water vapor. Acting as an absorbing agent in the atmosphere, it is the proportion of this water vapor content that decides the amount of incoming and outgoing radiation. Therfore, humidity directly affects the earth's heat economy.104 According to Givoni in his book Man, Climate and Architecture[105], atmospheric humidity may be expressed in several terms like absolute humidity, specific humidity, vapor pressure and relative humidity. He further notes that, "From the physiological point of view, the vapor pressure of the air is the most convenient way by which to express the humidity conditions because the rate of evaporation from the body is proportional to the vapor pressure differences between the skin surface and the ambient air. On the other hand, the relative humidity affects the behavior of many building materials and their rates of deterioration" (Givoni, p.14). Rahul Mehrotra[106] mentions in his article on "Architectural Responses in Tropical India" how adaptation of Modernistic architectural forms have reversed this natural process of weathering of traditional buildings which were heterogeneous in compositions responding to the various aspects of climate. "Elements such as awnings, window shades, cornices, copings, drip moulds, etc. fashioned to retard deterioration were important components of all traditional buildings in the tropics as well as elsewhere. In most Modern buildings, when these elements were removed, it was necessary to use a sealant – and so 'weatherproofing' replaced 'weathering'" (Mehrotra, p.204).

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[104] Kukreja, C.P. 1978. *Tropical Architecture*. McGraw-hill Book Company, New York.

[105] Givoni, B. 1969. *Man, Climate and Architecture.* Elsevier Publishing Company Limited, Amsterdam.

[106] Tzonis. A, L.Lefaivre and b. Stagno. (ed.). 2001. *Tropical Architecture: Critical Regionalism in the Age of Globalization*. "Architectural Response in Tropical India". Wiley – Academy, Italy.

Among the climatic elements, it is probably most difficult to architecturally respond to humidity. Humidity is the chief component for discomfort in hot humid tropics. If, for instance, the humidity is too high, the rate of perspiration of our body will be large compared with the amount of evaporation, this may cause the feeling of clamminess and dampness until some air movement occurred.

THE OTHER CLIMATIC CONSIDERATIONS

The other climatic considerations relevant to the holistic understanding of the tropical hot-humid climate are temperature, daylighting, rainfall and thunderstorms. As mentioned earlier, I believe that all these considerations are directly or indirectly related to the three basic climatic factors – sun, wind and humidity.

TEMPERATURE – The rate of heating and cooling of the surface of the earth is the main factor determining the temperature of the air above it. Solar radiation has an indirect effect on air temperature.[107] The variation of diurnal and seasonal temperature depends on the state of the sky.[108] Solar radiation being nearly constant in the tropics and also the high water content in the air results in small diurnal and seasonal variations in air temperature. However, it must be noted that the temperature of the ground or walls may be considerably different from surrounding temperature depending on color, heat capacity, conductivity and reflectance property of the surface material. "When

[107] Tzonis. A, L.Lefaivre and b. Stagno. (ed.). 2001. *Tropical Architecture: Critical Regionalism in the Age of Globalization*. "Architectural Response in Tropical India". Wiley – Academy, Italy.

[108] Olgyay, V. 1963. Design with Climate. Princeton University Press, Princeton, New Jersey.

subjected to strong solar radiation, roofs and walls of houses become warmer than the surrounding air". (Fry and Drew, p. 10).

DAYLIGHT – Daylighting considerations are directly related to the position of the sun in the sky, mainly two aspects – the sky component and reflected component. Therefore, effective daylighting design in a building depends on daylighting availability and its variation from time to time, sky luminance and their variations, orientations, façade and ground reflectance, room dimensions, window locations, interior reflection coefficients, and brightness balance between adjacent areas in the visual field (Kukreja, p74).

Fry and Drew observe that in the tropical humid climate, "The effect of the shadows cast by sunlight falling on to a building and the position of the sun at different times of the day with its degree of penetration into a building are definite and predictable" (p.33). Therefore, if designed carefully it will be possible to maximize daylighting in buildings. The challenge is to maintain a balance between daylighting in the interiors and preventing unnecessary heat gain.

PRECIPITATION / RAIN – Precipitation is generally in the form of rain and occasionally as hailstorms in the tropical hot-humid belt (Kukreja, p. 13). Givoni observes in *Man, Climate and Architecture*, that in this climate where humidity and rainfall is very high during most of the year, the daily incidence of rain is regular in most locations usually occurring in the afternoons. In tropical regions the air temperature which is steady throughout the day is mostly influenced to vary due to rains. Almost always there is a temperature drop after the rain showers. "Rainfall can be high in all areas and a major

concern to animal, pedestrian, and vehicle traffic flow. Dealing with surface runoff can be extremely difficult in towns, especially in built-up areas" (Salmon, p.101). Heavy rainfall in the tropical regions leads to the main cause of weathering of buildings. The damp humid climate tends to encourage the prevalence of fungi and insects. (Fry & Drew, 1964, p.33; Givoni, 1969, p.321)

THUNDERSTORMS – Almost always precipitation in the tropics is accompanied by violent thunderstorms formed due to the convergence of Trade winds from the north and south hemispheres. At this time an average wind speed of 125 – 140 mph is not uncommon.[109] This requires that the buildings in this region are well anchored to every other part (Salmon, p.109).

KOLKATA'S CLIMATE

Based on the World Climate Design Data 2001 ASHRAE Handbook, Calcutta situated between N 22° 38' longitude and E 88° 26' latitude has been described as a hot subtropical steppe climatic type by www.eere.energy.gov.

Summer – typically between March to mid June with average maximum temperature is as high as 35°C (95°F), monthly mean maximum relative humidity around 80% and maximum average wind speed about 8.88m/s.

Monsoon – typically between mid June to September with average maximum temperature is as high as 31°C (87°F), monthly mean maximum relative humidity around 90% and maximum average wind speed about 6 m/s.

[109] Salmon, C. 1999. Architectural Design for Tropical Regions. John Wiley & Sons, New York.

Autumn – relatively short and typically between October to November with average maximum temperature is as high as 29°C (84°F), monthly mean maximum relative humidity around 80% and maximum average wind speed about 8 m/s.
Winter – typically between December to February with average maximum temperature is as high as 25°C (77°F), monthly mean maximum relative humidity around 75% and maximum average wind speed about 4.63m/s.

The prevailing wind direction in Kolkata is South-West to North-East during summer to autumn months and North –south during winters. Rainfall is highest in the month of August: otherwise precipitation is evenly distributed in the monsoon months ranging between 175-330mm. Kolkata enjoys an average of 7 hours of sunshine per day.

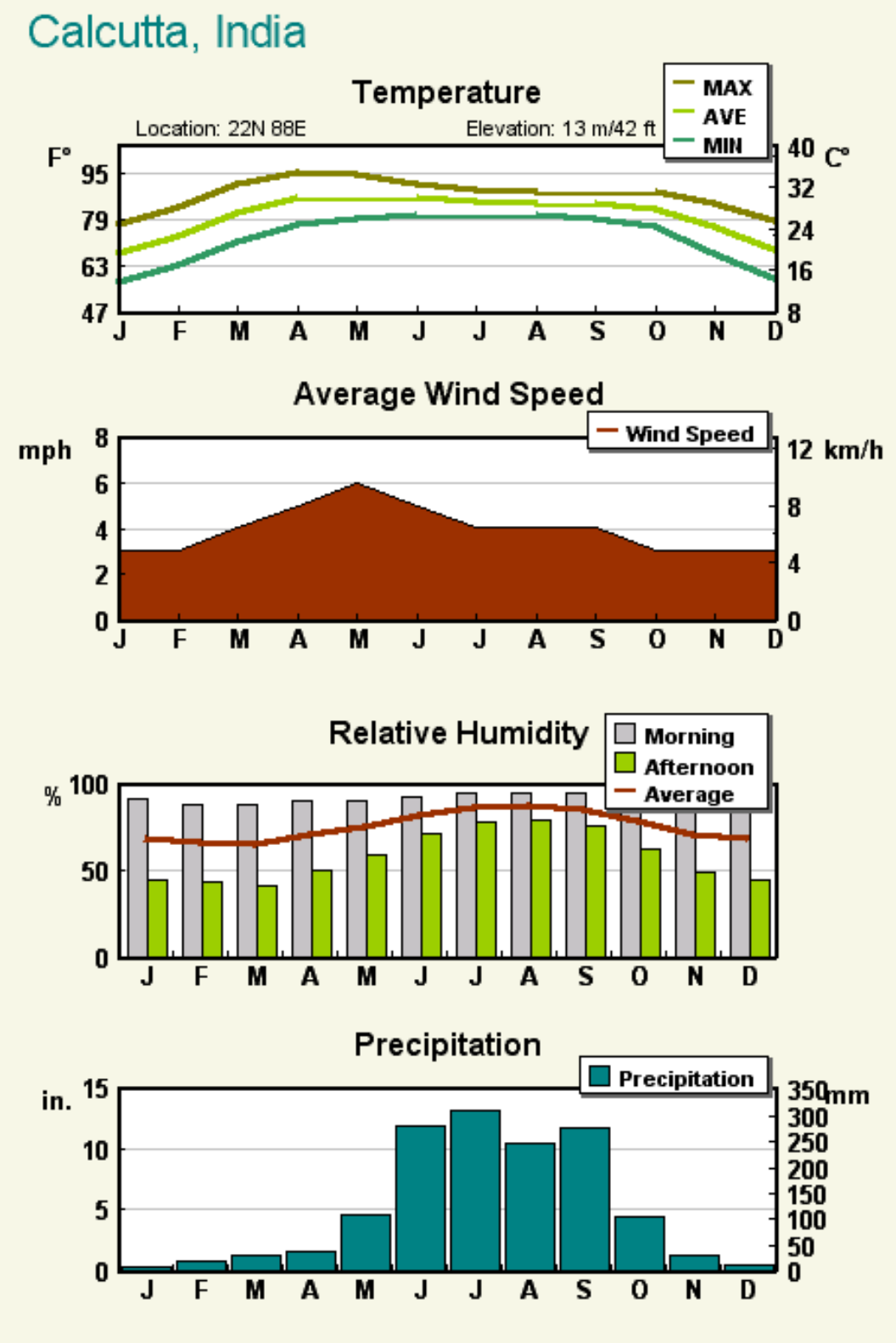

Figure 4.1: Climatic data for Calcutta

(Source: http://www.mytravelguide.com/travel-tools/climate-graphs/Calcutta-India.php?nav=)

KOLKATA COURTYARD CLIMATIC FACTORS

> *Courtyards represent an attempt to bring the forces of nature under partial control. This is somewhat like trying to regularly feed wild animals; one can never be sure when or how much interaction will result. Expectations of thermal comfort in and around the courtyard might be described as 'unpredictable to an acceptable degree'.*
>
> *- John Reynolds, Courtyards*[110]

The discussions in the previous chapters show that the courtyard has been long accepted as a microclimate generator in the house. Randhawa has acknowledged in The Indian Courtyard House111 that most of the courtyard houses in India were strongly guided by the local climate. In this section, the attempt is to find how courtyards adapt the climatic conditions prevailing in Kolkata. The previous chapter has analyzed the sociological implications of courtyard houses in the city. However, before proceeding to the case study research, it is important to highlight the bioclimatic principles of courtyard design that may favor the local hot-humid climate.

Recognizing the six critical factors that should guide architectural design in hot-humid climate as mentioned earlier in the chapter, it is evident that the most important criteria of the courtyard in Kolkata are to tame the sun, and channel the wind. Though humidity is an important aspect of the climate this research does not involve in the depth of how humidity is modified or adapted by the courtyard design. This research explores the roles of solar shading and natural ventilation in courtyard houses located in the hot-humid climatic region.

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[110] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*2002. New York: John Wiley
[111] Randhwa, T.S. *The Indian Courtyard House*. 1999. Prakash Books Pvt. Limited.

As pockets of space that are open to the sky, courtyards intensify some aspects of the climate, such as daylight, and dilute others, such as wind.

- John Reynolds, Courtyards[112]

The interest in the survey of old courtyard houses in North Kolkata was triggered from the above mentioned quote from John Reynolds' book on Courtyards. This also led to the idea that may be the proportion of mass and void in these houses helped in generating different climatic and human comfort conditions inside them. Certain aspects seemed critical in the study of comfort conditions in courtyards in Kolkata – What is the type of thermal mass and material finishing that envelops the building? What is the personal involvement of the occupants of the buildings and how do their lifestyle relate to the courtyard designs?

These questions have guided the research design and methodology and will be answered in detail in the next chapter on the basis of case studies in Kolkata.
The previous chapter has discussed in detail about the society and typical lifestyles of the occupants of the house. This chapter will discuss the favorable methods of taming the local climate in courtyard houses.

SUN

The sun guides two important aspects in the courtyard houses – the heat gained by the house and the entry of daylight into the house. The horizontal aperture in the form of courtyard in a house provides exposure to the solar sky movement. Naturally, the wider

[112] Reynolds, John. *Courtyards: Aesthetic, Social and Thermal Delight.*2002. New York: John Wiley

the aperture, the more chances of gaining heat from the sun. This may work well in the cold season, where the warmth of the sun inside this open courtyard may help in enhancing the use of the space. However, Kolkata's climate is defined mainly by the overheated season and long hours of sunshine; therefore, the approach of narrowing this aperture may be more conducive to the buildings in the city by preventing unnecessary solar exposure.

While avoiding heat gain is an important design strategy, filtering daylight into spaces may be more ideal than letting direct daylight enter into spaces. Solar shading seems to guide design in courtyard houses in hot humid climates. Therefore, use of light and airy materials and design near and around the courtyard may help in filtering the harsh daylight and create a cooler and softly lighted space. A narrower floor plate surrounding the courtyard rather than a wide horizontal building mass should also allow daylight to penetrate into the rooms. Proper solar shading in the courtyard may also help in protecting the inner open space as well as the interiors from rain.

WIND

One of the challenges of the courtyard house is to allow proper ventilation into the enclosed space and the surrounding rooms. The wider the horizontal aperture of the courtyard, the higher the chances that wind coming through the windward side rooms gets dispersed into and out of the open space, before reaching the leeward side rooms. The narrower floor plate may also help in allowing maximum cross ventilation within the structure by minimizing obstruction. The light and airy type building design

and finishes may also help in air penetration into the spaces and thereby increase the comfort conditions inside and outside the house.

COURTYARD HOUSE

In the attempt to find an ideal proportion of courtyard houses that may help in taming the climate of Kolkata – avoiding heat gain while maximizing natural ventilation - a few other spaces may also be emphasized; for example the role of arcades in the houses. Ideally the arcade surrounding the courtyard provides ideal conditions for solar shading, filtered daylight and natural ventilation. It may be useful to study the use pattern of the arcades in the different houses, to see if the proportions of the courtyards affect the use of the semi-open arcades.

Another important aspect for study will be the thermal mass of the building. It will be important to understand whether the thermal mass of the building helps in flattening the daily temperatures. The material used for finishes directly relates to the use of the space. For example, as a culture, Kolkatans enjoy sitting on the floor while performing different tasks like preparing meals or simply chatting. Does the use of particular floor finishes enhance these activities or prevent them? A floor, which easily radiates heat, may provide a more comfortable surface for sitting rather than one that retains heat.

CHAPTER 5: COURTYARDS OBSERVED

RESEARCH DESIGN AND METHODOLOGY

The universality of the courtyard building type has been discussed in previous chapters. However, the existence of courtyard houses in Kolkata, a hot humid climate type, seems a little paradoxical. The basic requirements of solar shading and cross ventilation for comfort in hot-humid regions seem to argue against the historically dominant courtyard buildings that are prevalent throughout the older neighborhoods in the northern parts of the city. Yet, it seems that people living in these courtyard houses prefer the comfortable living conditions found in these houses. This apparent contradiction triggered the author's interest in this research.

To understand the research design and methodology for this thesis it will perhaps be helpful to reiterate the research goals and objectives. The primary research intent is to examine the bioclimatic and socio-cultural appropriateness of courtyard buildings in modern Kolkata. The broader goal is to find a suitable "type" for courtyard buildings that can be conveniently adapted in the modern society while retaining their original values of thermal and socio-cultural responsiveness. A comparative case study research method has been adopted for analyzing a sample of courtyard houses in older northern parts of Kolkata and understanding their inherent bioclimatic and socio-cultural responsiveness. The research tools include: extensive on-site surveys of residents of the courtyard houses observed, on-site photography, on-site data measurement, computer simulation analysis and finally literature review and analytical sketches. These tools help to address the research questions on both their qualitative and quantitative

aspects. Based on these facts the research design may be divided into the following subparts:

On-site data collection

Data assimilation and analysis

LIMITATIONS OF THE RESEARCH DESIGN

There are some inherent limitations of this research method which have been listed below:

Due to the distance between the places where the thesis is being written and the case studies, and the limited time for actual site visits, most of the decisions regarding the choice of the case studies were impromptu based on the ease of getting permission from the occupants of the building to participate in the research efforts.

Some of the case studies are based on photography of houses that had been collected earlier but could not be visited during the short duration I was in India.

The surveys were designed in English. However, the respondents mainly answered in Bengali (the local language), so the responses had to be translated into English for the purpose of the thesis.

All the houses which were chosen for detailed study and instrument set-up had children and servants in the house over whose behavior the researcher had no control. As a consequence the experimental results have been accepted in full faith that the instruments were not displaced or tampered with. Fortunately, the results did follow the survey responses, therefore minimizing the chances of error.

Finally, data collected by instruments were taken during winter, which is a not typical climatic condition for a hot-humid city. However, the survey was designed to give a

more comprehensive overview of the use, activity and climatic comfort of the houses throughout the year.

COMPARATIVE CASE STUDY METHOD – A SOCIO-BEHAVIORAL STUDY

In January 2005, I visited India to conduct the on-site data collection after receiving IRB[113] permission from the Kansas State University. My purpose was to visit, survey, and photograph different courtyard buildings in the older northern parts of Kolkata. The main objective was to choose two specific courtyard houses on which to perform detailed climatic data measurements using data recording devices from the Agents of Change/Vital Signs Toolkit[114]. The first two detailed case studies were chosen in small part because of the residents' ease at permitting me to mount dataloggers. However, the proportions of these two courtyards were not much different. Therefore, a third case study was selected for detailed bioclimatic analysis on the basis of the differences noted in the physical parameters (for example length, breadth and depth (height of surrounding walls) of the courtyards from the first two case studies. Attention was also given to the socio-economic composition of the families in all the surveyed courtyard houses to make sure that they were similar.

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[113] KSU's IRB is committed to providing a comprehensive and compliant Research with Human Subjects program for researchers, students, and potential human subjects. The Committee on Research Involving Human Subjects serves as the Institutional Review Board (IRB) mandated by federal laws and regulations, and is responsible for oversight of all activities involving research with human subjects. (http://www.k-state.edu/research/comply/irb/). The IRB application and consent form that was submitted to the Compliance committee is also attached in the appendix.

[114] The detail about the tools used has been attached to the appendix.

The aim of the study is to see how these physical parameters of courtyard proportion influence the thermal qualities of the building and also to assess the perceived human comfort level of the occupants.

SURVEY DESIGN

The survey research may be divided into two main components – preliminary and detailed. During the preliminary survey of the different courtyard houses, the various physical and socio-cultural factors that influence life and activities in and around the courtyards of these houses were also observed. A short questionnaire[115] requiring approximately fifteen minutes to complete was given to the head of the family or his wife in each house. The intent was to gather the users' perceptions about the thermal comfort of their homes. Based on this preliminary survey of these ten courtyard buildings and their occupants, three dwellings were chosen for more detailed study. The choice for the detailed case studies was also dependent on the occupants' consent to participate in the research. This meant that the occupants agreed to allow a detailed inventory of climatic data (through precise measuring tools) as well as behavioral data (through a questionnaire prepared for the head of the family). The detailed questionnaire[116] had been designed to take approximately thirty to forty-five minutes to complete. The detailed case studies were done to correlate the actual thermal data from the building with the perceived human comfort levels of the occupants, based on the measurement of temperature, humidity, light intensity, air speed and air movement in and around the courtyard as well some adjoining rooms. The detailed questionnaire

[115] Short questionnaire is attached to the appendix
[116] Detailed questionnaire is attached to the appendix

survey also attempts to understand the activity patterns of the occupants as correlated with their assessments of thermal comfort.

DATA MEASUREMENTS

Detailed data measurements of climatic data like ambient temperature, humidity, light intensity and wind speed in the courtyard and the surrounding rooms with the help of state of art instruments borrowed from the Agents of Change program at the University of Oregon. The data recordings were performed in the three houses chosen for detailed case studies. The following instruments were employed to gather data for 24 hours in each of the houses:

HOBO – Data loggers or HOBOs (Refer to figure 5.1) were used to record temperature, humidity and light intensity at different locations in the house to understand how these three parameters varied within the 24 hour time interval. Points for installation of HOBOs were decided on-site by conceptualizing two imaginary sections through the E-W and N-S axes of the house. The sections were conceived at the same vertical distance with respect to the floor. Generally, a vertical distance between 1- 1.5m, (based of an average human height while he/she in sitting or standing) was used unless there was any obstruction in such placement of the HOBOs. This placement helped to maintain readings within the human "living zone". In a house with more than two floors, the HOBOs' were placed in the lowermost and the topmost floors. For each section dataloggers were installed on the exterior side of the room, in the interior of the room, in the arcades and in the courtyard. Special care was taken to properly prevent the HOBO installed in the exterior of the building from receiving direct sun and thermal

conduction from other materials. Because permission was granted to install the HOBOs for only one day, the placements of the instruments had to be carefully decided in order to cover all possible and easily accessible directions. One datalogger was used by the researcher during the survey interview with the head of the family. This helped in marking the time period of the interview and also in taking readings of the different climatic conditions prevailing during the interview.

All data from the Onset HOBO dataloggers were downloaded with the help of the compatible Onset Greenline application. The downloaded data were then exported to a Microsoft Excel application to create analytical tables and graphs.

Figure 5.1: Picture of Onset HOBO used.

RAYTEK GUN – The Raytek gun (Refer to figure 5.2) was useful in recording instantaneous temperature readings at different levels and on different surfaces. The Raytek gun readings were important in understanding the stratification of temperature in enclosed space. This also helped me understand the temperature differences above the level of HOBO placement. The Raytek gun was also used to take instantaneous surface temperature readings of the various building materials. This helped to give an indication

of the thermal properties of the different building materials. Readings were taken at an interval of 30 minutes in all the points where the dataloggers had been installed.

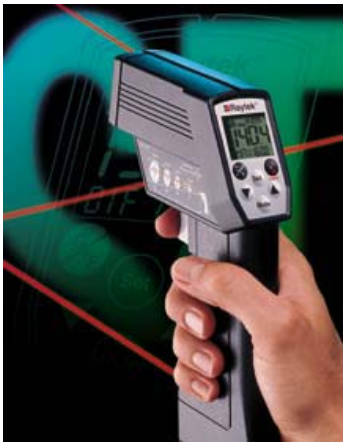


Figure 5.2: Raytek Gun

VELOCITY STICK AND ANEMOMETER – These two instruments (Refer to figure 5.3) were used at the same time to record instantaneous readings for temperature, humidity and particularly wind speed in predetermined areas (mainly at the location of HOBO's so as to verify on-spot data with datalogger recordings). Since there was no other way of measuring air movement and speed, the recording of the two instruments was used to verify the wind speed acquired from the meteorological office in Kolkata and to record any microclimatic variations. Readings were taken at an interval of 30 minutes in all the points where the dataloggers had been installed.

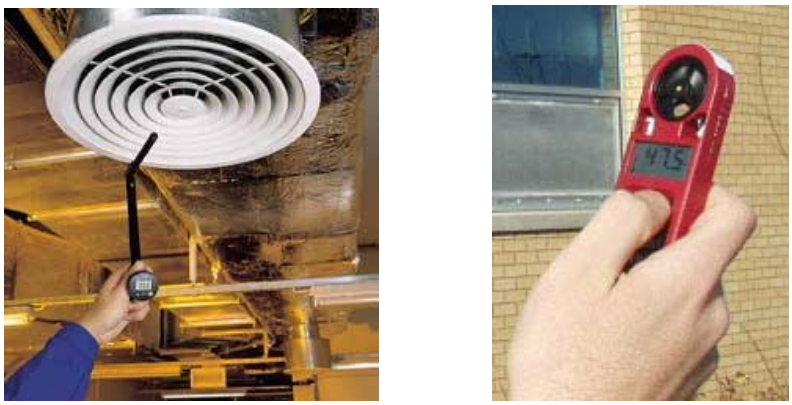


Figure 5.3: Velocity stick (left) and anemometer (right)

MEASURING TAPE – The measuring tape was used for the purpose of measuring the proportions of the building and courtyard. It was required in both the preliminary and detailed case studies to measure the different physical parameters of the courtyard and surrounding rooms. These measurements in the preliminary stage helped in choosing the buildings for final case studies.

COMPASS – The compass was valuable in determining the orientation of the building as well as that of particular rooms.

PRELIMINARY SURVEY ANALYSIS

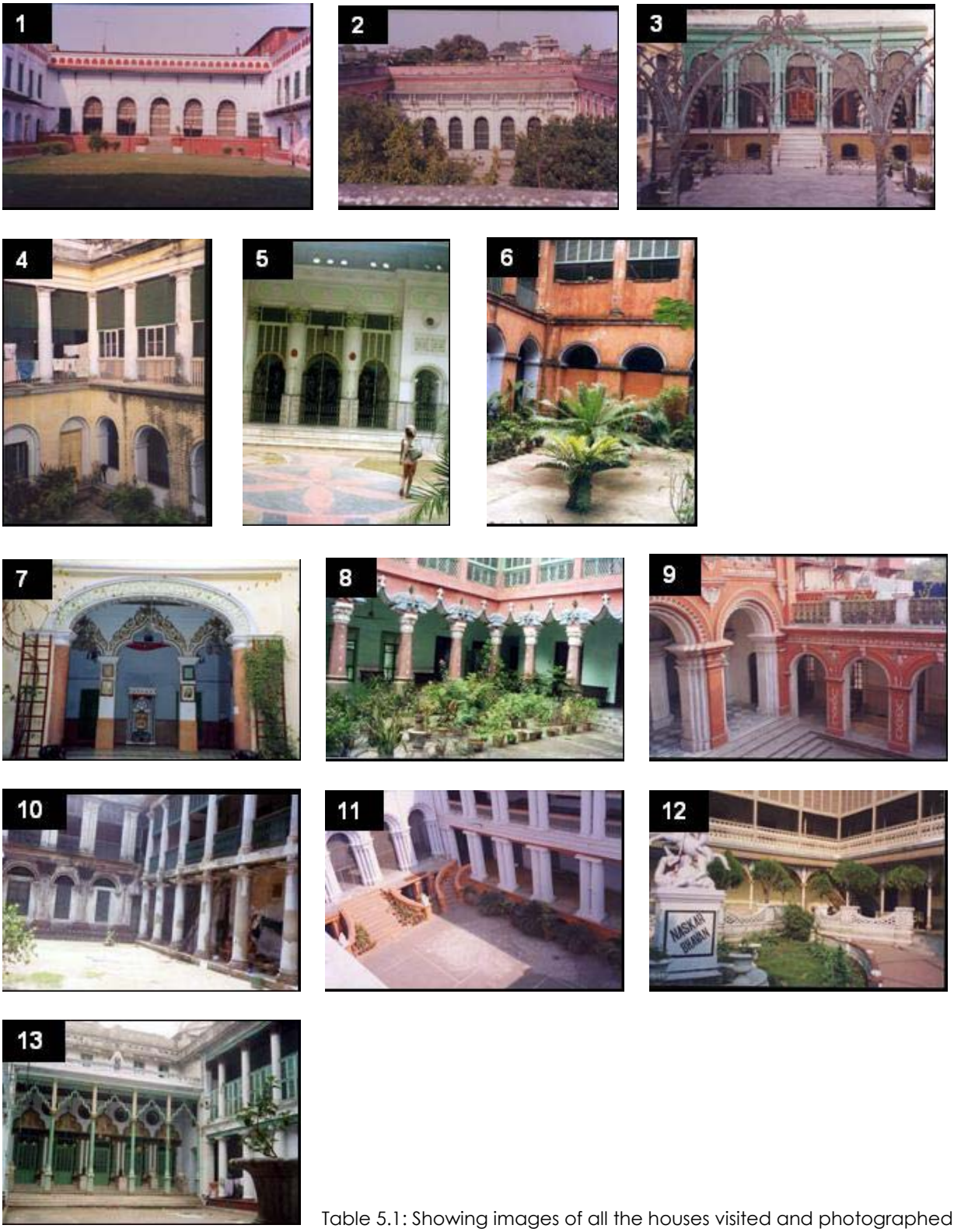


Table 5.1: Showing images of all the houses visited and photographed for this research.

Preliminary Survey Analysis											
Questions		**House 1**	**House 2**	**House 3**	**House 4**	**House 5**	**House 6**	**House 7**	**House 8**	**House 9**	**House 10**
A. Demographic and general information:											
1	Age	60	70	69	36	55	45	45	22	57	45
2	Sex	M	M	M	F	F	F	F	F	M	M
3	Religion	Hindu	Hindu	Hindu	Hindu	Hindu	Hindu	Hindu	Hindu	Hindu	Hindu
4	How long have you lived in Calcutta?	Born	Born/ 168 yrs	7th - 10th generation	Born	Born	250 years, 4th generation	200 years, 5th generation	Born/ 7th generation	Born / 3rd generation in this house	Born
5	How long have you lived in this courtyard house?	30 or more years	30 or more years	30 or more years	20-30 years	30 or more years	30 or more years	30 or more years	30 or more years	30 or more years	30 or more years
6	How many people are currently residing in the house?	12 (+ 10 staff)	2 (+ 16 staff)		16 (+ 40 staff)	5 (+4 staff)	17 (+50 staff)	20 (+ 20 staff)	4 (+7 staff)	4 (+4 staff)	5
7	Are they all family members?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Idea of the different residents in the house on the basis of their age and occupation.	Joint Family / Real estate	House property	Joint family/ Real Estate	Joint Family/ Lawyer, Engineer, CA	Joint Family/ Engineer	Joint Family/Advocate, Airlines, Real Estate	Joint Family/ Lawyer, Professor, Leather Garments Designer, Real Estate	Real Estate	Joint family but seperated by division of the house along the courtyard/Real Estate	
9	Are there times when there is a family gathering?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
10	Which part /room of the house is mostly used for family gatherings?	Room/ Puja-Courtyard	Rooms/ Thakurdalan	Courtyard	Courtyard and hall/ thakurdalan	Bigger gatherings in courtyard	Office or drawing room	Outer garden and courtyard - 200 people and above, rooms -less than 100, arcades - small gatherings	Outer Courtyard for big gatherings, inner courtyard for family gatherings	Outer Courtyard for big gatherings	No courtyard, only ventilation shafts
11	Are there security issues related to the courtyard houses? If yes, how do you address them?					No	Security guards	Outsiders enter house property regularly due to temple within the compund	Yes, generally surrounded by iron nets		

Table 5.1A: Showing survey results for demographic and general information

All the houses surveyed showed that their residents have been living in those houses for generations. The rich cultural Babu trend of the past is still intact, as in most of these houses the number of staff is nearly thrice the number of residents, living in them to serve the family. Most of these families are into real estate business, mainly taking care of their large properties. Besides house 10 which did not have a proper courtyard, all the families agreed that in case of social gatherings their courtyard is used extensively.

Most of the houses had a thakurdalan[117] which was used extensively during the different religious festivals, such as Durga Puja, Kali Puja, Dol (festival of colors) etc. In some of the courtyard was used for music conferences, theatres and plays.

Questions		House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10
B. Courtyard Form and Functions:											
1	Is the courtyard used for daily activities?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
2	If yes, do you regard the courtyard as a private or a public space?	Private	Private	Both	Private	Private	Private	Private	Private - inner court, Public access is givn to outer court	Private/Both	
3	What are the most common activities in the courtyard?	Social Occassion	Durga Puja	Jamai Sashti and Bhai Phota	Religious functions, programs (songs), parties	Badminton	Marriage	Washing utensils	Religious festivals	Religios rituals	
		Marriages	Card playing	Drying/ washing	Playground		Badminton/ Cricket	Servants space	Badminton - outer court (neighbors also play there)	Marriage and other social rituals	
		Not daily use/Rooms used mostly	All Bengal Music Conference	Car parking			Funeral		Marriage	Badminton	
		Sacrifice	Badminton	Interior - bath, achar, bori					Inner court - Drying clothes, preparing meal, female domain	Cooking and washing in inner courtyard	
		Theater (in past)								Histoically, theatres in the outer courtyard	
4	Which family members would you suggest uses the courtyard the most?	Women do not enter courtyard	Mostly men	Mainly staff	Children		Kids, mainly as inner playground	Mainly servants	Female members	Female members - inner courtyard	
5	Do you use the arcade around the courtyard?	Common passage	Not much	No arcade	Used	Yes	Yes	Yes, mostly by family members	Yes	Yes	
6	What are the most common activities in the arcade?			No arcade - Direct access rooms, level of coutyard same as first floor.	Adda, sitting, drying clothes, extended living rooms	Sitting, chatting	Evening tea, chatting, daily purposes	Cooking, socializing, sitting	Social and religious rituals, storage space and sleeping area for servants	Circulation passage, sitting, during social occassions and festivals as extended gathering spaces	
7	Which is your most preferred time in the courtyard? Why?	Occassionally used	Morning and evening	Morning	Evening and night		Evening	Morning, arcade is used as extended living room	Early mornings and evening	Evening, outdoor sitting space	
8	Which is your most preferred season in the courtyard? Why?		Winter	Winter	Winter		Summer- evening, Winter- morning	Arcade used in summer afternoons/ evenings and in winter throughout the day	Summer noon/ not required to be used/ otherwise cooler than outside due to solar shading	Winter	

Table 5.2: Showing survey results for courtyard form and functions

[117] Thakurdalan is the open or semi arcaded space in front of the Puja or worship room where the different religious idols are kept.

Questions		House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10
C. Courtyard Comfort:											
1	Which part of the day is the courtyard most comfortable to use? Please explain why.	Daytime - Winter/ Autumn/ Spring	Daytime - winter	Morning	Winter		Evening	Evening	Morning/ afternoon	Evening	
2	Which part of the day is the courtyard most uncomfortable to use? Please explain why.	Summer afternoons	Summer afternoons	Summer from afternoon	Hot summer afternoon/ monsoon water logging problems		Afternoon, 1pm when there is direct sun	Summer noon	Summer	Summer afternoon	
3	When the following rooms are used the most during a typical day-										
	Living room				Evening		After 6-7pm	Mainly closed, arcade used instead	Thoughout the day	Morning/ night; Library used around noon as it is the coolest room in the house	
	Master Bed room				Whole day		Whole day	throughout the day	Night	night	
	Kitchen				Morning		Morning and after 7pm	Daily meal preparation time	Morning till noon	Morning	
	Dining room				4 times		Breakfast, lunch, dinner		During meals/ though living and dining spaces are combined	During lunch and dinner	
	Puja room		morning/ evening		Third floor - used daily		Morning/Evening	Morning/Noon/Evening	Morning/Noon/Evening	Morning/ evening	

Table 5.3: Showing survey results for courtyard comfort

Most of the houses had two courtyards – an outer courtyard (public domain); and an inner courtyard (mainly private domain). When questioned about the daily use and activities in the courtyard, most of the families tended to prefer the interior rooms for most of the activities, besides House 8 where the residents mentioned many daily chores being done in the inner courtyard. Most residents of the different houses agreed that the best time to use the courtyard was winter mornings or summer evenings; while the courtyards became unbearable during summer afternoons.

Questions		House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10
D. Evaluative and Reflective questions:											
1	Are there any advantages in staying in an old courtyard house?	Air, light, ventilation, common area, playground-secured for children, wife in good terms - patriachial	Space - living space much more	Family prestige, social gathering, games, religious funtion, multipurpose	Open space, open mind, light and ventilation	Open air	Spacious, well ventilated, children gets space for playground, ample sun and air, surrounding verandah used for bicycling and walking	Spacious, well ventilated and ample light	Spacious, outdoor space that may be used freely by female occupants	Spacious - especially for social occassions, sufficient air and light	
2	Are there any disadvantages in staying in an old courtyard house?	No help from govt, huge maintenance problems, liability to landlords, security issues	Too large so economically difficult to maintain	Unsafe, security problems, problem of encroachment, high maintenance	No problems/ entry and securily issues	Maintenance/ Security issues/ Tax/ Mobility problems	Maintenance, staff required, damp, needs lot of renovation , not compact design	Maintenance	Economic constrains due to high maintenance, not compact design, mobility difficulty for aged	Expensive maintenance, cleaning, labor problems	
3	Given a choice would you like to keep living in a house with a courtyard or move into a modern day high rise apartment? Clarify your preference.	Prefer old courtyard buildings	Not apartment building	Apartments no tradition, conservative, not religious, no ventilation and good light	Joint family-courtyard house		Prefer old courtyard buildings	Prefer old courtyard buildings	Sentimental values attached to courtyard houses, extended family can be housed within the same compound	Prefer apartments due to easy maintenance and less family problems	

Table 5.4: Showing survey results for evaluative and reflective questions

Nearly all the residents of the different courtyard houses observed that due to lack of social interest, split between joint families and economic constraints, most of these heritage courtyard buildings are becoming social and economic burdens to the families. High maintenance costs are compelling the residents to sell their properties to real estate agents who in turn replace these houses with high rise apartments. Given a choice most of the residents agreed that they would prefer to live in the courtyard

houses, which besides housing traditional, religious and social values gave them high quality of life with spacious rooms and outdoor, ample light and air.

DETAILED CASE STUDIES

BIOCLIMATIC ANALYSIS

Bioclimatic analysis of the three chosen final case study houses was done with respect to the comfort and use of the courtyard and the surrounding rooms. To understand the bioclimatic significance of these houses, the analysis is based on courtyard thermal performance with respect to both solar shading and ventilation. The occupant responses to the preliminary and detailed surveys are used to correlate with the measured and simulative data and verify their results.

The bioclimatic analysis is based on the understanding that both sun and wind are vital factors to consider for designing in a hot-humid climatic region. The benign qualities of solar shading and natural cross ventilation help in achieving occupant comfort. The paradox, it seems, is that shading is enhanced by making the proportions of the courtyard deep, with a thicker layer of surrounding rooms. Ventilation is enhanced by making the framework light and airy allowing maximum air movement. Therefore, it seemed that understanding the effects of mass and proportion of these buildings was essential to designing a courtyard that integrates the values of both shading and ventilation. To be able to draw an inference based on comparison of different results, buildings with contrasting aspect ratios and solar shading indices were chosen.

$$\text{Aspect ratio} = \frac{\text{area of the courtyard floor}}{(\text{average height of the surrounding walls})2}$$

Solar Shadow Index = (South wall height)/(North-South floor width)

Three courtyard houses were chosen for in-depth field research. Out of the three chosen houses, two houses were chosen on the basis of their similarities in physical parameters and most importantly aspect ratio. Again, attention was given to choosing a third dwelling which highlighted differences from the other two with regard to the physical parameters of the courtyards aspect ratio (length, breadth and height of surrounding walls). This similarity between two and dissimilarity between two helped in testing the hypothesis that courtyard proportions affect the climatic response of the building and perceived human comfort level of the occupants. The final choice of the three buildings was also based on the following factors:

1. All three houses are made of high thermal mass construction and are as similar as possible in all other respects.
2. The socio-economic compositions of the families in all the surveyed courtyard buildings are similar.

Detailed Case study 1:

Case study 1 is henceforth referred to as House "A". Though in reality there is one outer courtyard and two inner courtyards in this structure, for the purpose of the thesis, the outer courtyard has been chosen for analysis. The outer courtyard is designated as Courtyard "A" in this study. It is rectangular in shape (see Figure 5.4). Its length is 14.78 m (48.5ft), its breadth 9.6 m (31.5 ft), and the height of the surrounding walls is equal to 12.19m (40 ft). The courtyard is sunken 0.54m (1.8 ft) below the interior level of the ground floor. The aspect ratio of the courtyard is 0.95.

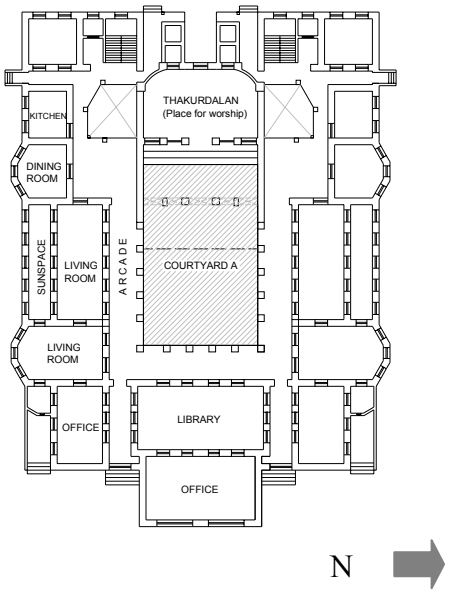


Figure 5.4: Showing courtyard "A" (top) and a schematic lower level plan of the house (right).

Detailed Case study 2:

Case study 2 is henceforth referred to as House "B". In reality there is also one outer courtyard and one inner courtyard in this house. However, for the purpose of this study, the inner courtyard has been chosen. The outer courtyard is designated as Courtyard

"B" in this research. Courtyard "B" (see Figure 5.5) is also rectangular in shape but deeper in proportion than Courtyard A. The length is equal to 12.19 m (40ft), breadth is equal to 4.05 m (13.3 ft), depth of courtyard level from surrounding floor level is equal to 0.3m (1ft) and the height of each of the surrounding walls (ground level to the top of the parapet) is equal to 15.24m (50 ft). The aspect ratio of Courtyard B is 0.21.

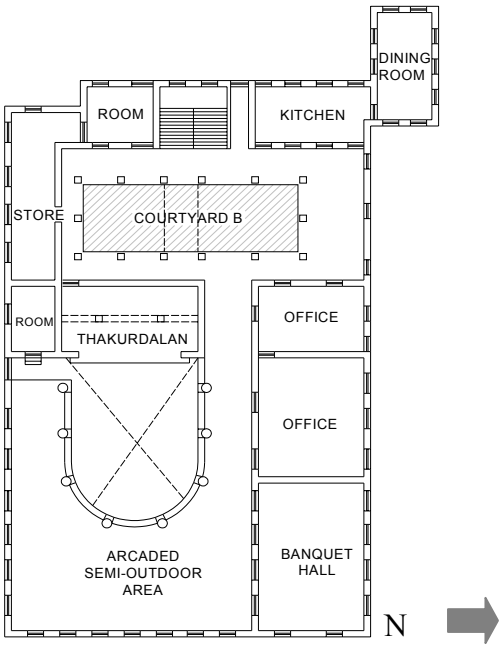
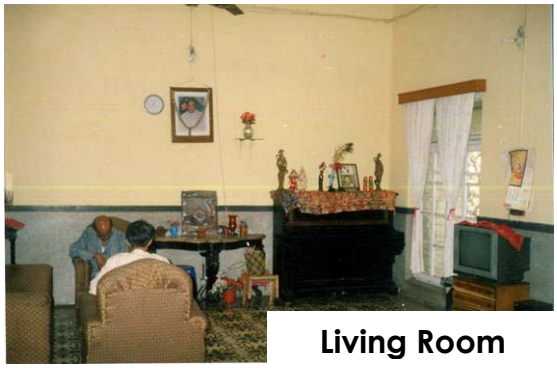


Figure 5.5: Showing courtyard "B" (top) and a schematic lower level plan of the house (right).

Detailed Case study 3:

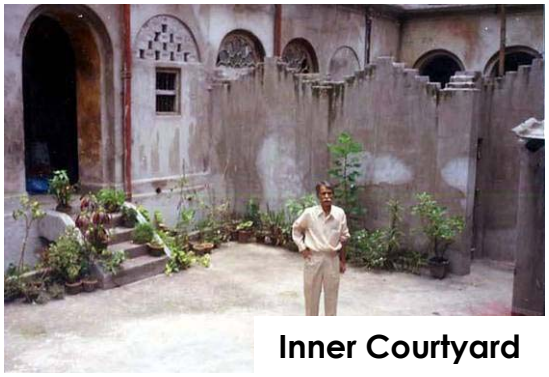
Case study 3 is referred to as House "C". This house has only one inner courtyard and an extensive garden outside. This courtyard has been designated as Courtyard "C" in this study. Similar to courtyard A and B, Courtyard "C" is also rectangular in shape (see Figure 5.6). Its length is 16 m (52.5ft), its breadth 7.92 m (26 ft), and the height of the surrounding walls is equal to 12.19m (40 ft). On the east, west and south sides the courtyard is sunken at a depth of 0.88m (2.9 ft) from the interior floor level, while on the

north side the depth is 0.6m (2ft). The aspect ratio of the courtyard was determined to be 0.95 which is similar to courtyard "A".



Living Room

View from roof



Inner Courtyard

Outer Garden

Arcade on the south and west side

Terrace on the east side

Figure 5.6: Pictures of different spaces from House C

ANALYSIS OF ON-SITE DATA

DATA MEASUREMENTS WITH HOBO DATALOGGERS:

Data was collected during January 2005. As described earlier, HOBO dataloggers were installed at strategic locations in each of the three houses to record temperature variations during a particular day at regular intervals. Since the data recording was done in winter for a primarily hot-humid area, the survey design focused on questions concerning of year round resident activity patterns due to changes in climatic factors.

The recorded temperature data was compared to the ambient temperature conditions during the particular days of data collection. The average high and low temperatures for the days of data recording are taken from www.Weather.com. Since the temperature measurements were not taken on the same day for each house, the data recorded has been compared against the monthly average maximum and minimum ambient temperatures for January as available from the above mentioned website118. The monthly average high was taken to be 25OC (77OF) while the average low was considered 14OC (57.2OF). The temperature data collected from different rooms, arcades and the courtyard were compared to these average temperatures mentioned above to analyze the effectiveness for passive thermal comfort strategies in different spaces of the homes.

[118] http://www.weather.com/activities/travel/businesstraveler/weather/climo-monthly-graph.html?locid=INXX0028&from=dailyAvg_bottomnav_business

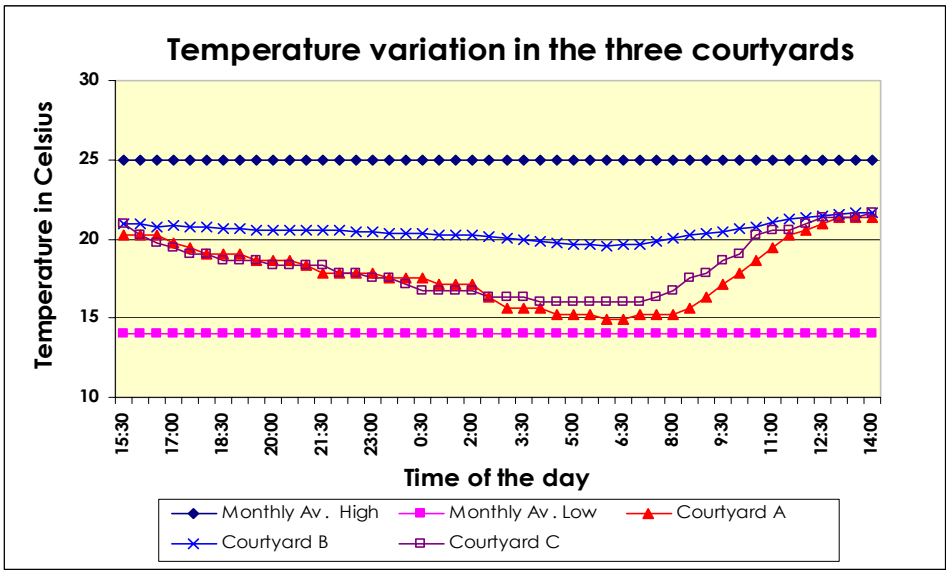


Figure 5.7: Showing the comparison of temperature recorded in the three courtyards with the monthly average high and low temperatures.

Courtyard A = 0.95 aspect ratio = shallow courtyard in House A

Courtyard B = 0.21 aspect ratio = deep courtyard in House B

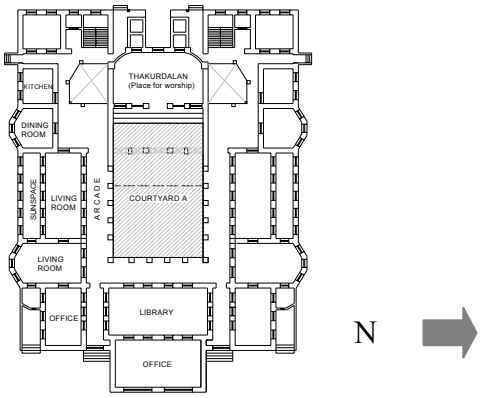
Courtyard C= 0.95 aspect ratio = shallow courtyard in House C

Courtyard A and C (shallow courtyards) both have a higher aspect ratio than Courtyard B (deep courtyard). From observation it initially had seemed that courtyard A was shallower proportionally; however, after careful measurement and calculation it seems the proportions of courtyard C are also nearly as shallow. Therefore, both Courtyards A and C have more sky exposure as compared to Courtyard B. This explains why the temperature curves in the courtyard A and C have a tendency to drop and rise sharply depending on the solar movement in the sky. From figure. 5.7, it is evident that the temperatures in Courtyard A and C drop fast after sunset while rising rapidly after sunrise, thus creating a microclimate similar to the external climatic conditions.

Courtyard B, which has a 0.21 aspect ratio, is less influenced by the external climatic conditions and remains rather unaffected by the sky exposure. The microclimate generated within the deep courtyard maintains a more stable temperature condition varying within a range of only 1-2◦C whereas in the shallow courtyards the temperature varies within a range of 5◦C. An interesting observation in this case is that due to the similar proportions both Courtyard A and C show similar characteristics, maintaining a more or less matching graphic pattern. In fact, the temperatures recorded after sunset produce an overlapping graph line. The temperature rises faster in Courtyard C in the afternoon. This may be due to the fact that the recordings had been taken on different days when the external climatic conditions may have varied in reality.

ANALYSIS OF "HOUSE A" WITH COURTYARD A

Courtyard A = 0.95 aspect ratio = shallow courtyard in House A



While the temperature variation in the courtyard is steep (15◦C to about 22◦C), interior temperature is more constant. It is evident from Figs. 5.8, 5.9 and 5.10 that as we move from the courtyard center through the arcades to rooms the temperature becomes much more stable. While the central courtyard temperature varies within a range of

approximately 7◦C, in the arcades (both first and second floor) temperature varies nearly 4 -5◦C and inside the rooms temperature varies only within only 1-2◦C.

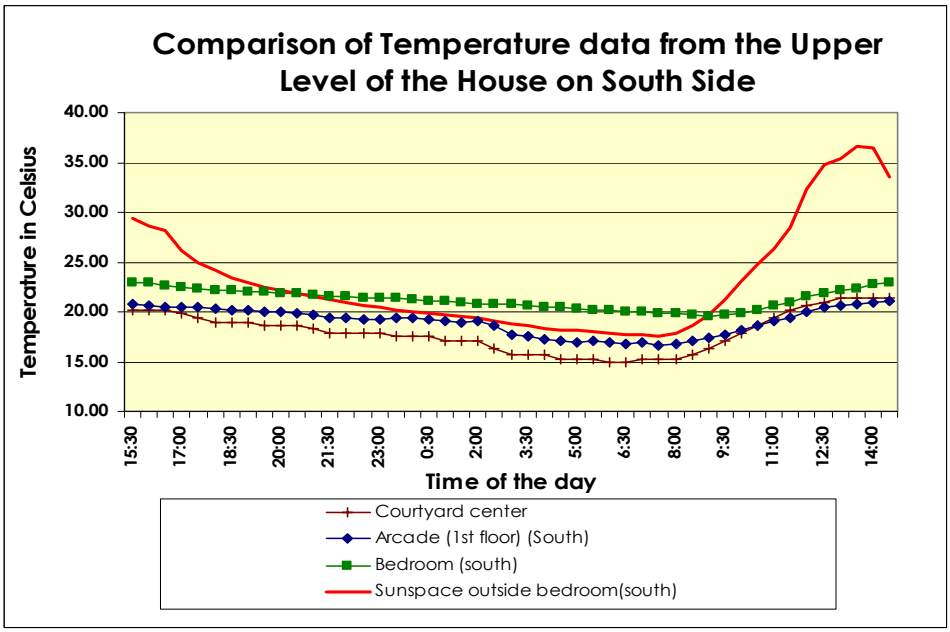


Fig.5.8: House A: Comparison of temperature variation in the east side of the house.

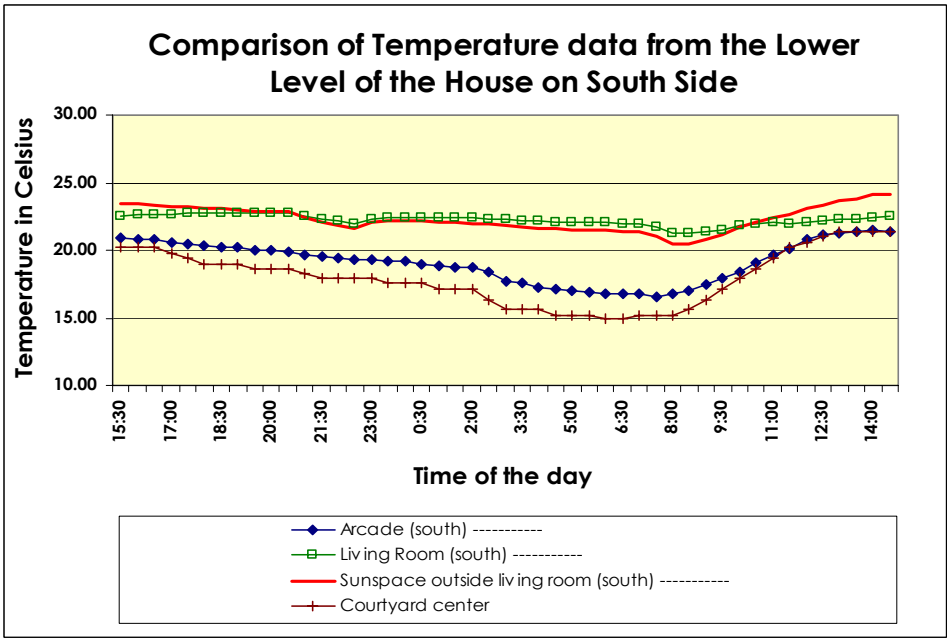


Fig. 5.9: House A: Comparison of temperature variation in the lower level of the house on the south side.

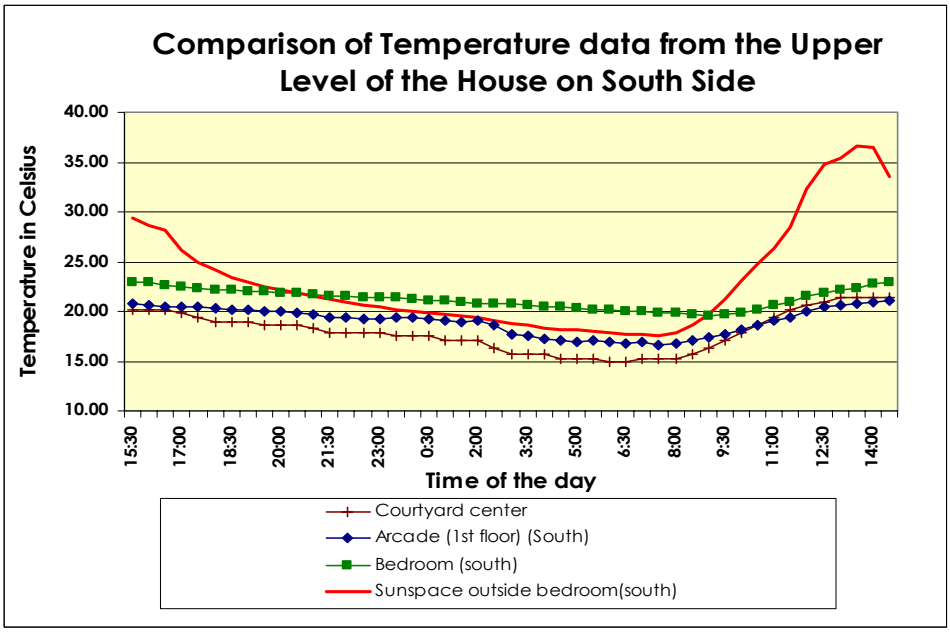


Fig. 5.10: House A: Comparison of temperature variation in the upper level of the house on the south side.

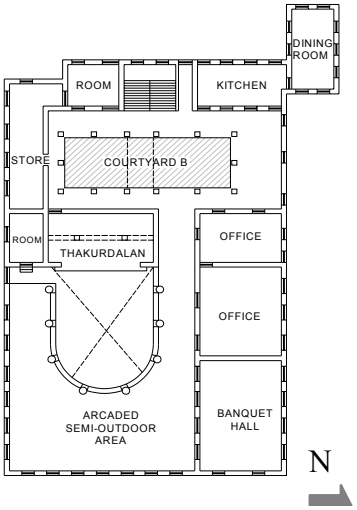
As per figure 5.8 the library, which is located on the first floor, is the most stable and comfortable room in the east side of the house. In the survey, the residents verified that the library was the coolest room. They described that even during summer it seemed as comfortable as a modern air-conditioned room. They preferred to spend time in the library on hot summer afternoons. This is mainly due to the fact the library did not receive any direct sunlight and it was buffered from the high overhead sun by a layer of second floor rooms. The office on its east side and the arcade on its west buffered the library from direct sun.

Figs. 5.9 and 5.10, indicate that the sunspaces on the south side help in stabilizing the temperature in the adjacent living room (lower level) and bedroom (upper level). The sunspace has double shuttered windows at regular intervals. During summer, the wooden shutters are closed but the paneled glass window shutters are kept open,

shading the interiors from the direct radiation while allowing ventilation. During winter the wooden louvers are kept open while the paneled glass shutters are kept closed, increasing solar gain in the space, as indicated by a high recorded morning temperature gain (Figure 5.10) in the upper level. The ground level sunspace recorded a more stable pattern of temperature, as it is protected from direct sun due to the position and proportion of the opaque wall surface above the windows (Figure 5.9). Both figures 5.9 and 5.10, show that the temperature in the livable rooms remains stable, being cooler during the day but warmer by night than the adjoining sunspaces. This is because the heat absorbed by the sunspace during the day is transferred to the living areas in the night. The head of the household also confirmed this pattern during the survey. He said that he and his family preferred to use the lower level living room during the day as it remained cooler throughout the year, while the bedroom is mostly used during the night in summer.

ANALYSIS OF "HOUSE B" WITH COURTYARD B

Courtyard B = 0.21 aspect ratio = deep courtyard in House B



Ambient temperature conditions in the House B, which has a deep courtyard, is much more stable than that recorded in both house A and C. Figs. 5.11, 5.12 and 5.13 indicate that the temperature variation from the exterior to the interiors in the house did not show much difference. The Courtyard B floor is shaded from direct sun exposure throughout the year except for a brief period during summer noon, when the sun is directly overhead. This self-shading property of the courtyard helps it to maintain a comfortable microclimate inside. This is probably why the residents indicated that they utilized the courtyard all year round. It seems from their description, that the courtyard is very comfortable during summer months and late afternoons contrary to the observations made by families living in the shallower courtyard house.

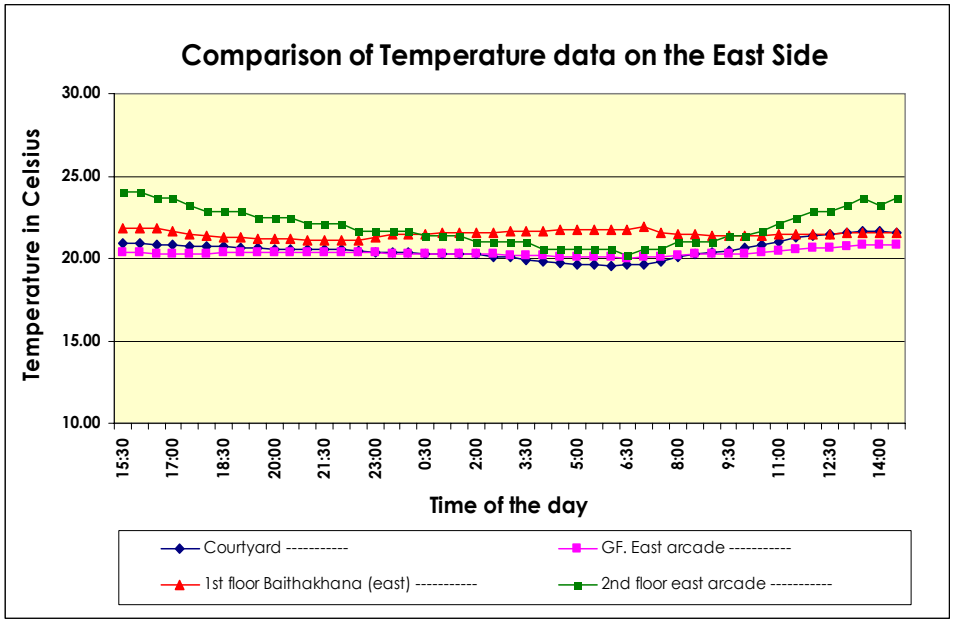


Fig. 5.11: House B: Comparison of temperature variation in the east side of the house

Figure 5.11 shows that the only large temperature variation is observed in the topmost floor arcade, which receives direct sunlight. Therefore, while the ground floor arcade does not show much variation in temperature curve throughout the day, the upper floor arcade is more influenced by direct exposure to the sun and air.

Fig.5.12 shows a comparison between the temperatures in the courtyard and the semi-outdoor arcade spaces at three levels of the House B. The highest arcade, with the largest sky exposure, follows a diurnal temperature curve, rising dramatically as the morning sun progressed to higher latitudes.

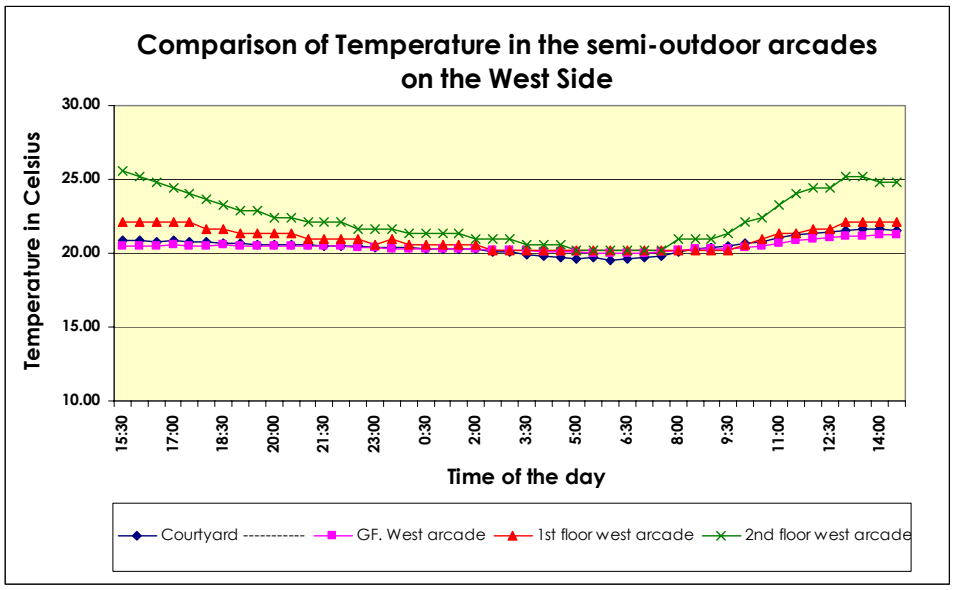


Fig. 5.12: House B: Comparison of temperature in the different levels of arcades on the West side

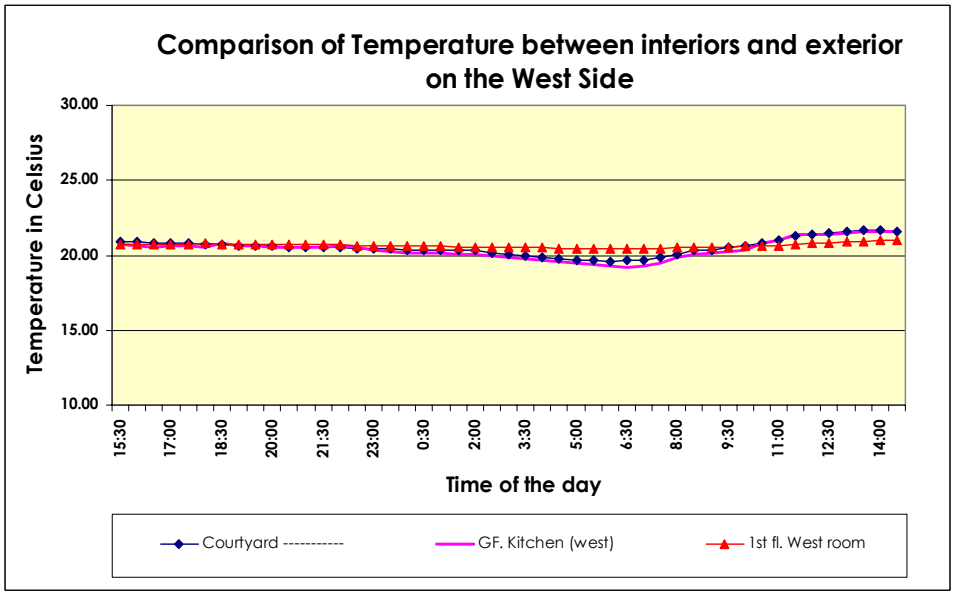


Fig. 5.13: House B: Comparison of temperature in the different levels of arcades on the West side.

Fig. 5.13 indicates how the interior temperature curve closely follows Courtyard B conditions, in some cases being indistinguishable from it. Similar and stable temperature conditions are noticed in both the exterior courtyard and interior rooms form the data measurements. This tempered indoor and outdoor condition also encourages activity in the courtyard, where the residents can carry on their daily routine within a shaded

outdoor environment. The survey discussions also supported the findings from the temperature measurements. The head of the household confirmed that during the afternoon the women of the house usually prefer to rest in the rooms in the middle level in winter, indicating that upper level rooms become too hot and ground level rooms are too chilly. This is because the deep proportions completely cut the lower sun angles from reaching the courtyard surface during winter, creating a kind of cool sink. Again during summer, when it gets very hot outside, the rooms in the lower floor are preferred because they remain the coolest.

ANALYSIS OF "HOUSE C" WITH COURTYARD C

Courtyard C= 0.95 aspect ratio = shallow courtyard in House C

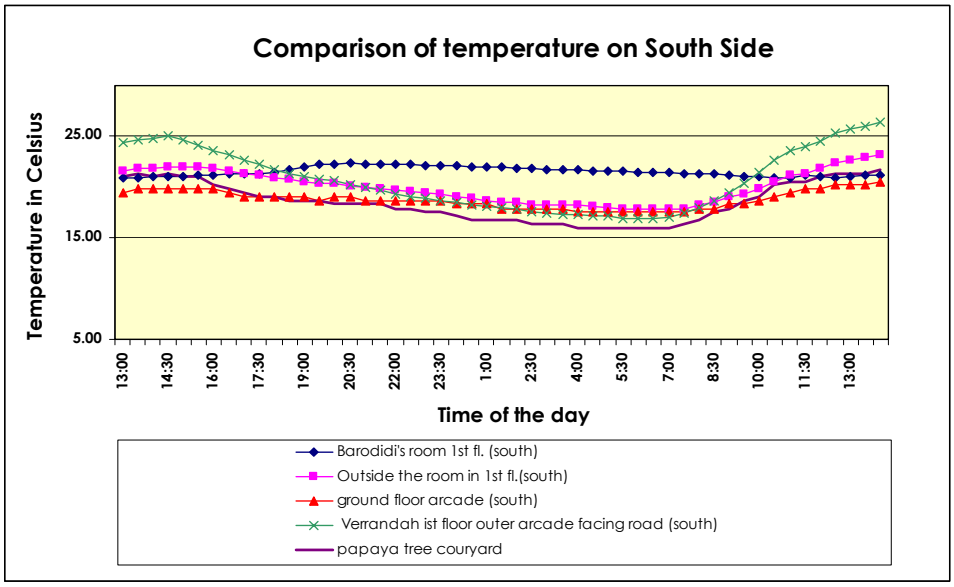


Fig 5.14: House C: Comparison of temperature on the South side in the first floor with courtyard.

Figure 5.14 shows how the shallow proportions of the Courtyard C results in a similar temperature variation trend as seen earlier in Courtyard A. The shallow proportion causes direct solar exposure of the courtyard floor; therefore, the courtyard and the arcades are affected by the external climatic conditions. The southern room on the first floor, on the other hand, maintains a more stable temperature due to the thick thermal massing around it. The thick layer of wall helps in preventing excessive heat entry during the day and in storing heat by night when the outside temperatures dip rapidly in the under heated season. The higher temperatures in the verandah facing south are desirable in winter. This is verified in the survey where the residents describe this arcade as an extension of their living room. In fact, during my visit I observed the family spend a major part of the day in the well sunlit arcade.

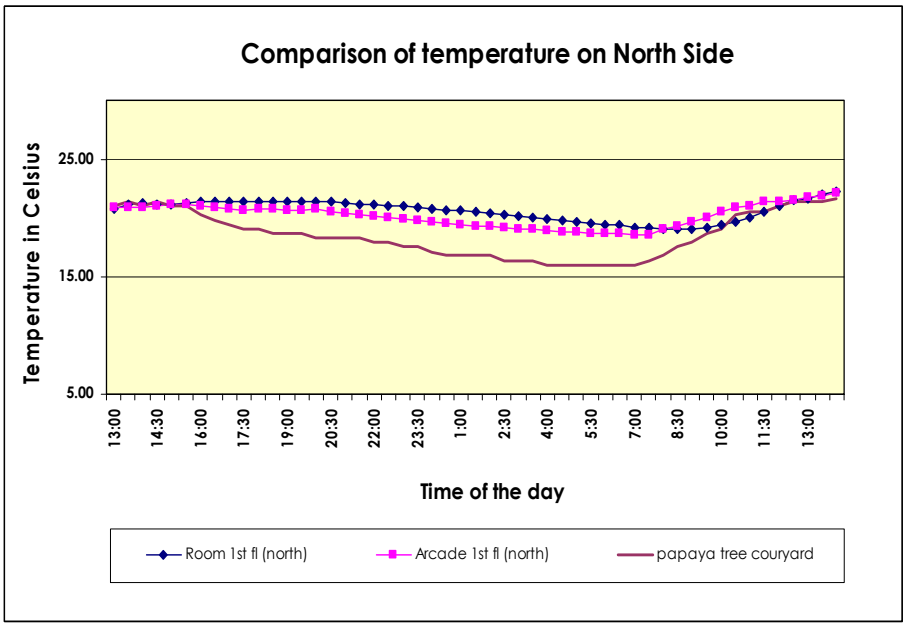


Fig 5.15: House C: Comparison of temperature on the North side arcades with the courtyard.

In figure 5.15, the north facing room in the first floor shows higher temperatures in the night, showing the thermal retention capacity within the walls of the room. The arcade temperatures rise higher during the day because it receives direct sunlight. In fact, the lower winter sun angle causes heat and light to penetrate even into the room, which is evident from the higher afternoon temperatures. During summer, however, the arcade buffers the higher sun angles and therefore the room temperature does not rise so steeply, thereby providing cooler and more comfortable conditions inside.

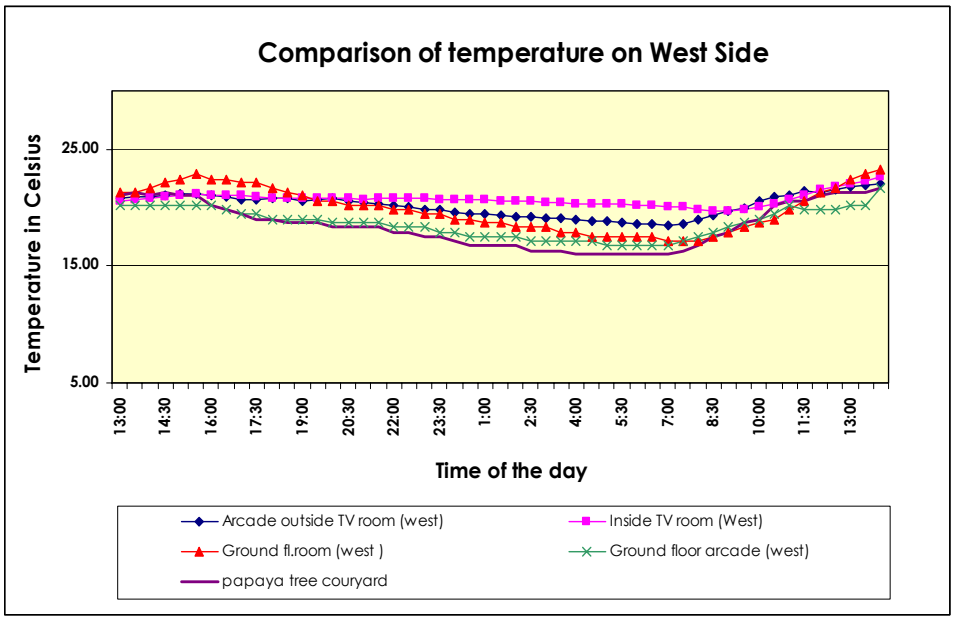


Fig 5.16: House C: Comparison of temperature from the interior rooms to the exterior on both levels.

Figure 5.16 shows that the room in the west maintains a stable high temperature as compared to the courtyard. Interestingly the ground floor room follows a trend similar to that of the ground floor arcade. This seems a little unusual but this room did not belong directly to the family so I was not allowed to go inside and place the HOBO. Instead one of the family members kept it on my behalf; therefore I had no control over the HOBO's placement which may have resulted in inaccurate data recording. However, if these readings are accurate then it may be inferred that the ground floor room is much more affected by external ambient climatic conditions.

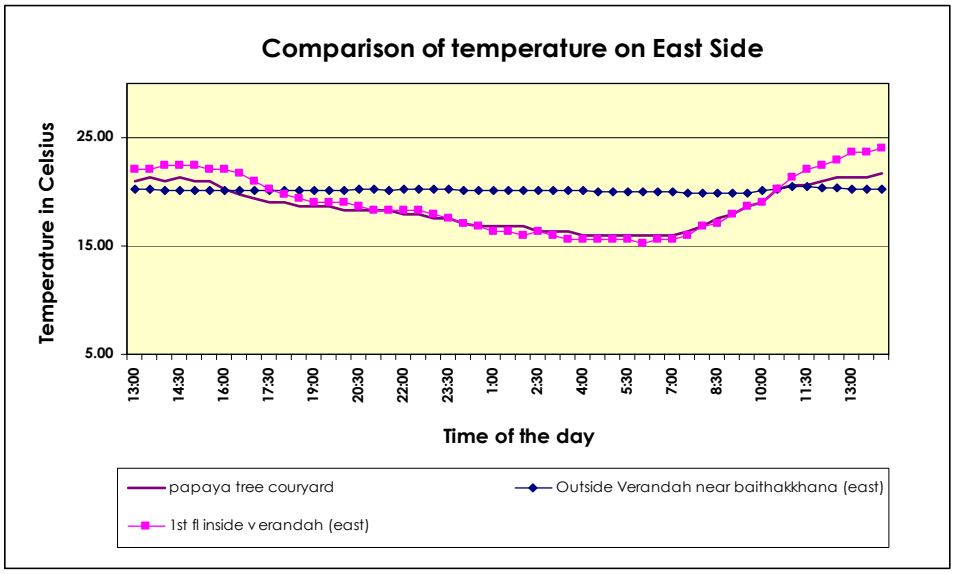


Fig 5.17: House C: Comparison of temperature from the interior rooms to the exterior on both levels.

Figure 5.17 indicate that the verandah on the east side of the living room (baithakkhana) is less influenced by outside climatic conditions. The main reason for this is that due to its placement (enclosed) this verandah is practically self shaded throughout the day. On the other hand, the open terrace adjacent the surrounding verandah affects the temperature variations recorded in the verandah. The adjoining open area influences this verandah to act like an exterior space too. Thus, the temperature graph in this area follows a similar path as the one in the courtyard.

CONCLUSIONS BASED ON SURVEY RESPONSES

On-site data measurements indicate that the temperatures in the deep Courtyard B (House B) are nearly the same in the courtyard, arcade and adjoining rooms. On the other hand, data recordings in the courtyard, arcade and adjoining rooms in the shallow courtyard houses (House A and House C) show more temperature fluctuations among the different spaces. Observing each of the individual spaces, it may be seen that in House A and C, the courtyards show the greatest diurnal temperature range

and the adjoining rooms the least daily variation. These results can be explained by the greater exposure to the sun in the shallow courtyards and the arcades. It is significant to note, however, that the temperatures are very stable and nearly the same in the rooms adjoining the arcades in both the shallow and deep courtyards. This would suggest that the arcades of all House A, House C (shallow) and House B (deep) provide good sun shading for the adjoining rooms, which has the effect of stabilizing temperatures. The results from the data measurements and the survey help in the analysis of the "thermal sailing" nature of the occupants as described by Reynolds in his book Courtyards.

In the shallow courtyard houses (House A and House C), it seems from the residents' descriptions of their daily and yearly activities that though the courtyard is used for special social or religious occasions, the rooms themselves are much more comfortable for most other purposes. In both the houses residents stated that, because the shallow courtyard allows exposure to the sun over an extended period of time during the day, especially in the summer when the sun is high, this important outdoor room becomes too hot for use except during the evenings when the sun sets in the overheated season. This definitely restricts the residents' courtyard activities. The residents of House A specified that even during winter the courtyard is only used by the children in the house in the late afternoons to play badminton. Otherwise, the courtyard is not used for daily activities. In House C the courtyard is mainly used by servants for household work. The deep layer of moss at the edges of Courtyard C also provided insight about its limited use.

The residents of both House A and C which have shallow courtyards noted that the high thermal mass walls of the surrounding rooms allow a thermal lag between the exterior temperatures and the interior temperatures resulting in cooler days and warmer nights. The residents of the House A prefer to use lower level rooms during the day. This is because the lower level rooms favor the optimal conditions of solar shading, whereas the upper level rooms gather heat from the roof which is exposed to direct sun. The temperature variation in the House A from inside to outside was also steep, explaining why the residents prefer to use their rooms more than the outdoor courtyard or the arcades. In case of the House C, since lower level rooms are mainly used as servants' quarters or other utility purpose, the residents lived in the upper floor rooms.

The "House B"(deep) courtyard house the interview shows us a different picture with respect to the shallow courtyard houses. In this case, the residents stated that they prefer to use their courtyards more than their rooms. They listed a number of daily activities that occur in the courtyards like cooking, dining, washing utensils, drying clothes and socializing. In fact, from their descriptions it seems evident that, unlike the residents of the House A and C (shallow courtyard houses), who claimed their courtyard became unbearably hot during summer, the residents of House B (deep courtyard house) enjoyed their courtyard mostly during the summer. The deep courtyard (House B with aspect ratio of 0.21) effectively shades the courtyard floor area all year long. The minimal sun penetration in this courtyard throughout the day (both in winter and summer) helps in stabilizing the temperature differences between the exteriors and the interiors, thereby encouraging more outdoor activity. The courtyard itself, therefore, gets the most favorable conditions of shade, and cool daylight all year round.

For the shallow courtyards (in House A and House C) to offer their residents improved comfort it would be necessary to provide enough shading by trees and/or architectural means to offset the effects of greater exposure to the high overhead sun, especially in the summer. Integration of the courtyard in daily life activities by such means will also encourage residents to use the space more often in winter. As it stands, the deep courtyard space of the House B is more integrated into the users' daily activity pattern because it provides comfortable outdoor conditions throughout the year. The self shaded courtyard by the high thermal mass construction of the surrounding arcades and rooms' in House B help to dampen both high and low temperatures.

INSTANTANEOUS DATA MEASUREMENTS:

Quantitative data was also gathered with on-spot measuring tools such as – the Raytek gun for measuring surface temperatures of wall, floor, ceiling and different building materials; the velocity stick for measuring mainly air speed and ambient temperature; and the anemometer for measuring air speed, ambient temperature and humidity ratio. In each of the houses, House A, B and C, on-spot measurements were taken six times in locations near the location of the HOBOs. These spot measurements locations being near the HOBO helped in comparing the temperature data to check the efficiency of the instruments in determining different weather conditions under similar conditions. The following analysis and graphs are used to observe and determine if there is any pattern of relationship between the surface temperatures of the room at different levels and the effect of wind on the ambient and surface temperatures.

ANALYSIS OF "HOUSE A"

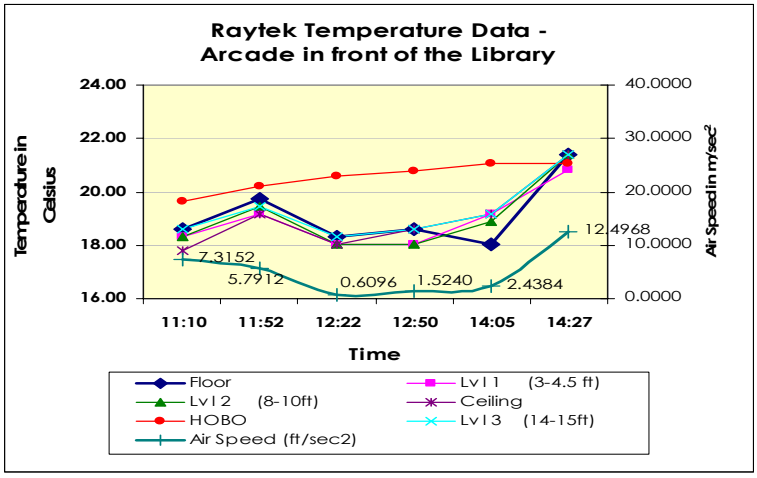


Figure 5.18: Surface temperature graph – arcade in front of library

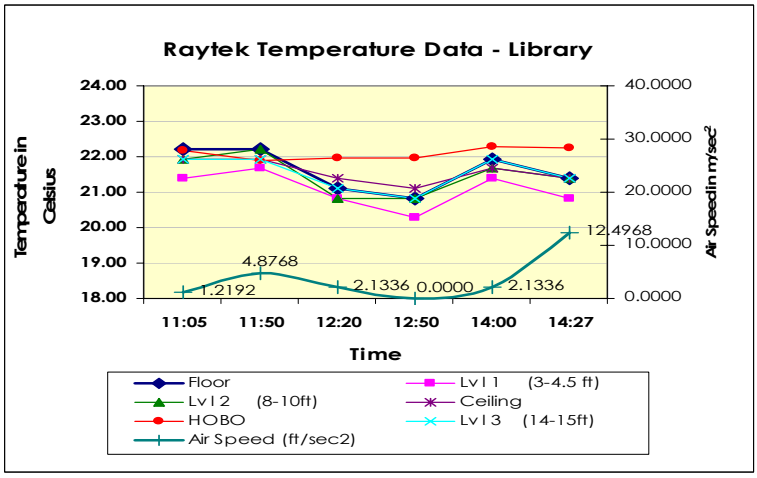


Figure 5.19: Surface temperature graph of the library

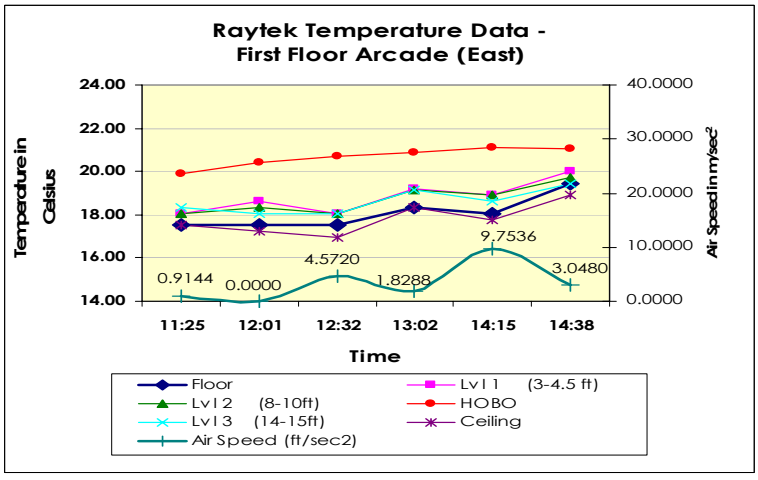


Figure 5.20: Surface temperature of the east first floor arcade

Figures 5.18 and 5.19, show the surface temperatures at different levels on the inner and outer layer of the wall in the east-facing library. This gives us an idea of the direct effect of sun on the outer surface of the building and how the thermal mass of the building environment helps in regulating the temperature variation inside the room. Again, Figure 9 shows us the temperature differences at various levels outside the room in the first floor arcade, giving us a better perspective on how the surface temperatures of exterior wall surfaces change according to the different floor levels of the house. Interestingly, the average wind speed at the ground level is higher than that at the first floor level showing an average of 5.03 m/sec^2 in the arcade and 3.81 m/sec^2 inside the library at the ground floor level; while it is only 3.35 m/sec^2 at the upper floor level. These differences are due to the fact that measurements were taken at different times.

The temperatures on the outer surface of the wall, as shown in Figure 8, show greater variation ranging between 17^o C to 22^o C than temperatures in the interior wall surface. This is because the outside climatic conditions have a direct influence on the wall. Before noon, it seems the surface temperature is inversely proportional to the air speed. While the sun is still rising from the east to attain its overhead position, the outer wall surface in the arcade is well shaded. Therefore, as higher speed of cooler air strikes the exterior surfaces the temperatures drop. In the afternoon, when the sun is directly overhead and the ambient air temperature rises, the surface temperature of the exterior surfaces rises with the air speed. As higher speed but warmer air blows against the wall and floor, the temperature increases dramatically (as depicted in recording taken at 14:05 and 14:27 hrs).

Inside the room, which is well protected from the sun rays, the surface temperatures are directly proportional to the air speed (refer to figure 9). The inner wall temperatures drop by nearly two degrees when there is no wind inside the room right after noon. Later in the day, when the ambient air temperature rises due to the higher sun position, the inner wall still retains its more or less steady temperature state due to the inherent thermal mass and thermal lag properties of the building construction. Therefore, even when there is a sudden flush of wind inside the room (which may have been caused due to the sudden gush of wind entering the room as the researcher opened the entry door to record temperature inside the room), the wall, floor, ceiling surface temperatures remain low while the ambient temperature in the room shows a slightly rising tendency (measured by the HOBO).

As one moves higher from the warmer courtyard floor level during the day (Figure 10), the ambient temperature of wind flowing past the courtyard surface drops. Therefore the surface temperature along the exterior arcade surfaces in the upper floor also decreases as cooler winds strike against them. Though there is a tendency for ambient air temperatures to rise may be noticed as the day progresses, whenever the wind speed increases the surface temperatures decrease as the wind takes away some of the warmth from the wall.

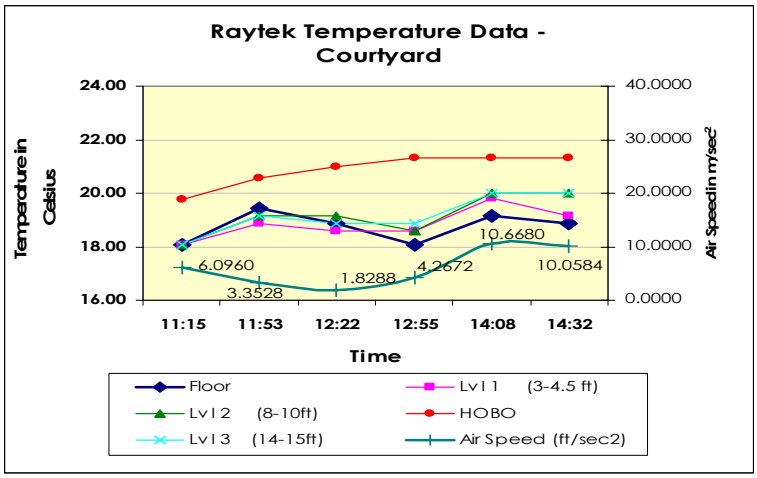


Figure 5.21: Surface temperature recorded in courtyard A

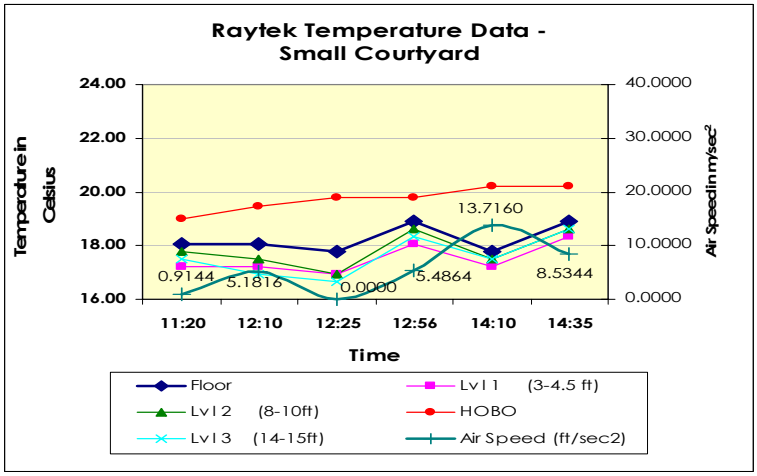


Figure 5.22: Surface temperature recorded in the small courtyard

In figures 5.21 and 5.22, the ambient temperature shows a steady rise of nearly two degrees from the pre-noon to the post-noon stage (refer to HOBO recordings). At the different levels of wall and floor surfaces of both the courtyards the temperature seems to rise when air speed decreases before noon. In the afternoon, temperature rise in the bigger courtyard even with an increase in wind speed. This is because around this time the sun is in its overhead position directly heating the courtyard floor and surrounding walls.

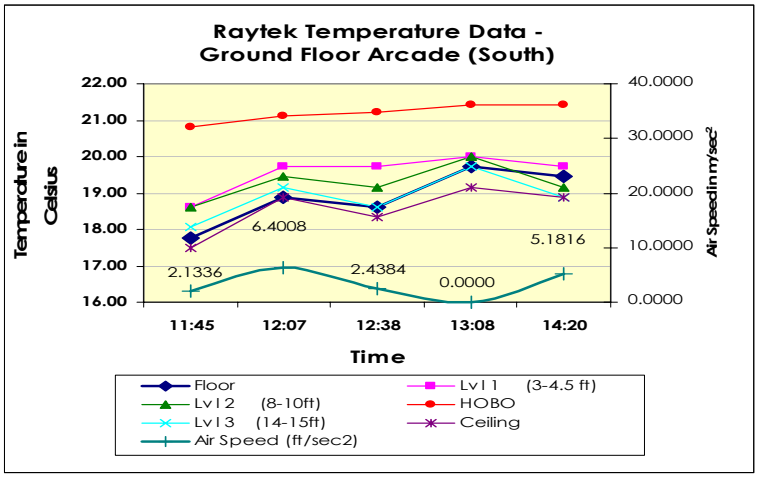


Figure 5.23: Surface temperature recorded in ground floor arcade (south)

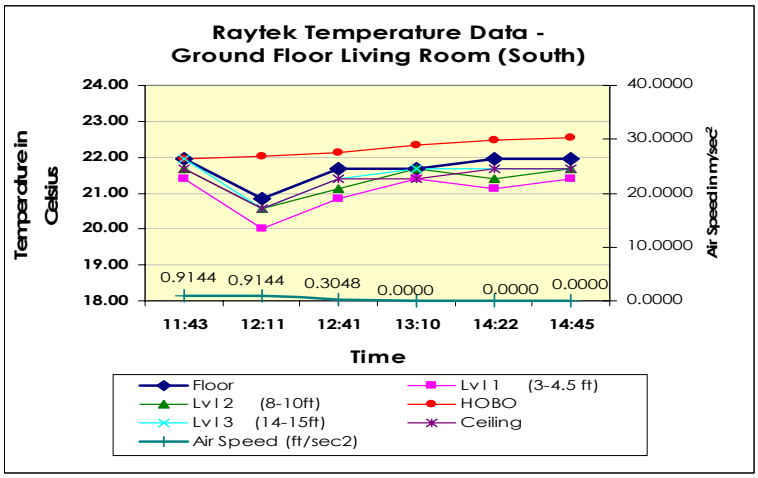


Figure 5.24: Surface temperature recorded in living room (south)

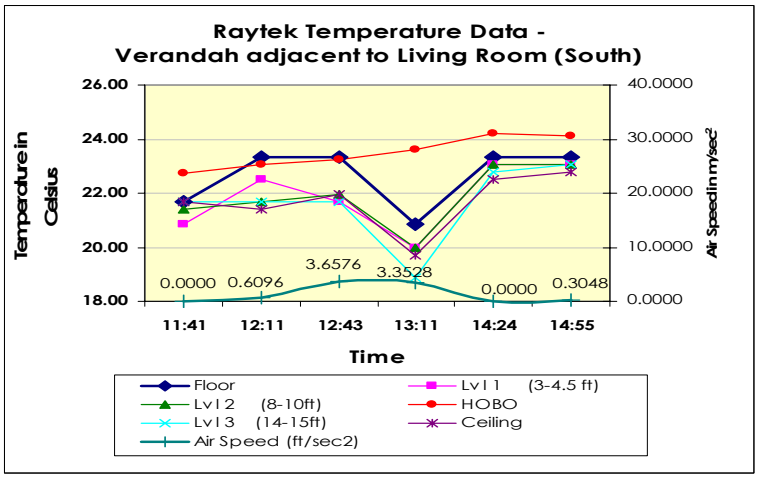


Figure 5.25: Surface temperature recorded in verandah next to living room

Figures 5.23, 5.24 and 5.25 show data recordings taken on the basis of observing the variation of surface temperatures and air speed along an imaginary section through the south side of the house.

The recordings in the semi-open arcade (Figure 5.23) show a general tendency of rising surface temperatures which seem to be facilitated by higher wind speed before noon. In the afternoon the surface temperatures at the different levels increase by nearly 3 degrees Celsius and are only tempered when there is sufficient air movement in the space to carry away some heat from the surfaces.

Inside the room (Figure 5.24) the thick thermal mass envelope helps in maintaining a more steady temperature at all the different levels. The variation of the surface temperatures inside are moderate, ranging between 1 to 2 degrees Celsius when there is air inside the space but obtaining a rather steady state when there is no air movement.

The enclosed verandah (Figure 5.25) receives diffused sunlight throughout the day. Many of the wooden and glass window shutters were closed during the period of data measurements. In the ground floor verandah, the direct sunlight is prevented by the properties of window shutters and massing of the building. This is why even under similar air movement conditions, around 12:43 and 13:11 hours, the surface temperature drops suddenly. As the sun moves higher in the sky the shading properties within the space cool the surfaces considerably. Later in the afternoon the continuous penetration of

heat from the diffused sunlight steadies the surface temperatures at a higher level especially without any air movement within the space.

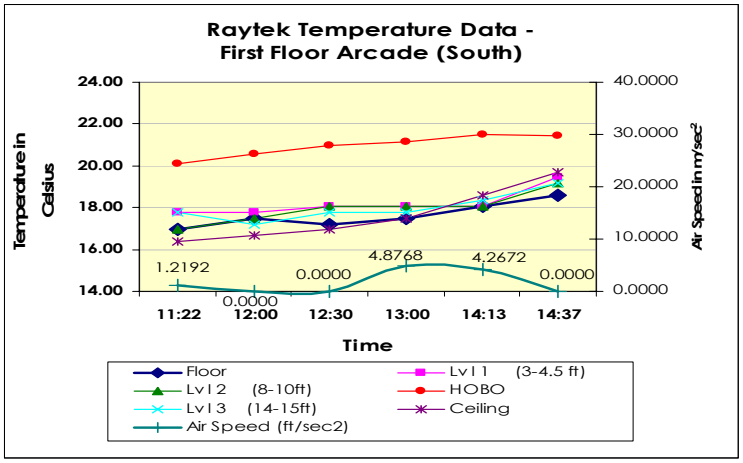


Figure 5.26: Surface temperature in first floor arcade (south)

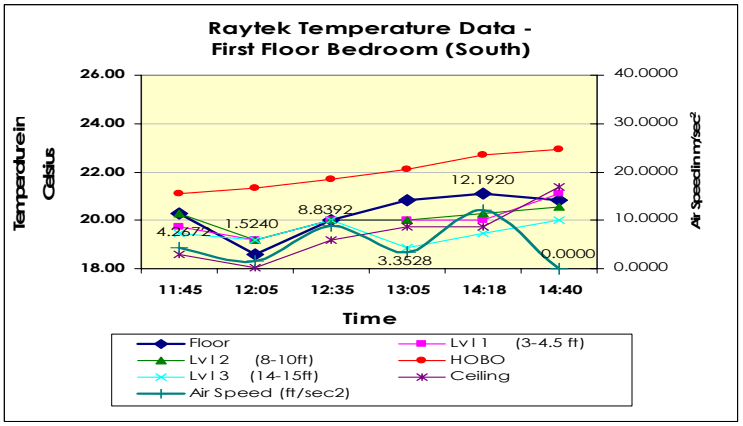


Figure 5.27: Surface temperature in first floor bedroom (south)

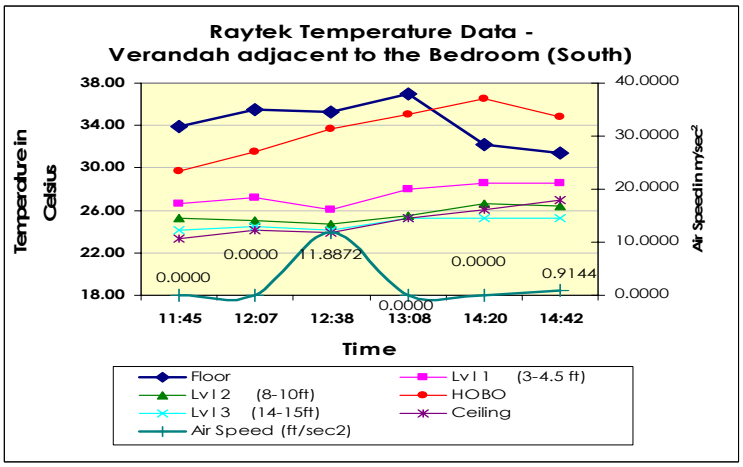


Figure 5.28: Surface temperature of first floor verandah (south)

In the upper level semi-open arcade (Figure 5.26), the surface temperatures at all the levels from the floor to the ceiling show a steady rise but remain negligibly affected by air movement in the space. The terrace on top of the upper floor arcade gets heated with direct sun rays from the overhead sun. This explains the dramatic increase in surface temperatures of the arcade ceiling. The floor and other levels of the wall get heated as the ambient air temperature rises with the progression of the day but not as rapidly as the ceiling.

Inside the room (Figure 5.27) the surface temperatures are lowered when the air movement in the space drops. Again, surface temperatures rise when warm air enters the room.

The verandah on the south side of the courtyard adjacent to the bedroom (Figure 5.28) shows the maximum variation of surface temperatures in the house. This semi-open space is completely influenced by the solar movement in the sky. Therefore before noon, when the sun angles are directly incident on the floor, the surface becomes tremendously hot reaching about 38 degrees Celsius. However, as the sun rises higher in the sky and is directly incident on the terrace above, the floor surface of the verandah starts to cool down while the temperature of the ceiling (just below the terrace) rises. The surface temperatures of the wall level nearest to the floor (at 3- 4.5ft level) show higher temperatures than the other levels as it gets heated from direct and reflected solar rays throughout the test period.

ANALYSIS OF "HOUSE B"

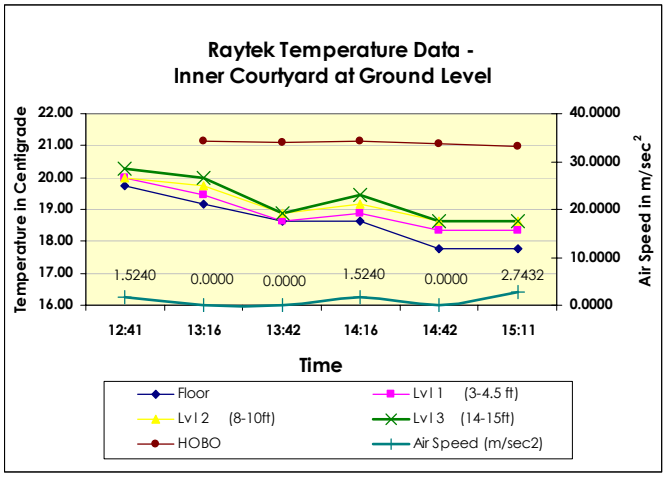


Figure 5.29: Surface temperature in the inner courtyard

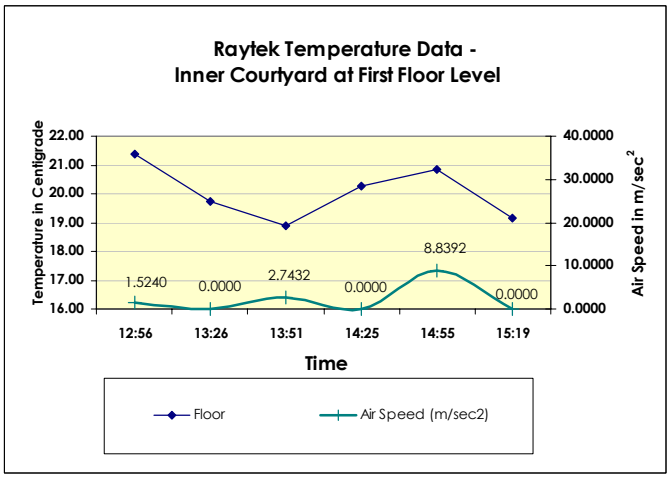


Figure 5.30: Surface temperature in the inner courtyard at first floor level

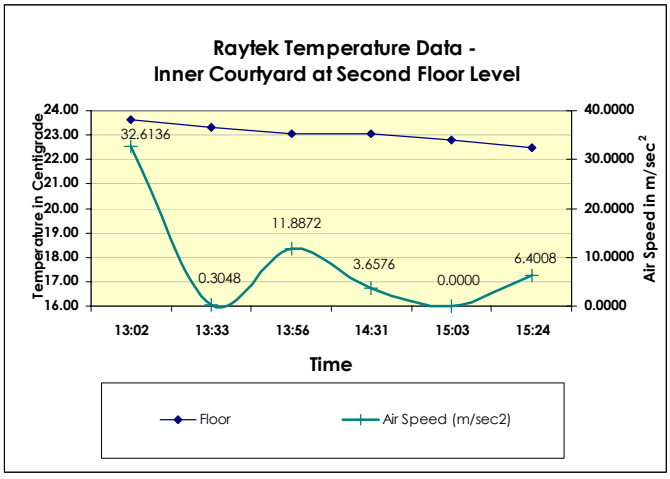


Figure 5.31: Surface temperature in the inner courtyard at second floor level

Figure 5.29 shows that the solar shaded deep courtyard has a decreasing surface temperatures as the day progresses. As the sun moves from the overhead position to the west, the temperatures of the courtyard surfaces decrease by approximately 2 degrees Celsius. The temperature variation seems to be complemented by wind in the space. As the outside temperature reaches the day's maximum, the heat in the air brought in by the air movement in the court leads to a slight rise in temperature of the surfaces.

Figure 5.30 also shows similar effects as recorded in the first floor level of the courtyard, where the temperature rises by nearly one degree Celsius when the air movement increases around 14:55p.m. Otherwise, the temperature decrease by nearly 2 degrees Celsius as the sun's position in the sky tilts towards the western horizon.

The upper floor level of the courtyard (Refer to figure 5.31) has the maximum exposure to the movement of the sun. Therefore, the general surface temperature graph is at 2 degree Celsius higher than the temperatures of the surfaces in the floors below. The surface temperature variation of the second floor level is also less affected than the floors below due to decreasing solar shading properties as one moves to the upper floor levels.

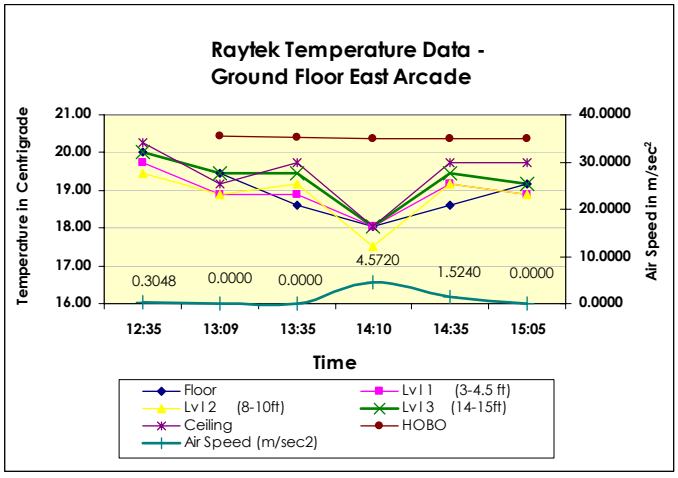


Figure 5.32: Surface temperature of ground floor arcade (east)

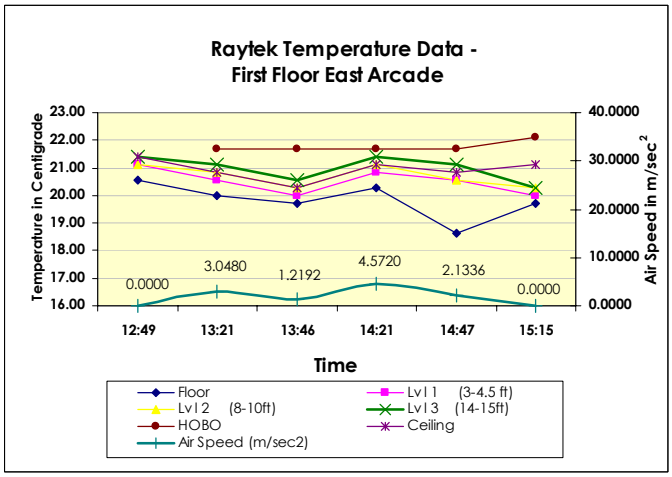


Figure 5.33: Surface temperature of first floor arcade (east)

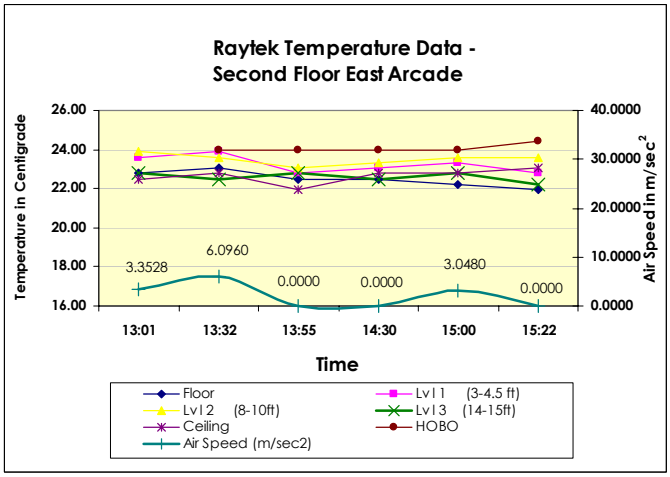


Figure 5.34: Surface temperature of second floor arcade (east)

Inside the arcade (Refer to Figure 5.32), the relation between air movement in the space and surface temperatures changes considerably. Though the ambient temperatures inside the arcade remain steady, the surface temperatures dip when air hits the surfaces at a higher speeds, taking away some of the heat from the surface (as recorded around 14:10 p.m).

The range of ambient air temperature in the first floor arcade is higher than that at the ground floor level (Refer to figure 5.33). Interestingly, when air speed rises the surface temperatures also show a rise. This may be due to hot air rising which transfers some heat to the surfaces as the air hits against them. The ambient temperature shows a slight rise after 3p.m. which is also reflected in the temperature rise of the ceiling and the floor. This may be because at that time the sun directly hits the first and second level floor surfaces.

The ambient temperature in the second floor was again one degree Celsius higher than the floor below (Refer to figure 5.34). The constant exposure to the sun may have helped in maintaining a steady surface temperature, which does not show much variation due to air movement, unlike the floors below.

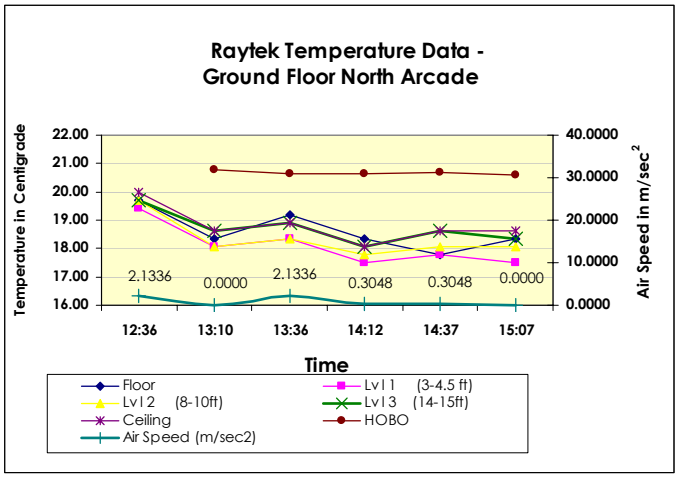


Figure 5.35: Surface temperature of ground floor arcade (north)

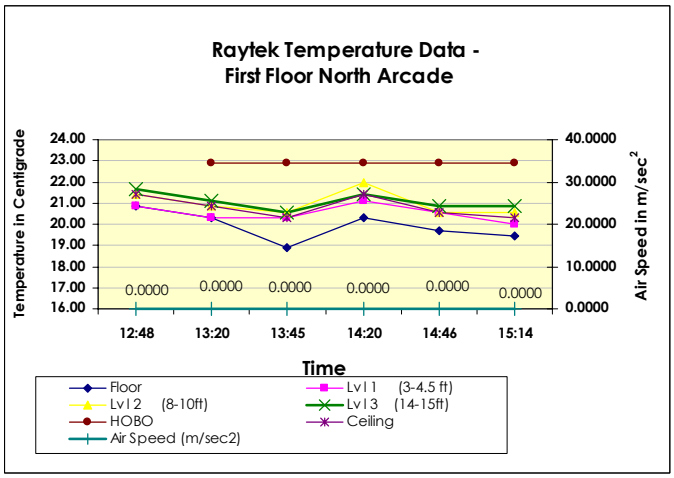


Figure 5.36: Surface temperature of first floor arcade (north)

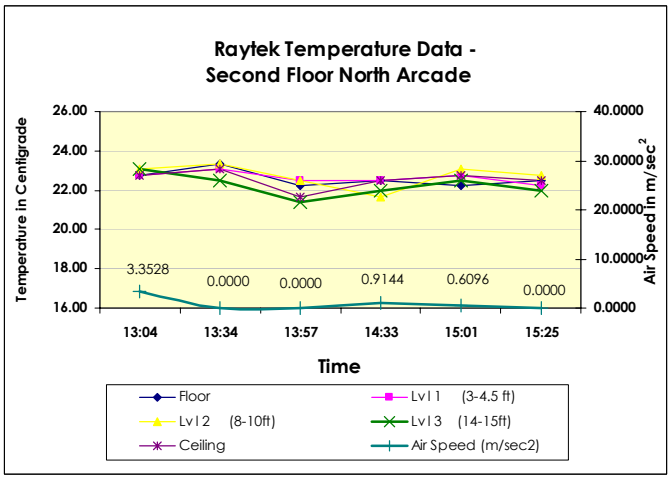


Figure 5.37: Surface temperature of second floor arcade (north)

The surface temperature variations among the three floor levels on the north side follow similar characteristics as on the east side. Figure 5.35 shows that even when the ambient air temperature is steady, the surface temperatures show a slight variation within a range of 2 degree Celsius depending on the air movement in the space. The solar shaded ground floor also records considerably lower surface temperatures than the upper floors.

The difference between the ambient air temperature and surface temperatures flattens considerably in the first floor (Refer to Figure 5.36). This is because there is a greater solar exposure on the upper floors. Since there was no recorded air movement in the space during the data measurement interval, it is difficult to explain the sudden rise in surface temperatures around 14:20p.m, except that the sun position may have allowed direct radiation on the floor at that time.

The floor surface temperatures on the second floor are quite steady during the time of data gathering (Refer to figure 5.37). The second floor has maximum exposure to the sun and this explains the higher temperatures of the different surfaces and at different levels compared to that of the floors below.

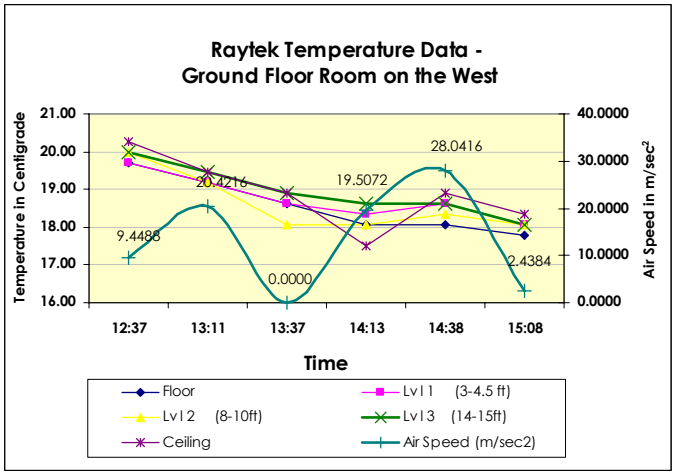


Figure 5.38: Surface temperature recorded in ground floor room (west)

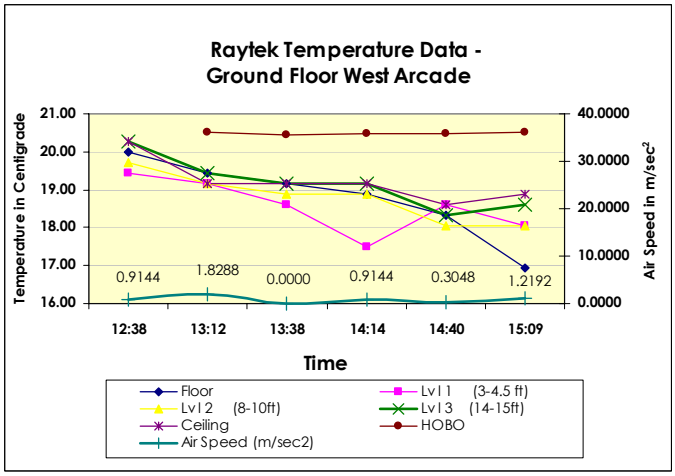


Figure 5.39: Surface temperature recorded in ground floor arcade (west)

Figures 5.38 and 5.39 show that both in the arcade and the room on the west the surface temperatures show a declining trend in the afternoon. As the sun moves to the western horizon from the overhead position, the inner arcade in the west is sufficiently shaded and buffered by the room on the exterior side. This explains why the mosaic floor loses heat and within a period of 3 hours the temperature of the floor surface drops by nearly 3.5 degrees Celsius. Inside the room the higher air movement in the living zone displaces hot air towards the ceiling. This accounts for the sudden rise in temperature of the ceiling surface around 14:38 pm.

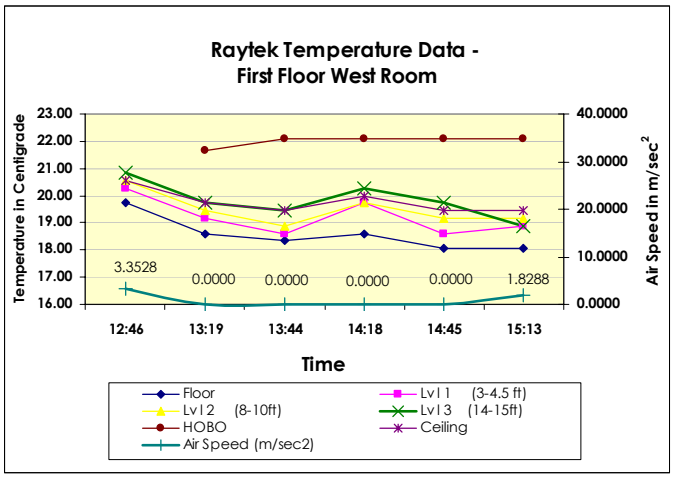


Figure 5.40: Surface temperature of first floor room (west)

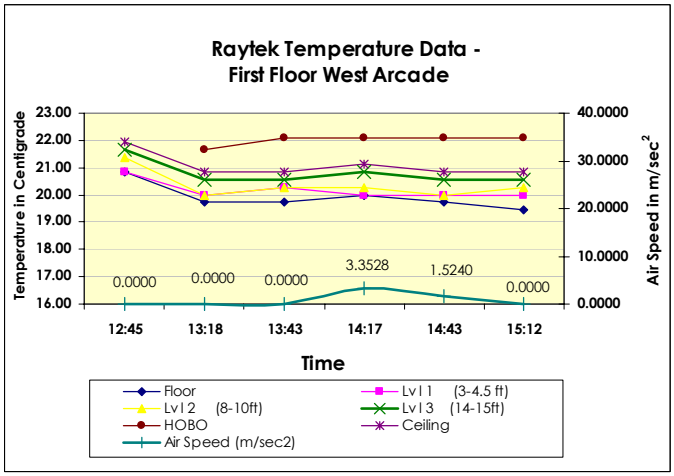


Figure 5.41: Surface temperature of first floor arcade (west)

Figures 5.40 and 5.41 show the surface temperatures recorded in the first floor room and arcade on the west. In general, the graphs closely follow the results observed in the ground floor, with the temperatures rapidly declining after noon, as the surfaces receive shade and rapidly loose heat. Interestingly, the ambient air temperature remains steady at a higher temperature than the surfaces around. In both the room and the arcade, the floor surface loses heat most rapidly. This explains why the residents prefer sitting on the floor in the arcades to rest, talk, knit, prepare food or eat on a summer or winter afternoon.

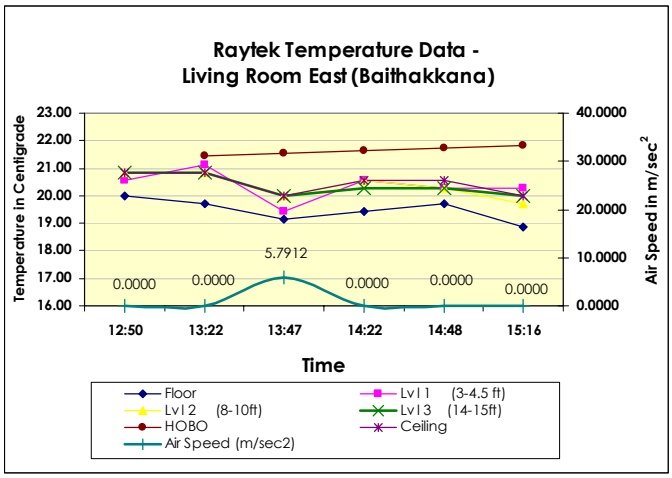


Figure 5.42: Surface temperature recorded in the living room

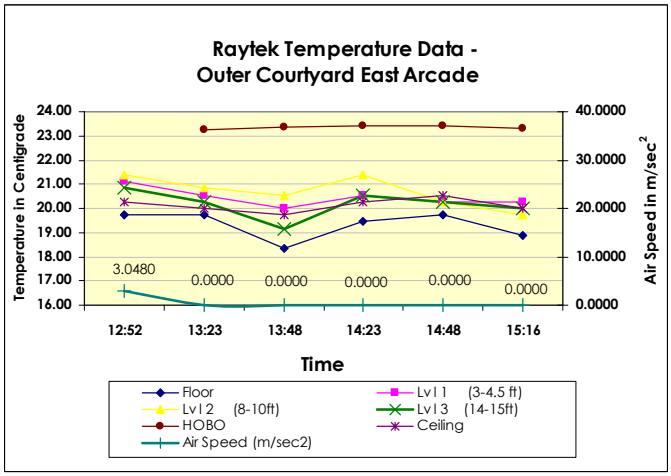


Figure 5.43: Surface temperature recorded in outer courtyard (east)

Figure 5.42 shows that while the ambient temperature in the living room rises in the afternoon the surface temperatures decrease in the room. The room is properly shaded and therefore the different surfaces cool down faster than the ambient air temperature. The stone floor loses heat most rapidly. In the outer courtyard east arcade, the ambient air temperature remains nearly 3 degrees higher than the surrounding surface temperatures. This is because of the solar shading properties of the arcade (Refer to figure 5.43).

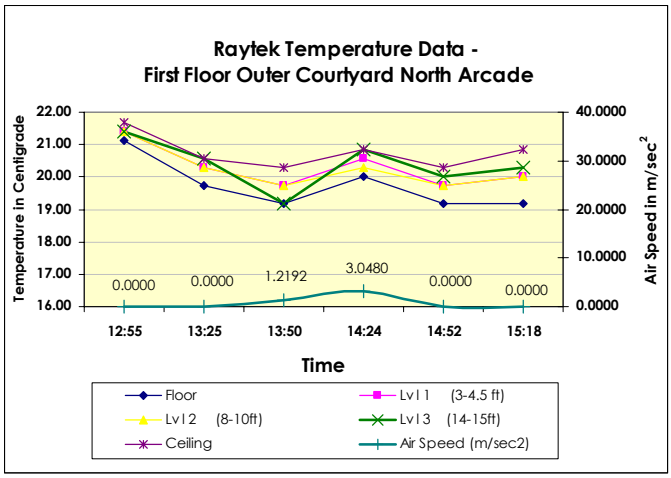


Figure 5.44: Surface temperature recorded in outer courtyard arcade (north)

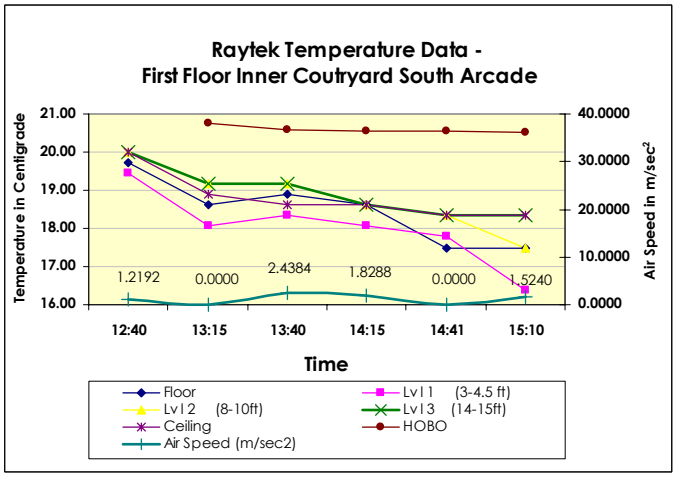


Figure 5.45: Surface temperature recorded in inner courtyard arcade (south)

In the first floor north arcade, the level 3 surface temperature varies a total of 3 Celsius degrees as the surface receives incident sunlight from the setting sun (refer to figure 5.44). The surface temperature graph of the first floor southern arcade facing the inner courtyard shows that the material of the wall has a higher capacity of losing heat rapidly as compared to the floor surface material. Therefore at 15:16 hours, the temperature of level 1 at 3-4.5ft level is much lower than that of the floor at the same time and under similar conditions.

ANALYSIS OF "HOUSE C"

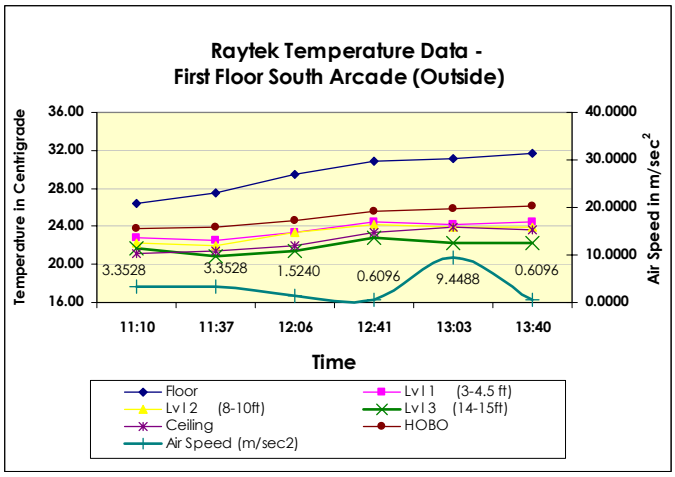


Figure 5.45: Surface temperature recorded in first floor arcade (south)

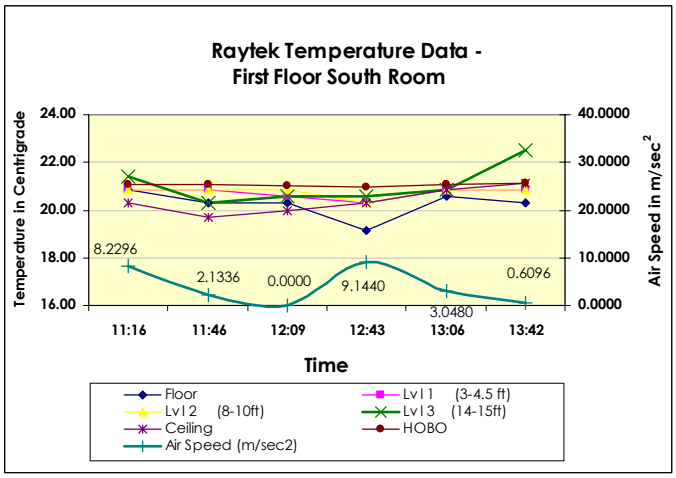


Figure 5.46: Surface temperature recorded in first floor room (south)

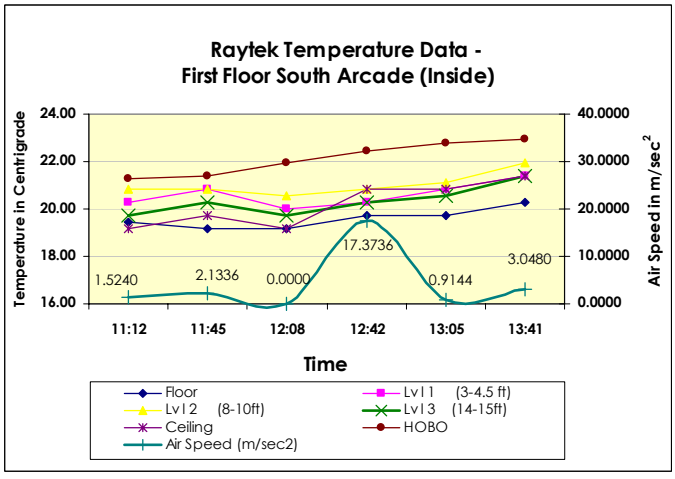


Figure 5.47: Surface temperature recorded in first floor arcade inside

From the figure 5.46 it is clear that, during the interval of data measurement, the sun was directly hitting the arcade on the first floor level. As the sun moves from the east to the west, the floor becomes hotter due to continuous exposure to the sun. The ambient air temperature still remains nearly 6° C less than the floor, which receives direct rays from the sun. The temperatures of the surfaces at different levels also rise as the day progresses. This is due to direct exposure to the sun and therefore the surface temperatures remain relatively unrelated to the effects of the air movement in the space.

Figure 5.47 shows that the ambient air temperature inside the room remained very steady during the data gathering with the Raytek Gun, Anemometer and velocity stick. However, there seems to be a slight variation in the surface temperature of the floor and at level 3 (14-15ft). It seems difficult to explain why the floor temperature at 11:16 hours is nearly 2 degrees Celsius higher than at 12:43 hours, when there is similar air movement inside the room. Again, it is difficult to account for the sudden rise in level 3 surface temperature around 13:42 hours. Otherwise, the graph shows that surface temperatures at the different levels remain rather steady.

As per figure 5.48, it is evident that, even in the southern arcade facing the inner courtyard, the data recordings show that the ambient air temperature rises by nearly 2 degrees Celsius as the day progresses. In this case, however, the other surfaces are shaded from the direct sun. The ceiling which is directly below the open terrace shows the maximum rise in temperature is conducted to this surface. The temperatures of surfaces at different levels also show a steady rise as the ambient air temperature increases.

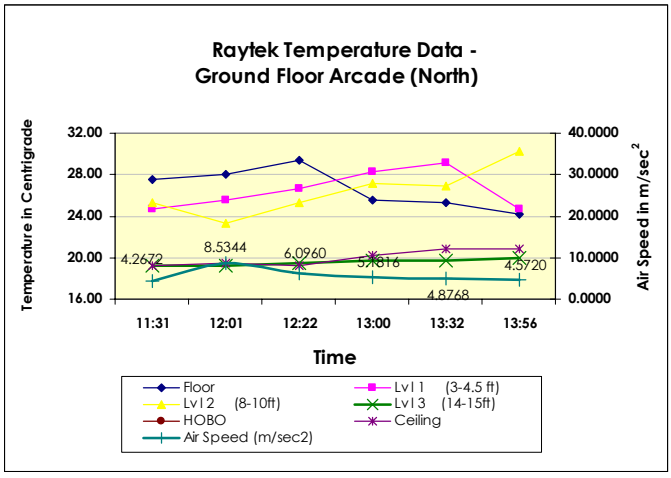


Figure 5.49: Surface temperature recorded in ground floor arcade (north)

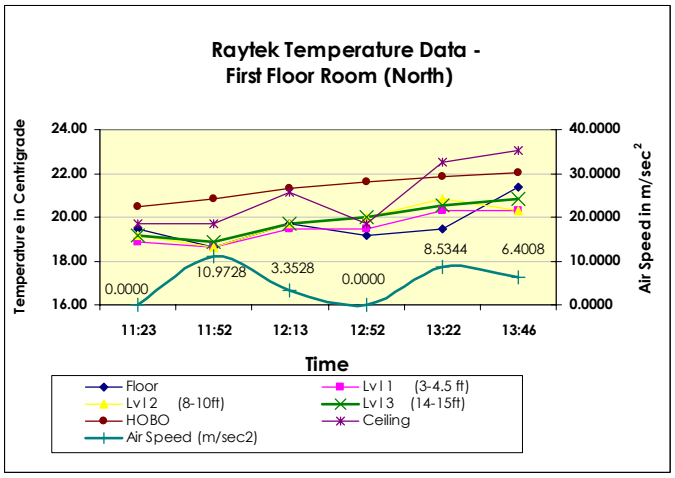


Figure 5.50: Surface temperature recorded in first floor room (north)

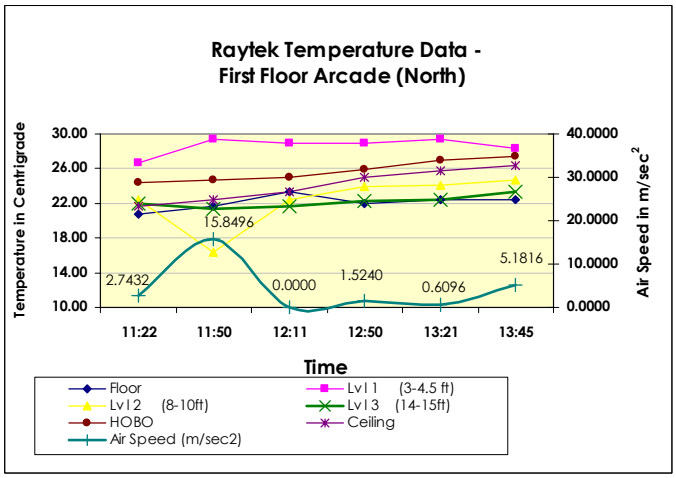


Figure 5.51: Surface temperature recorded in first floor arcade (north)

Figure 5.49 shows how the surface temperature changes as the angle of incidence of the sun changes during the day. Around noon, when the sun is high above in the sky, it is directly incident on the floor. As the day progresses the angle of the sun is lowered in the sky and it directly hits at higher levels of the arcade. This explains why the floor cools down while the temperatures of levels 1 and 2 rise considerably. The sun angle is never directly incidental on the ceiling or level 3 and this explains the relatively low temperatures of these surfaces.

Figure 5.50 shows the surface temperature of the ceiling rises steadily, only dropping when there was no air movement inside the room. The temperatures of the other surfaces also show an increasing trend. The ceiling temperature rises faster as the open terrace gets heated by the sun and conducts the heat below. Inside the room, due to proper shading from direct sunlight, the temperature is moderately steady and within a comfortable range.

Figure 5.51 shows that the surface temperature of level 1 was higher than the temperatures of the other surfaces. This is because the southern sun angle was directly incident on this level. It is interesting to note, the stratification of heat at the different levels. The temperature difference between level 1 and level 3 is nearly 7 degrees Celsius within a height of difference of only 10ft. The ambient air temperature and the ceiling closely follow each other's increasing trend in temperature due to solar exposure. The floor and level 3 which are shaded properly by the arcade have a steadier and relatively low temperature state.

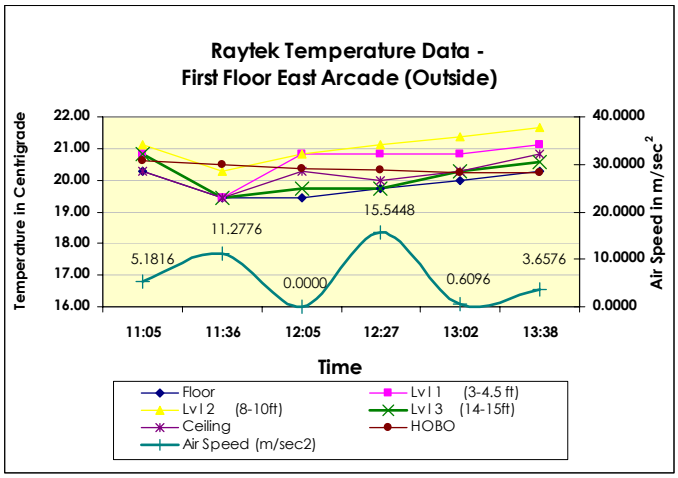


Figure 5.52: Surface temperature in east first floor arcade

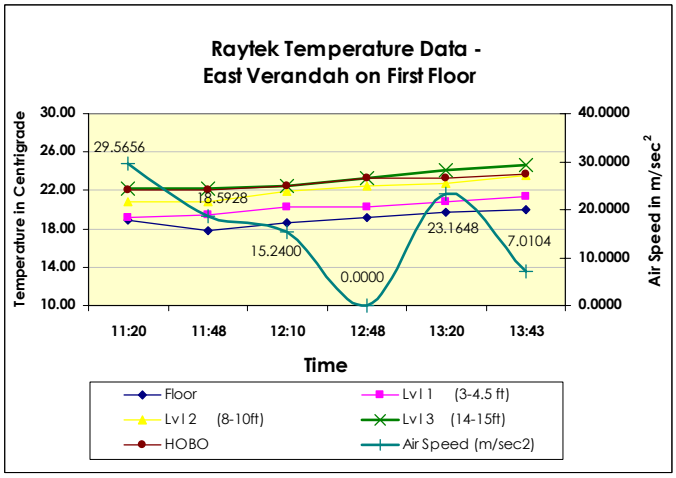


Figure 5.53: Surface temperature recorded in eastern verandah

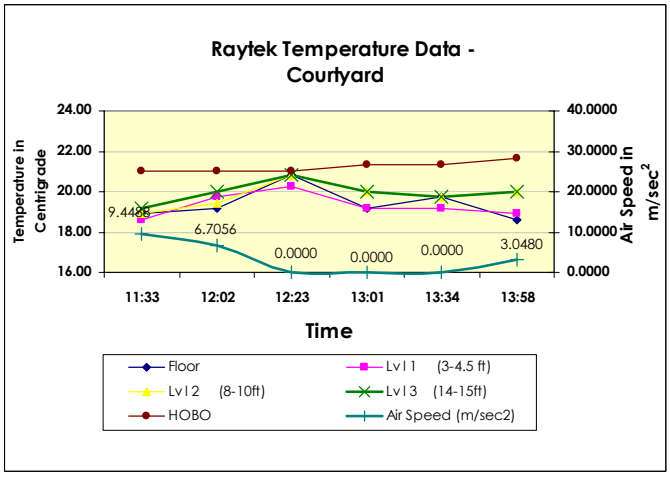


Figure 5.54: Surface temperature recorded in the courtyard C

Figure 5.52 shows that when the ambient air temperature in the first floor east arcade remained steady, the surface temperatures varied within a range of 2 to 3 degrees Celsius based on sun movement and shading properties of the arcade. It may be noted that before noon, air movement in the space actually lowered the temperature, while after noon air movement in the space raised the surface temperatures. This is because as the day progresses heats up the surfaces as it blows over them.

The open verandah shows an increasing temperature graph as the ambient air temperature rises in the afternoon. The high air movement in the space does not much affect the temperature graph (Refer to figure 5.53).

Figure 5.54 shows that while the ambient air temperature in the courtyard increased the surface temperatures at the different levels of the wall decreased. During the data measurement interval, there is hardly any air movement in the courtyard. This prevents in drawing relation between surface temperatures and air movement in the space.

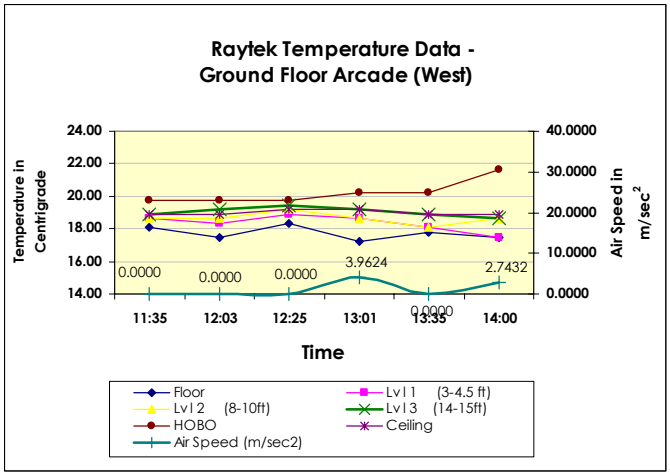


Figure 5.55: Surface temperature recorded in ground floor arcade (west)

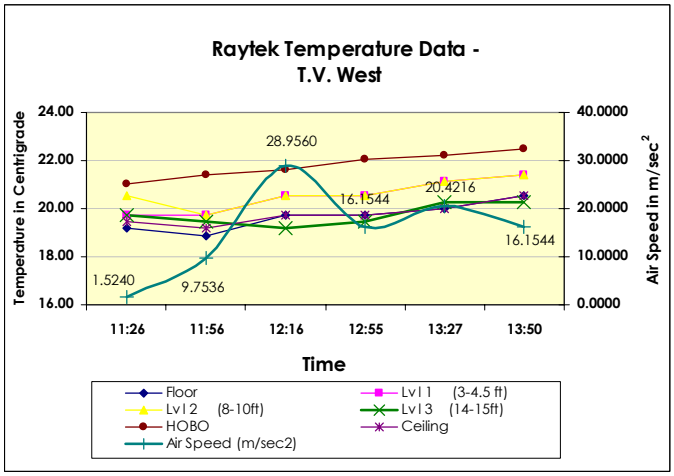


Figure 5.56: Surface temperature recorded in TV. room (west)

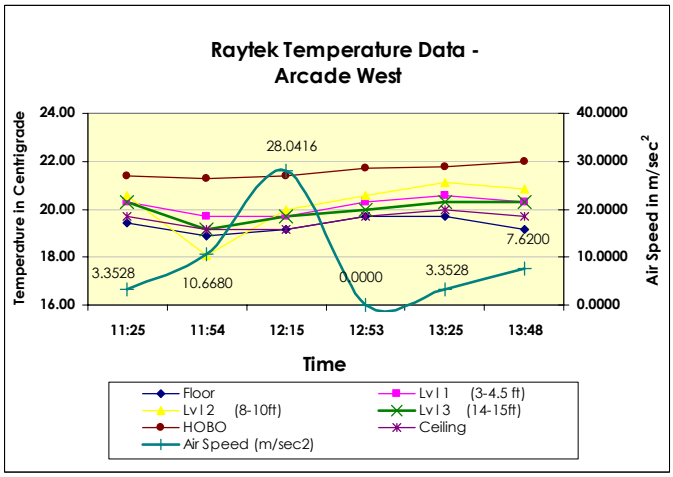


Figure 5.57: Surface temperature recorded in western arcade

Figure 5.55, 5.56 and 5.57 compares the surface temperatures in the ground floor and first floor arcades and first floor room. The air speed in the ground floor is lower than in the first floor as evident from the average air speeds. The average recorded air speed in the ground floor was 1.12 m/sec2; while in the first floor arcade it was 8.84 m/sec2 and in the first floor room it was 15.49 m/sec2. In all the three cases, the ambient air temperature was higher than the temperatures of each of the surfaces at different levels.

Figure 5.55 shows that around 14:00 hours the ambient air temperature raises by nearly 2 degrees Celsius as the temperature reaches maximum for the day. Otherwise, the other surfaces range 2 degrees.

Even in the first floor the surface temperatures vary within a range of 2 degrees both in the room and the arcade (Refer to figure 5.56 and 5.57 respectively).

SIMULATION ANALYSIS

FloVent (Version 5.1) simulation software by Flomerics. Ltd has been used to model ventilation patterns of the courtyard houses. Computational Fluid Dynamics is a powerful tool in simulating air flow and ventilation inside and outside a building. As Iannone119 has pointed out, due to the non-linearity of the physical phenomena passive cooling systems based on natural ventilation are more difficult to design in comparison with the traditional mechanical systems. The FloVent software based on conservation laws of mass momentum and energy using Navier-Stokes equations, has been used as an analytical tool for this research.

The Flovent 5.1 trial version software was available for only a limited time. Therefore, to be able to use the software efficiently during this time, only two of the courtyards types A and B were chosen for the detailed ventilation simulation study. These two houses were chosen out of the three as they were more disparate in their proportions and would therefore be able to show the influence of courtyard proportions on ventilation more evidently. Here, the two Courtyards A and B have been referred to as shallow and deep courtyards respectively based on their aspect ratios.

MODEL SET-UP IN FLOVENT

Since both indoor and outdoor environments are being modeled the effects of natural ventilation and solar radiations have complicated the modeling process. Considering that the main purpose of the research is to understand if the courtyard proportion (aspect ratio) affects human comfort in courtyard houses in Calcutta, the model has

[119] Iannone, F. Natural Ventilation and Sustainability Designing with Computational Fluid Dynamics. 2001. CLIMA200, Napoli. It is now available on http://flovent.com/technical_papers/

been simplified to highlight differences in proportions of the two courtyards. However, FloVent's superior parallel processing, rapid optimization and design integration attributes have helped in maintaining high levels of accuracy in the method and analysis.

Basic assumptions to simplify model geometry:

1. Both the sections in the houses were considered along the east-west axis.
2. The doors and windows in the models have been considered to be open during the run period.
3. The doors and windows on the exterior and interior walls facing the courtyard have been kept aligned.
4. The geometry of the houses has been reduced to simpler cubic forms by straightening wall surfaces.
5. The simulation has been analyzed for a steady state set-up. Keeping the working parameters similar, the basic assumptions to simplify wind and solar radiation calculations were:
6. Based on the ASHRAE Handbook, one of the important wind directions in Calcutta blows from the east direction. Therefore though the south wind is predominant in Calcutta, we have simulated an east wind.
7. The solar radiation has been considered for summer solstice, June 21 at 12:00 hrs.
8. The materials chosen for the different surfaces in both the buildings have been kept the same.

Physical model generation

The physical dimensions for the two courtyards were considered to be:

Table 5.1: Model dimensions for Courtyard "A" house

Courtyard A - Physical dimensions			
Space	**Length (m)**	**Breadth (m)**	**Height (m)**
Courtyard	15.09	9.57	-
Arcade_ground lvl.(east and west)	9.14	9.57	0.6
Arcade_ground lvl.(south)	37.38	9.14	0.6
Room _East	6.09	12.62	12.19
Room _West	6.09	12.62	12.19
Room_South	37.38	6.09	12.19
N.B: The rooms on each side were vertically divided by arcades into two floors with room height in each floor equal to 5.2m (17ft)			

Table 5.2:Model dimensions for Courtyard "B" house

Courtyard B - Physical dimensions			
Space	**Length (m)**	**Breadth (m)**	**Height (m)**
Courtyard	4.05	12.19	-
Arcade_ground lvl.(east and west)	6.4	12.19	0.3
Arcade_ground lvl.(south)	16.7	5.49	0.3
Room _East	4.69	13.44	15.24
Room _West	4.11	13.44	15.24
Room_South	16.7	3.05	15.24
N.B: The rooms on each side were vertically divided by arcades into three floors with room height in each floor equal to 4.5m (15ft)			

Table 5.3:Material properties used in both the houses for different thermal surfaces

Material Properties used in the analysis			
Type	**Density (kg/m^3)**	**Conductivity (Watts/m. deg.K)**	**Specific Heat (Joules/kg. degK)**
Brick	1970	0.7	800
Concrete	2240	1.3	795
Lightweight aggregate concrete	1600	0.68	837
Marble	2600	2.6	880
N.B: The material properties have been taken from the 1997 ASHRAE Hanbook Fundamentals (SI edition).			

Wind simulation

The wind flow is simulated using the wind generator option available in FloVent's website: (http://www.flovent.com/support/idx_webparts.jsp). The wind generator is comprised of six small uniform wind sources stacked one above the other to simulate the increase in wind speed with increase in height from the ground. For Kolkata, a wind of 5m/s (16.4ft/s) blowing from the east was deemed appropriate for this study.

COMPUTER SIMULATION OF FLOVENT MODEL

ANALYSIS OF "HOUSE A"

In the shallow "Courtyard A" house, the results of the 5 m/s wind blowing from the east direction showed that the speed of the wind significantly decreased as the wind moved from the east rooms through the courtyard to the west rooms. The wind blowing over the eastern face is diverted upward over the roof and seems to lose some of its velocity as it blows over the wider courtyard. Though the cross ventilation effect is

facilitated by aligned openings in the house, there is evidence of some backflow and turbulence in the eastern rooms. The courtyard floor also evidences some backflow, while there seem to be suction effects near the lower floor rooms on the western façade drawing in wind from the upper stream. The wind velocity in the lower floor remains more consistent than in the upper floor. In the lower floor the incoming wind velocity is less than the velocity on the upper floor. However, as the wind moves across the courtyard, the wind velocity in the upper floor loses its velocity and cooling capacity significantly as part of it is diverted over the roof. (Refer to fig.5.58)

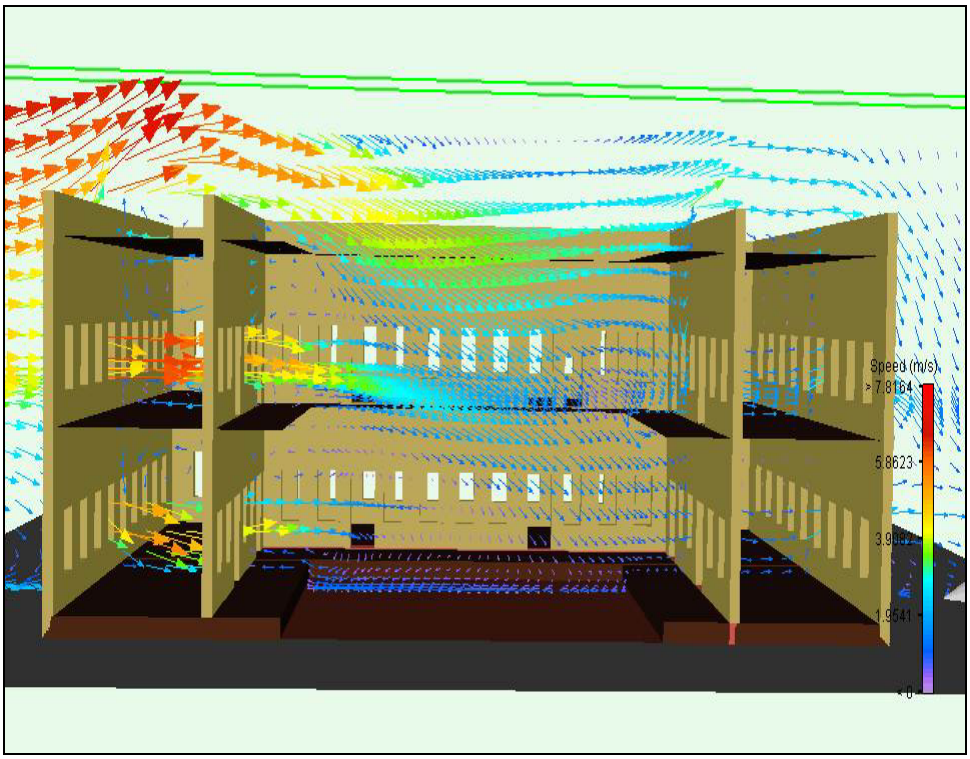


Figure 5.58: Air flow pattern in the courtyard "A" (shallow) house.

ANALYSIS OF "HOUSE B"

In the deeper "Courtyard B" (see figure 5.59), the 5m/s east wind does not lose as much of its velocity as it moves through the rooms in the east, across the courtyard and into

the rooms on the west, which is attributable to the decreased distance between the rooms on the east and west. Though the speed remains more consistent in the upper floors, the wind seems evenly distributed in the whole house. In the deep courtyard house, a low pressure zone is formed near the top of the courtyard, drawing up some of the air from the space below. In the rooms on the east, some backflow and turbulence is visible. However, the relatively small distance between the east and west rooms helps to nullify the effect of such backflow or turbulence, inducing the wind flow to pass through without any significant effect on wind velocity.

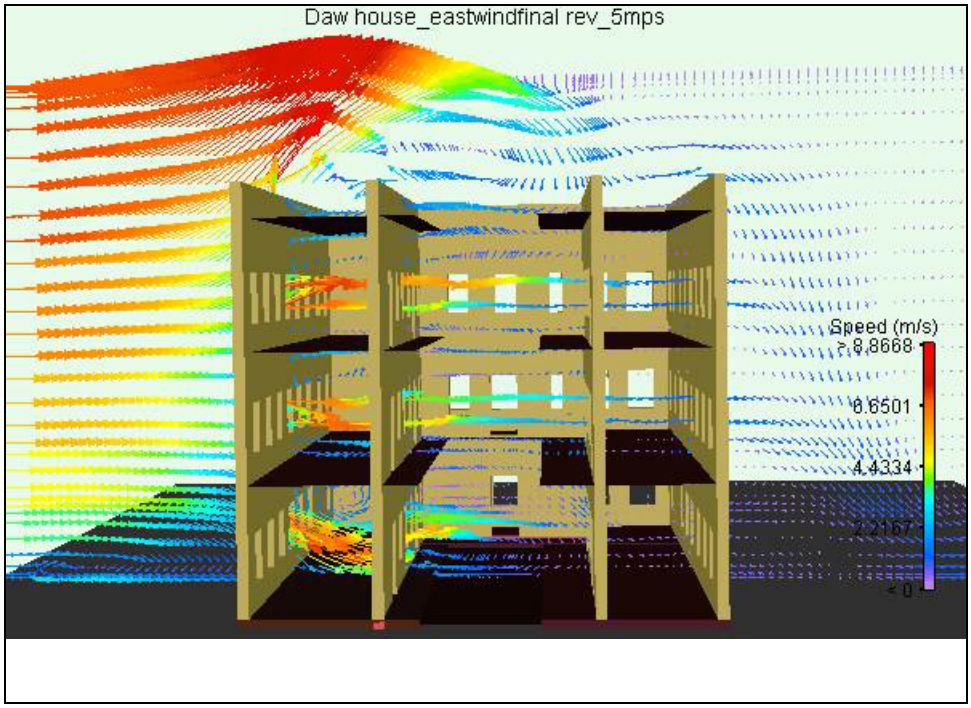


Figure 5.59: Air flow pattern in the courtyard "B" (deep) house.

COMPARATIVE ANALYSIS OF FLOVENT MODELS OF THE TWO COURTYARDS

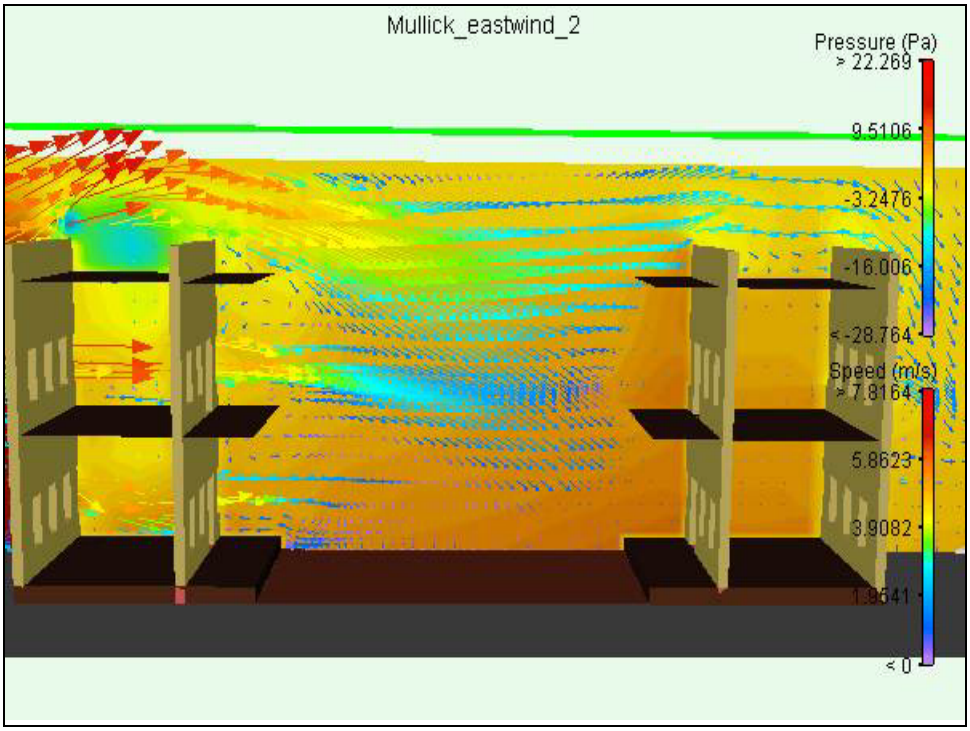


Figure 5.60: Air flow pattern superimposed on the pressure graph along the sectional plane, in the courtyard "A" (shallow) house.

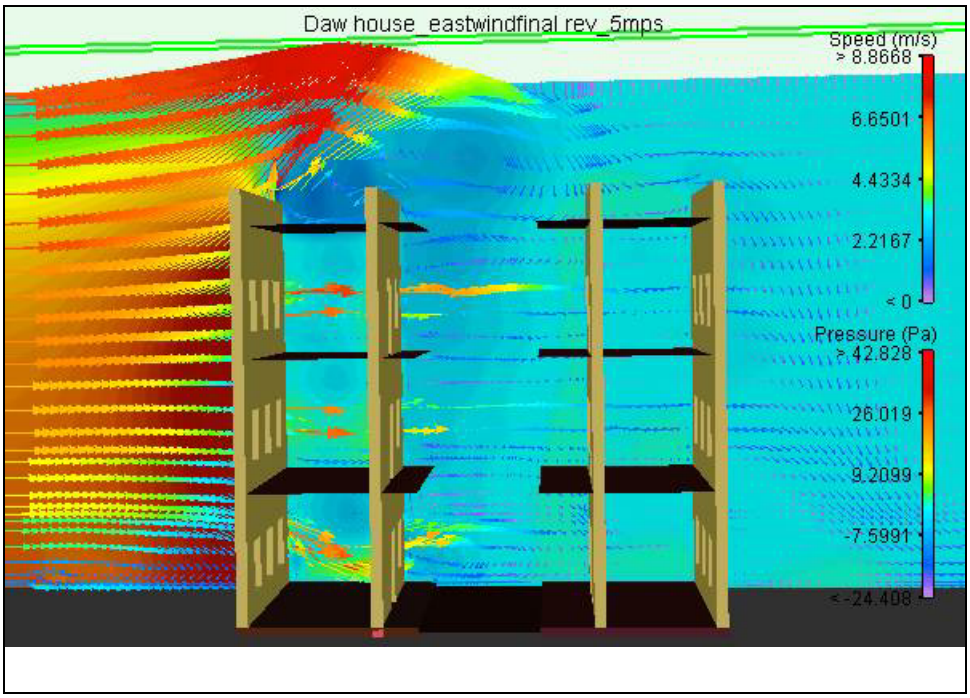


Figure 5.61: Air flow pattern superimposed on the pressure graph along the sectional plane, in the courtyard "B" (deep) house.

Superimposing the pressure and wind velocity graphs together, it is evident that the even distribution of wind velocity in the "Courtyard B" house is a result of the evenly distributed but lower pressure along the sectional plane of the house. The courtyard proportions in the deep "Courtyard B" house restrict the air within it, forcing it into the rooms on the west through the aligned openings. On the other hand, as the courtyard becomes wider the air is allowed to move more freely, approximating the effect of an open area without any obstruction. This creates new high pressure and low pressure areas in the courtyard. In the "Courtyard A" house a higher pressure area may be seen near the western façade of the courtyard. The rooms immediately to the west of this facade experience a lower pressure zone than that on the courtyard facing wall. The pressure gradient is small throughout the entire sectional plane, which is evident by the small the variation in the colors. This pressure difference allows the air to move through the western rooms, though at a significantly lower speed. Part of the wind force and cooling capacity is also lost due to the wind direction being diverted over the parapet. There is a small negative pressure zone near the top of the courtyard which might account for the upward diversion. In the shallow courtyard, where the wind more or less resumes its laminar flow, the pressure gradient is much lower than in the deep courtyard. This may be due to the proportions of the courtyard studied in this research. Further parametric study of differential proportions may result in a better understanding of the pressure gradients and the effect of aspect ratio on wind flow patterns.

COMPARATIVE ANALYSIS OF FLOVENT MODELS BASED ON SURVEY RESPONSE

In House A (shallow courtyard house) the residents' emphasized that though the courtyard was used for special social or religious occasions; interior rooms were much

more comfortable for most other purposes. Most of their daily and yearly activities took place indoors. They remarked that the wide courtyard allowed free air movement within the rooms especially in the upper floors. This pattern was also seen in the simulation study of the building. The residents also noted that the shallow courtyard allowed exposure to the sun over an extended period of time during the day, especially in the summer when the sun is high. This caused this space to become too hot for use except during the evenings when the sun went down in the overheated season. They added that in summer they watered the courtyard floor regularly to create an evaporative cooling effect. This climatic discomfort and high maintenance cost of the bigger courtyard restricted the residents' courtyard activities.

The residents' also described how the walls of the surrounding rooms with high thermal mass delayed the heat transfer from the exterior to the interior. This allowed for cooler days and warmer nights. The family members stated that during a typical summer day they preferred to keep the wooden window shutters closed with the louvers open in a manner to allow air circulation. This helped in blocking the hot sunlight but still allowed external wind flow within the rooms. The residents' of the shallow courtyard preferred to use lower level rooms during the day. This is because the lower level rooms exhibit the optimal conditions of solar shading and ventilation, while the upper level rooms, though they had an adequate ventilation pattern, gathered heat from the roof exposed to direct sun.

The House B (deep courtyard house) residents' interview showed us an entirely different picture. As might be expected from the FloVent study, the residents confirmed that they

preferred to use their courtyards and arcades more than their interior rooms. This may be linked to the even air flow distribution in the house. They listed a number of daily activities in the courtyards like cooking, dining, washing utensils, drying clothes and socializing. From their descriptions it seemed evident that unlike the residents of the House A (shallow) house, who claimed their courtyard was unbearably hot during summer, the residents of House B (deep) enjoyed their courtyard mostly during the summer (Das, Gabbard and Coates, 2005)120. They did mention that in the summer it was hot at mid-day due to the intensity of the high noon sun. They stated that during this time they preferred staying indoors to avoid the heat – most of the family members (especially female members) retreated to their bedrooms for a comfortable siesta. The lower floor and middle floor rooms benefited from the deep courtyard because they effectively shaded the courtyard floor area while still allowing cross ventilation. The minimal sun penetration in the courtyard and these rooms, along with cross ventilation helped in enhancing comfort conditions within the rooms. The even air flow distribution evident from the FloVent models shows that ventilation helps in stabilizing the temperature differences between the exteriors and the interiors, thereby encouraging more outdoor activity. The courtyard in this case gets the favorable conditions of shade, cool daylight and effective ventilation.

[120] Das, N, T Gabbard and G Coates. 2005. Calcutta: Comfort in Courtyard Houses. Kansas State University, Manhattan, KS.

CONCLUSION FROM THE SIMULATION-VENTILATION STUDY

Fry and Drew121 have aptly described in their book Tropical Architecture that "there are three main considerations influencing architectural design in the tropics…These concerns are, first, people and their needs; second, climate and its attendant ills; and third, materials and the means of building" (Pg. 20). Therefore, for a more comprehensive understanding of the effects of aspect ratio on ventilation comfort in the courtyard house, an in-depth analysis is required of both shading and wind on the building. In this research natural ventilation flow has been analyzed on the basis of a simulation of only two simplified courtyard forms. As mentioned earlier, this may be a limitation for the complete understanding of differential courtyard proportions on natural ventilation; further parametric explorations, which were beyond the scope of this research, are certainly called for in order to more fully understand how aspect ratio affects ventilation patterns in courtyard houses.

The analysis of data gathered through surveys in these houses has helped to account for some of the variables not considered in the FloVent model. This has definitely helped to reinforce the understanding of thermal qualities. The essence of this simulation study, points to the usefulness of the FloVent software in preliminary form analysis for understanding the effects of proportional changes of building massing on ventilation cooling. This is an excellent conceptual design tool and the software shows potential for creating a more sophisticated analysis by adding solar radiation calculations and producing transient runs.

[121] Fry, M and J. Drew. 1964. Tropical Architecture in the Dry and Humid Zones. Reinhold Publishing Corporation, New York.

CHAPTER 6: COURTYARD DESIGN IMPLICATIONS

COURTYARD TYPE – VERNACULAR OR MODERN TYPE?

Time present and time past are perhaps both present in time future and time future contained in time past.

- T.S.Eliot

Today the typical architectural and design engineering solution to the "energy crisis" concentrates on making buildings more efficient by increasing the efficiency of mechanized heating and cooling systems. With increasing frequency, buildings tend to become hermetically sealed to protect the artificial interior climate. This Western trend in architecture is catching up fast with the soaring ambitions of the architects and masses in developing countries.

Figure 6.1: Sketch of a courtyard garden

...past cultures had integrated metaphysics into their gardens as an adjunct to microclimate and habitat design.

- Chip Sullivan, Garden and Climate[122]

Sue Roaf[123] et.al mention in Adapting Buildings and Cities for Climate Change that buildings are like our third skin. Considering that this is true, the question is whether our modern approach of layering and closing in buildings is an appropriate design philosophy for hot-humid tropical cities such as Kolkata?

According to Anthony Tzamtzis[124], one of the important principles for designing in hot humid climate is allowing air movement over the skin for enhancing human comfort. Should this notion not be carried to the building of housing for us? The question is also whether courtyards in the residential architecture of Kolkata provides a breathing space or is actually consuming valuable floor space?

Figure 6.2: Old courtyard house in Kolkata

Figure 6.3: New high rise apartment complex in Kolkata

[122] Sullivan, Chip. 2002. *Garden and Climate.* New York: McGraw-Hill.
[123] Roaf, Sue, David Crichton and Fergus Nicol. 2005. Adapting Buildings and Cities for Climate Change. Architectural Press, Amsterdam.
[124] Tzamtzis, Anthony. 1986. Passive Design: Principles for Hot Humid Climates. Miami-Dade Community College, Miami, Fl.

The second question seems easier to answer, though it depends entirely on urban planning policies. Schoenauer and Seeman[125] have shown how efficiency in land use may be increased and justified by employing courtyard houses in central urban areas with high-rise multiple housing developments.

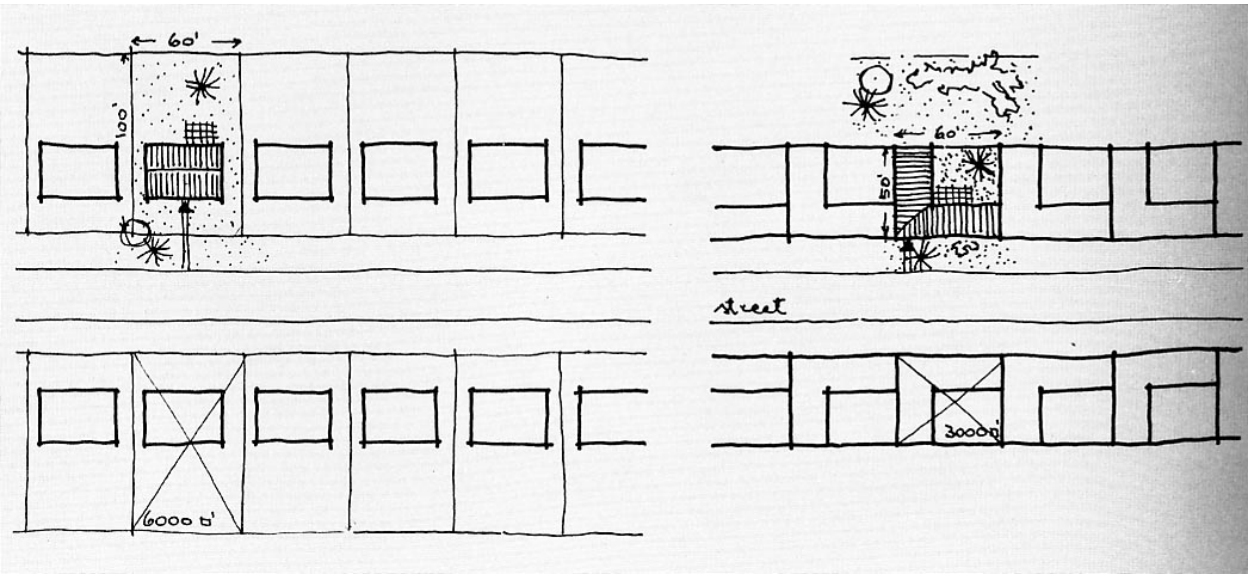


Figure 6.4: Diagram to show efficiency in land use by using adjoining courtyard houses instead of single family homes.

(Source: The Court-Garden House)

The first question seems more intriguing, to first accept whether the courtyard is a mere traditional form best relegated to the past or if courtyard design might have applicability in the modern residential architecture of Kolkata. This debate brings us back to the initial questions that triggered this research –

- Are there any benefits or design intelligence embedded in the courtyard houses in Kolkata?

[125] Schoenauer, Nobert and S.Seeman. 1962. *The Court Garden House*. Montreal McGill University Press.

- Does the courtyard form have only traditional values or can they be replicated and readapted as modern forms in the city?

And most importantly, the underlying question that binds the results of this comparative case study research, do courtyard proportions affect the nature, performance and use of the courtyard?

From the occupant surveys it is evident that the residents clearly perceived the design superiority of courtyard dwellings as opposed to the modern high rise apartments. Nearly all the residents of the surveyed courtyard houses agreed that strong traditional social values were embedded in these heritage structures. Some of the residents claimed that the spacious courtyard buildings in comparison to the match box apartments helped in encouraging an open-minded nature among the residents. They observed that there are a lot of problems and adjustments required in the joint family system but that the openness of the courtyard houses allowed private and semi-private spaces in a manner that each resident could (and did) learn to adapt with each other. The courtyard also provided a common area for children to play within the secured boundary of the house and provided an extension of spaces for living, dining and cooking. The courtyard dwellings also provided adequate facilities for conducting religious affairs and social gatherings, thus satisfying the socio-cultural needs of the families residing in them.

The occupant surveys have also highlighted some inherent blemishes of courtyard design. Many residents observed that courtyard houses required more land space, were difficult to maintain due to economic constraints. Mobility problems among the

old were observed since the layout of most of these houses created distance between different functional spaces. Another problem is that courtyard housing today is often associated with low cost housing design, as popularized by famous Indian architects like Correa. Therefore, today there seems to be an invisible social stigma attached to the form. Therefore modern architects like Correa have struggled endlessly to remove this stigma with some splendid designs adapting the primordial courtyard form. Yet, the question remains - is there a way to solve some of these problems in modern design so that we can get the best of the both worlds?

Some design considerations seem ideally suited for application in the hot-humid climate of Kolkata, based on this research finding. They are listed below as speculations for future design of housing in the city -

1. **SOLAR ACCESS**: As per the bioclimatic chart, solar radiation is helpful only in the afternoons of January and February. Other than that, in most of the other months only wind can give comfort in Kolkata's predominantly hot-humid climate.
2. **PROPORTION OF THE BUILDING**: Ventilation is most vital aspect contributing to human comfort.
3. A lower aspect ratio is better for ventilation. Therefore, ideally the square of average height of the surrounding walls should be less than area of the courtyard. Height of wall should be directly proportional to the area of the courtyard ie as the height of the wall increases the area of the courtyard should also increase.
4. A bigger surface area of courtyard may lead to more solar heat gain. Also the broader open space between the two sides of the building envelope may

cause the wind to follow an unobstructed laminar flow causing a major diversion over the roof on the leeward side of the building.

5. Since the courtyard floor may became too hot for comfort, a deep arcaded area surrounding the courtyard should be provided as a transition space within adjoining rooms and courtyards. Such an arcade may provide a comfortable space for outdoor activities. This space will benefit from both shade and also ventilation facilitated by the heated courtyard surface.
6. The verandahs and arcaded areas should ideally face the inner courtyards rather than street to enjoy the benefits of shade and wind.
7. The building plate of the surrounding rooms should be shallow and not very deep to facilitate circulation within rooms
8. To isolate the interior of the house from summer heat the rooms should be at a higher level than the courtyard.
9. To allow summer breezes to ventilate and cool, care should be taken to open up the south side of the building. This is because most of the summer breezes blow from south-west, south or south-east. Caution must be made to protect the interiors from overheating by opening the south side too much. Windows should therefore be designed in a manner to be able to provide shade from south sun but allow southern breezes.

In the end, to reiterate, it seems that the courtyard type remains timeless even today.

Enclosed on all four sides, this ancient and flexible space can incorporate passive devices into its design to provide seasonal outdoor comfort. The size of courtyard can vary from very intimate to quite spacious. In every case, the courtyard creates a wonderful frame for light and air.

- Chip Sullivan, Garden and Climate[126]

From the comparative case study approach adopted for this research it is clear that there are benefits to residential courtyard design especially integrating the climatic and socio-cultural expectations of the residents of the city. It is also evident that the nature, performance and applicability of courtyard design are highly influenced by the courtyard proportions.

[126] Sullivan, Chip. 2002. *Garden and Climate.* New York: McGraw-Hill.

FUTURE DIRECTIONS

This research is the beginning in more than one way: it is the beginning to understanding whether architecture should merely be guided by climatic requirements or whether it should also respond to the social fabric and customs of the society; it is the beginning of the search for an answer to question whether everything modern should exclude design intelligence from the past or whether it should learn from the past; and most importantly, it is the beginning of a search for more carefully nuanced answers to the question of how to design for hot and humid climates.

It is generally accepted that courtyard houses work for hot-arid regions, but the case studies in this research show that with the right balance of proportion and massing a courtyard house may perform equally well in hot-humid regions. The inward turning plan of courtyard dwellings, which helps in enclosing private spaces within the house, also provides breathing space and openness to the sky in the oppressive weather conditions of hot-humid climates. Another important issue is that this research aids our understanding of the thermal properties of building materials in hot-humid architecture. Granted that this research does not go deeply into the implications of heavy thermal mass buildings in hot-humid climates; however, the Raytek surface temperature data surely begins to question some of our underlying assumptions about the appropriateness of high thermal mass materials in climates such as Kolkata. Again the convention is that heavy thermal mass buildings work in hot arid regions where it helps to flatten the steep diurnal variation of ambient conditions. In a hot humid climate, however, the diurnal temperature range is not so steep. So it seems normal to believe that heavy thermal mass building envelope may not appropriately relieve the

temperature conditions as they will tend to maintain a rather high median temperature throughout the day. However the Raytek data seems to question this basic principle. Both the HOBO ambient temperature and Raytek surface temperature recordings show that though the difference in courtyard proportions affect the use and activity in the open courtyard and semi-open arcades, the similar high thermal mass envelope around the rooms helps in maintaining similar and rather constant temperature conditions within the interiors in all the three case studies. This definitely opens door for future investigations.

This research also acknowledges the heritage and social values embedded within these historic courtyard houses in Kolkata. Once popularized by the wealthy and educated *Babus* of the city, most off these houses are slowly deteriorating due to issues of economic viability. This research raises ethical issues regarding the preservation of heritage structures in a rapidly transforming and globalizing society. Should the old order be entirely replaced by the new?

This research investigate many old houses in North Kolkata, however, their number had to be limited due to time and scope of this research. This paves a path in the beginning of appreciation of these historic structures. Are these historic courtyard houses imprints of the first wave of globalization in the city as brought in by the Imperialist traders? The strong Colonial influence in these traditional Indian dwellings begins to portray the products of the first generation Westernization of the society. It also shows how in the past, Western influence have been adapted and Indianized in the form of these courtyard houses. The question is, "can they be replicated again to echo the strong

Indian philosophies and cultural responses in modern architecture of Kolkata?" These questions may be of special interest to sociologists studying the evolution and emergence of *Babudom* in Bengal.

In general this research has been particularly interested in the bioclimatic responses of courtyard design. The research method of comparative case study has been very useful in collecting valuable data. However, now at the end while reflecting on this course of two years of study it seems there be other avenues or approaches that also could be fruitfully adapted in such a study. One of the most significant contributions of this research is definitely the use of the state of the art toolkit assembled by the Agents of Change, University of Oregon. This research in a way demonstrates the practical applications of the various tools that may be used in hands on building investigation today. Post occupancy surveys have been popular for quite sometime now. The use of sophisticated tools is rather recent development in the field of real building analysis. Importantly, most of the tools have been used to gather data in enclosed mechanically ventilated buildings. However, they have not been extensively used for the study of naturally ventilated buildings. This research shows a promising future for most of these tools for analyzing naturally ventilated buildings. The innovative approach of relating the effects of real-time surveyed data regarding the proportions and climatic responses of the building to post occupancy resident surveys help in strengthening the findings and conclusions for this research. This seems like a good research method for any such future building investigations.

While discussing the different tools used in this research, it seems appropriate to highlight some basic qualities of the instruments. The Onset Greenline HOBO seemed to be the most useful and user friendly data collecting tool. The easy installation and reading analysis of the instrument helps in enhancing the productivity of building investigations. The numbers of options for data collection and the inbuilt software to convert data into Microsoft Excel applications which helps to generate graphs for easy data interpretation are useful features of the instrument. The Raytek Gun is perhaps the most enjoyable and interesting instrument to work with due to its instantaneous reading capabilities. The instrument is very useful in collecting surface temperature data. However, the infra-red mechanism works better for solid material surfaces and does not seem to give good results on glass or similar transparent materials. The velocity stick (using ft/sec^2 as its reading unit) is another useful tool, especially for reading low air speeds. This instrument seems handy for natural ventilation conditions, unlike the anemometer which has higher wind speed scale and does not seem sensitive to lower wind speeds. One thing must be clarified is that this research mainly used all the tools to learn their practical applications. Therefore in the future any one or more of the tools may be selected to conduct more specific research.

This research also opens the arena for using computer simulation for natural ventilation studies. The Computational Fluid Dynamics Flovent software used for conduction ventilation simulation study proved to be an important simulation tool for extensive research. Modeling natural ventilation with Flovent is also a recent development in the field of building and energy simulation. There is a lot of scope of study and investigation in the application of Flovent in architecture and urban planning. The software's ability

to model sun and wind conditions, assign material properties to the buildings helps in conducting conceptual parametric studies for building and urban design. Much research can be done in this field. The software has extensive potential in the field of architectural applications and research.

Finally, it must be accepted again that this research is only a beginning – a glimpse into the potential for many future research investigations. This study provides a broad framework for identifying potential research topics.

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APPENDIX

IRB APPLICATION

FOR OFFICE USE ONLY: IRB Protocol # _____ Application Received: _____
Routed: _____ Training Complete: _____

Committee for Research Involving Human Subjects (IRB)

Application for Approval Form
Last revised on September 2004

ADMINISTRATIVE INFORMATION:

- **Title of Project:** (if applicable, use the exact title listed in the grant/contract application)
  Courtyard Houses in Old Calcutta: A typological Analysis
- **Type of Application:**
  ☒ New, ☐ Addendum/Modification,
- **Principal Investigator:** (must be a KSU faculty member)

Name:	**Prof. Gary Coates**	**Degree/Title:**	**Professor**
Department:	**Architecture**	**Campus Phone:**	**785-532-1105**
Campus Address:	**203 Seaton**	**Fax #:**	
E-mail	**gcoates@ksu.edu**		

- **Contact Name/Email/Phone for Questions/Problems/Emergencies:** **Nibedita Das/ nibedita@ksu.edu/ 785-317-0553**
- **Does this project involve any collaborators not part of the faculty/staff at KSU?** (projects with non-KSU collaborators may require additional coordination and approvals):
  ☒ No
  ☐ Yes
- **Project Classification** (Is this project part of one of the following?):
  ☒ Thesis
  ☐ Dissertation
  ☐ Class Project
  ☐ Faculty Research
  ☐ Other: _____
- **Please attach a copy of the Consent Form:**
  ☒ Copy attached
  ☐ Consent form not used
- **Funding Source:** ☒ Internal ☐ External (identify source and attach a copy of the sponsor's grant application or contract as submitted to the funding agency)
  ☐ Copy attached ☒ Not applicable
- **Based upon criteria found in 45 CFR 46 – and the overview of projects that may qualify for exemption explained at http://www.ksu.edu/research/comply/irb/about/exempt.html, I believe that my project using human subjects should be determined by the IRB to be exempt from IRB review:**
  ☐ No
  ☐ Yes **(If yes, please complete Section XII. C. 'Exempt Projects'; remember that only the IRB has the authority to determine that a project is exempt from IRB review)**

If you have questions, please call the University Research Compliance Office (URCO) at 532-3224, or comply@ksu.edu

Last revised on September 10, 2004

Human Subjects Research Protocol Application Form

The KSU IRB is required by law to ensure that all research involving human subjects is adequately reviewed for specific information and is approved prior to inception of any proposed activity. Consequently, it is important that you answer all questions accurately. If you need help or have questions about how to complete this application, please call the Research Compliance Office at 532-3224, or e-mail us at **comply@ksu.edu**.

Please provide the requested information in the shaded text boxes. The shaded text boxes are designed to accommodate responses within the body of the application. As you type your answers, the text boxes will expand as needed. After completion, print the form and send the original and one photocopy to the Institutional Review Board, Room 1, Fairchild Hall.

Principal Investigator:	**Prof. Gary Coates**
Project Title:	**Courtyard Houses in Old Calcutta: A typological Analysis**
Date:	**11.22.2004**

I. BACKGROUND (concise narrative review of the literature and basis for the study):
Attached

II. PROJECT/STUDY DESCRIPTION (please provide a concise narrative description of the proposed activity in terms that will allow the IRB or other interested parties to clearly understand what it is that you propose to do that involves human subjects. This description must be in enough detail so that IRB members can make an informed decision about proposal).
Attached

III. OBJECTIVE (briefly state the objective of the research – what you hope to learn from the study):
Attached

IV. DESIGN AND PROCEDURES (succinctly outline formal plan for study):

A. Location of study:	**Attached**
B. Variables to be studied:	**Attached**
C. Data collection methods: (surveys, instruments, etc – **please attach**)	**Attached**
D. List any factors that might lead to a subject dropping out or withdrawing from a study. These might include, but are not limited to emotional or physical stress, pain, inconvenience, etc.:	**Attached**
E. List all biological samples taken: (if any)	**N/A**
F. Debriefing procedures for participants:	**attached**

V. RESEARCH SUBJECTS:

A. Source:	**Attached**
B. Number:	**Attached**
C. Characteristics: (list any unique qualifiers desirable for research subject participation)	**None**
D. Recruitment procedures: (Explain how do you plan to recruit your subjects? Attach any fliers, posters, etc. used in recruitment. If you plan to use any inducements, ie. cash, gifts, prizes, etc., please list them here.)	**Attached**

VI. RISK – PROTECTION – BENEFITS: The answers for the three questions below are central to human subjects research. You must demonstrate a reasonable balance between anticipated risks to research participants, protection strategies, and anticipated benefits to participants or others.

2

A. **Risks for Subjects:** (Identify any reasonably foreseeable physical, psychological, or social risks for participants. State that there are "no known risks" if appropriate.)

No known risks

B. **Minimizing Risk:** (Describe specific measures used to minimize or protect subjects from anticipated risks.)

N/A

C. **Benefits:** (Describe any reasonably expected benefits for research participants, a class of participants, or to society as a whole.)

Attached

In your opinion, does the research involve **more than minimal risk** to subjects? ("Minimal risk" means that "the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.")

☐ **Yes** ☒ **No**

VII. CONFIDENTIALITY: Confidentiality is the formal treatment of information that an individual has disclosed to you in a relationship of trust and with the expectation that it will not be divulged to others without permission in ways that are inconsistent with the understanding of the original disclosure. Consequently, it is your responsibility to protect information that you gather from human research subjects in a way that is consistent with your agreement with the volunteer and with their expectations. If possible, it is best if research subjects' identity and linkage to information or data remains unknown.

Explain how you are going to protect confidentiality of research subjects and/or data or records. Include plans for maintaining records after completion.

VIII. INFORMED CONSENT: Informed consent is a critical component of human subjects research – it is your responsibility to make sure that any potential subject knows exactly what the project that you are planning is about, and what his/her potential role is. (There may be projects where some forms of "deception" of the subject is necessary for the execution of the study, but it must be carefully justified to and approved by the IRB). A schematic for determining when a waiver or alteration of informed consent may be considered by the IRB is found at http://www.ksu.edu/research/comply/irb/images/slide1.jpg and at http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm#46.116. Even if your proposed activity does qualify for a waiver of informed consent, you must still provide potential participants with basic information that informs them of their rights as subjects, i.e. explanation that the project is research and the purpose of the research, length of study, study procedures, debriefing issues to include anticipated benefits, study and administrative contact information, confidentiality strategy, and the fact that participation is entirely voluntary and can be terminated at any time without penalty, etc. Even if your potential subjects are completely anonymous, you are obliged to provide them (and the IRB) with basic information about your project. See informed consent example on the URCO website at http://www.ksu.edu/research/comply/irb/app.html). It is a federal requirement to maintain informed consent forms for 3 years after the study completion.

Yes	No	**Answer the following questions about the informed consent procedures.**
☒	☐	a. Are you using a written informed consent form? If "yes," include a copy with this application. If "no" see next paragraph.
☐	☒	b. In accordance with guidance in 45 CFR 46, I am requesting a waiver or alteration of informed consent elements (See Section VII above). If "yes," provide a basis and/or justification for your request.
☒	☐	c. Are you using the online Consent Form Template provided by the URCO? If "no," does

your Informed Consent document has all the minimum required elements of informed consent found in the Consent Form Template? (Please explain)

☐ ☒ d. Are your research subjects anonymous? If they are anonymous, you will not have access to any information that will allow you to determine the identity of the research subjects in your study, or to link research data to a specific individual in any way. Anonymity is a powerful protection for potential research subjects. (An anonymous subject is one whose identity is unknown even to the researcher, or the data or information collected cannot be linked in any way to a specific person).

☒ ☐ e. Are subjects debriefed about the purposes, consequences, and benefits of the research? Debriefing refers to a mechanism for informing the research subjects of the results or conclusions, after the data is collected and analyzed, and the study is over. (If "no" explain why.)

*** It is a requirement that you maintain all signed copies of informed consent documents for at least 3 years following the completion of your study. These documents must be available for examination and review by federal compliance officials.**

IX. PROJECT INFORMATION: (If you answer yes to any of the questions below, you should explain them in one of the paragraphs above)

Yes	No	Does the project involve any of the following?
☐	☒	a. Deception of subjects
☐	☒	b. Shock or other forms of punishment
☐	☒	c. Sexually explicit materials or questions about sexual orientation, sexual experience or sexual abuse
☐	☒	d. Handling of money or other valuable commodities
☐	☒	e. Extraction or use of blood, other bodily fluids, or tissues
☐	☒	f. Questions about any kind of illegal or illicit activity
☐	☒	g. Purposeful creation of anxiety
☐	☒	h. Any procedure that might be viewed as invasion of privacy
☐	☒	i. Physical exercise or stress
☐	☒	j. Administration of substances (food, drugs, etc.) to subjects
☐	☒	k. Any procedure that might place subjects at risk
☐	☒	l. Any form of potential abuse; i.e., psychological, physical, sexual
☒	☐	m. Use of surveys for data collection **IF YES, PLEASE ATTACH!!**

X. SUBJECT INFORMATION: (If you answer yes to any of the questions below, you should explain them in one of the paragraphs above)

Yes	No	Does the research involve subjects from any of the following categories?
☐	☒	a. Under 18 years of age (these subjects require parental or guardian consent)
☐	☒	b. Over 65 years of age
☐	☒	c. Physically or mentally disabled
☐	☒	d. Economically or educationally disadvantaged
☐	☒	e. Unable to provide their own legal informed consent
☐	☒	f. Pregnant females as target population
☐	☒	g. Victims
☐	☒	h. Subjects in institutions (e.g., prisons, nursing homes, halfway houses)
☐	☒	i. Are research subjects in this activity students recruited from university classes or volunteer pools? If so, do you have a reasonable alternative(s) to participation as a research subject in your project, i.e., another activity such as writing or reading, that would serve to protect students from unfair pressure or coercion to participate in this project? If you answered

this question "Yes," explain any alternatives options for class credit for potential human subject volunteers in your study.

XI. **CONFLICT OF INTEREST:** Concerns have been growing that financial interests in research may threaten the safety and rights of human research subjects. Financial interests are not in them selves prohibited and may well be appropriate and legitimate. Not all financial interests cause Conflict of Interest (COI) or harm to human subjects. However, to the extent that financial interests may affect the welfare of human subjects in research, IRB's, institutions, and investigators must consider what actions regarding financial interests may be necessary to protect human subjects. Please answer the following questions:

Yes	No		
☐	☒	a.	Do you or the institution have any proprietary interest in a potential product of this research, including patents, trademarks, copyrights, or licensing agreements?
☐	☒	b.	Do you have an equity interest in the research sponsor (publicly held or a non-publicly held company)?
☐	☒	c.	Do you receive significant payments of other sorts, eg., grants, equipment, retainers for consultation and/or honoraria from the sponsor of this research?
☐	☒	d.	Do you receive payment per participant or incentive payments?
		e.	If you answered yes on any of the above questions, please provide adequate explanatory information so the IRB can assess any potential COI indicated above. N/A

XII. PROJECT COLLABORATORS:

A. KSU Collaborators – list anyone affiliated with KSU who is collecting or analyzing data: (list all collaborators on the project, including undergraduate and graduate students)

Name:	Department:	Campus Phone:
Nibedita Das	Architecture	785-317-0553

B. Non-KSU Collaborators: (List all collaborators on your human subjects research project not affiliated with KSU in the spaces below. KSU has negotiated an Assurance with the Office for Human Research Protections (OHRP), the federal office responsible for oversight of research involving human subjects. When research involving human subjects includes collaborators who are not employees or agents of KSU the activities of those unaffiliated individuals may be covered under the KSU Assurance only in accordance with a formal, written agreement of commitment to relevant human subject protection policies and IRB oversight. The Unaffiliated Investigators Agreement can be found and downloaded at (http://www.ksu.edu/research/comply/irb/forms/invagree.pdf). The URCO must have a copy of the Unaffiliated Investigator Agreement on file for each non-KSU collaborator who is not covered by their own IRB and assurance with OHRP. Consequently, it is critical that you identify non-KSU collaborators, and initiate any coordination and/or approval process early, to minimize delays caused by administrative requirements. If you are collaborating with another institution or performing human subjects research at another site, you should review Part 2, Section IV of the KSU Assurance available online at http://www.ksu.edu/research/comply/irb/mpa99.htm.)

Name:	Organization:	Phone:
None		

Does your non-KSU collaborator's organization have an Assurance with OHRP? (for Federalwide Assurance and

Multiple Project Assurance (MPA) listings of other institutions, please reference the OHRP website under Assurance Information at: http://ohrp.osophs.dhhs.gov/polasur.htm).

☐ **No**
☐ **Yes** **If yes, Collaborator's MPA #** _____

Is your non-KSU collaborator's IRB reviewing this proposal?

☐ **No**
☐ **Yes** **If yes, IRB approval #** _____

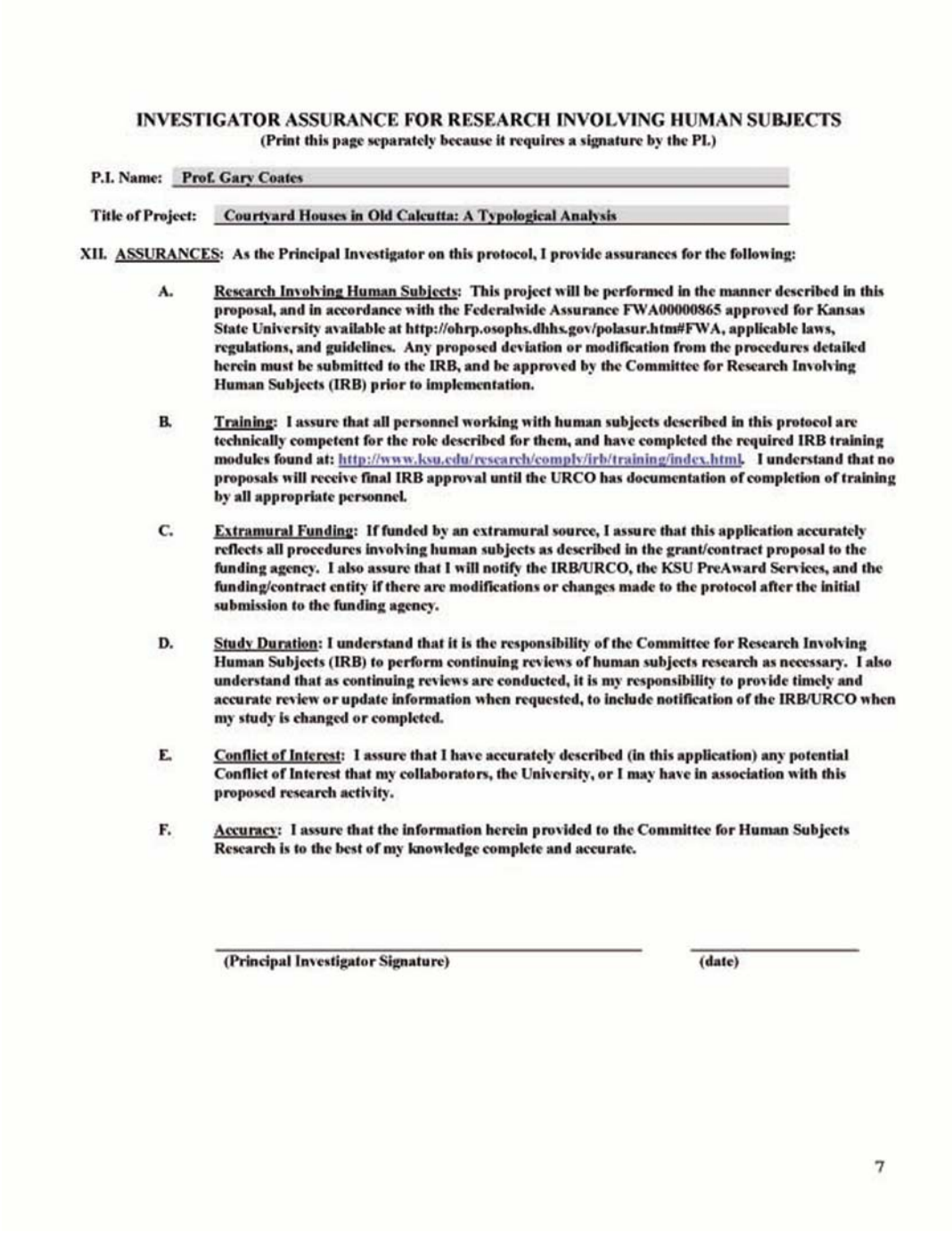
C. Exempt Projects: 45 CFR 46 identifies six categories of research involving human subjects that may be exempt from IRB review. The categories for exemption are listed on the KSU research involving human subjects home page at http://www.ksu.edu/research/comply/irb/about/exempt.html. If you believe that your project qualifies for exemption, please indicate which exemption category applies (1-6). Please remember that only the IRB can make the final determination whether a project is exempt from IRB review, or not.

Exemption Category: _____

XIII. CLINICAL TRIAL ☐**Yes** ☐**No**

(If so, please give product and funding agency.)

If you have questions, please call the University Research Compliance Office (URCO) at 532-3224, or comply@ksu.edu



INVESTIGATOR ASSURANCE FOR RESEARCH INVOLVING HUMAN SUBJECTS

(Print this page separately because it requires a signature by the PI.)

P.I. Name: Prof. Gary Coates

Title of Project: Courtyard Houses in Old Calcutta: A Typological Analysis

XII. ASSURANCES: As the Principal Investigator on this protocol, I provide assurances for the following:

A. **Research Involving Human Subjects: This project will be performed in the manner described in this proposal, and in accordance with the Federalwide Assurance FWA00000865 approved for Kansas State University available at http://ohrp.osophs.dhhs.gov/polasur.htm#FWA, applicable laws, regulations, and guidelines. Any proposed deviation or modification from the procedures detailed herein must be submitted to the IRB, and be approved by the Committee for Research Involving Human Subjects (IRB) prior to implementation.**

B. **Training: I assure that all personnel working with human subjects described in this protocol are technically competent for the role described for them, and have completed the required IRB training modules found at: http://www.ksu.edu/research/comply/irb/training/index.html. I understand that no proposals will receive final IRB approval until the URCO has documentation of completion of training by all appropriate personnel.**

C. **Extramural Funding: If funded by an extramural source, I assure that this application accurately reflects all procedures involving human subjects as described in the grant/contract proposal to the funding agency. I also assure that I will notify the IRB/URCO, the KSU PreAward Services, and the funding/contract entity if there are modifications or changes made to the protocol after the initial submission to the funding agency.**

D. **Study Duration: I understand that it is the responsibility of the Committee for Research Involving Human Subjects (IRB) to perform continuing reviews of human subjects research as necessary. I also understand that as continuing reviews are conducted, it is my responsibility to provide timely and accurate review or update information when requested, to include notification of the IRB/URCO when my study is changed or completed.**

E. **Conflict of Interest: I assure that I have accurately described (in this application) any potential Conflict of Interest that my collaborators, the University, or I may have in association with this proposed research activity.**

F. **Accuracy: I assure that the information herein provided to the Committee for Human Subjects Research is to the best of my knowledge complete and accurate.**

(Principal Investigator Signature) **(date)**

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Background:

"It seems that for courtyard comfort,…the worst climates are hot and humid, where little wind is available to relieve stuffiness…"(Reynolds, 2002, Courtyards, p.80)

Reynolds description of courtyards as not being suitable for hot humid climates triggered my interest in the subject. Being a resident of Calcutta, I have always observed that the older

parts of Calcutta, both in the north and south, were made up of old courtyard residential buildings. Calcutta is predominantly a hot humid climate zone. I had always assumed that these courtyard-houses, which were built during the Colonial rule of Bengal and owned by the affluent families under the Raj worked well bioclimatically. This research intends to find if these traditional old courtyard houses are actually thermally comfortable. It also tries to discover what the socio-cultural implications of these courtyard dwellings are. The ultimate goal of the proposed research is to find if 'courtyard architecture' is thermally and socio-culturally acceptable and appropriate for modern day Calcutta.

Project/Study Description:

The research intends to choose two models of courtyard buildings for detailed case study from a survey of a minimum of ten courtyard residences in Calcutta. The case studies will be chosen on the basis of their mutual differences in the physical parameters of the courtyards for example length, breadth and depth (height of surrounding walls) and research on how they influence the thermal qualities of the building and also the perceived human comfort level of the occupants. The socio-economic compositions of the families in all the surveyed courtyard buildings are intended to be kept similar.

The researcher intends to visit at least ten families residing in courtyard buildings located in the older parts of Calcutta in January 2005. The intention of this visit is to record through observation different physical and socio-cultural factors that influence life and activities in and around the courtyards of the houses. A short questionnaire requiring approximately fifteen minutes for completing will be handed to the head of the family to support data gathered through physical observation and rough measurements of the courtyards. Two appropriate models for detailed case studies will be chosen on the basis of this preliminary survey of minimum ten courtyard houses and their occupants. The idea is to evaluate the importance of the courtyard within the daily activities of the families through these surveys. Choice for detailed

case studies will also depend on the permission granted by the residents of the chosen houses to perform detailed inventory for gathering climatic data through precise measuring tools and behavioral data through questionnaire prepared for the head of the family. It is estimated that the detailed questionnaire will require approximately thirty minutes for completing.

The detailed case studies intend to correlate the actual thermal data from the building with the perceived human comfort levels of the occupants. The detailed case study will include measurement of temperature, humidity, light intensity, air speed and air movement in and around the courtyard as well some adjoining rooms. The detailed questionnaire survey will also try to understand the activity patterns of the dwellers and correlate it to the thermal responses of the occupants.

Objective:

The research intends to find the appropriateness of courtyard buildings in modern Calcutta's architecture on the basis of their bioclimatic and socio-cultural responses. The researcher hopes to find a suitable model for courtyard buildings as can be adapted in the modern society.

Design and Procedures:

A. Location of study: Calcutta, India
B. Variables to be studied: Climatic factors: temperature, humidity, light intensity, air speed and air movement. Behavioral factors: activity pattern diurnally and annually, perception of comfort with respect to thermal properties, ventilation, lighting quality. Physical design factors: form, materials, orientation, proportion, scale, position of rooms, interior and exterior finishes.
C. Data collection methods: Survey and measuring instruments to collect climatic data

a. First type of survey- short form (approximate time for completion 15 minutes) for occupants of minimum ten buildings visited in order to finally select two best models of courtyard houses for detailed case study. Measuring tape will be used for preliminary understanding of the proportions of the building.
b. Second type of survey- long form, a more detailed questionnaire (approximate time for completion 30 minutes) for occupants of only the final two case studies. Precision measuring instruments and data loggers will be used to record temperature, humidity, light intensity, air speed and air movement over a period of 24 hours.
c. Survey questionnaires attached.

D. List any factors that might lead to a subject dropping out or withdrawing from a study: Inconvenience, conflict in time schedules, family emergencies.

E. List all biological samples taken: Not applicable

F. Debriefing procedures for participants: N/A

Research subjects:

A. Source: residents of courtyard houses in Calcutta

B. Number: Minimum of ten families

C. Characteristic: None

D. Recruitment procedures: Contact each family by visiting, explaining the thesis interest and providing the informed consent form

Risk- Protection- Benefits

A. Risks for subjects: "No known risks"

B. Minimizing Risk: N/A

C. Benefits: providing the document including the case study findings and photographs with the occupants of the final case study buildings, acknowledging the support of other participants in the final thesis report and sharing any information that they may request pertaining to their own residence.

Confidentiality

The confidentiality of the families will be given prime importance. The questioned persons will be assigned 'subject numbers' on the basis of the order of visit. In the thesis, each house visited and any particular occupant of the visited houses will have their own codes. Therefore all record and documentation will be done on the basis of these assigned and corresponding codes for all reference, thus maintaining the confidentiality of the subjects. The address of the houses will not be used in the thesis documentation.

EXAMPLE OF SHORT SURVEY FORM USED DURING PRELIMINARY SURVEY:

Purpose of the short questionnaire and detailed content checklist

- Introduce myself to the potential case study buildings residents
- Understand their interest in the research work. Explain the need to do further detailed measurements and survey and find out if they will cooperate.
- Find out how old the house is and how many generations have been staying there. Find out the demographics of the household. This will help in deciding the human level for installation of dataloggers. For example if there are children in the family, preparations may be required as to how to prevent them from disturbing the dataloggers recordings in the researcher's absence.
- Permission to take preliminary measurements of courtyard area, surrounding wall height, each storey height, average room depth, number of windows on exterior wall and in the interior wall. Enquire if the family possessed any architectural drawings of the house.
- Should help identify two most suitable courtyard houses in relation to diversity in aspect ratio but similarity in family structure.
- Get an idea of the usability of the courtyard in the family's daily life activities and the idea of comfort in the house for different activities
- Whether the family is happy with the way the house functions or would like to move to high rise modern flats
- Perception of the house about the advantages and disadvantages of living in a courtyard house.

Possible Survey questions:

A. Demographic and general information:

1. Age: _____
2. Sex: _____

3. Religion: _____

4. How long have you lived in Calcutta? _____

5. How long have you lived in this courtyard house?

   0-10 yrs 10-20 yrs 20-30 yrs 30 or more yrs

6. How many people are currently residing in the house?
7. Are they all family members? _____ Yes _____ No
8. Kindly give me an idea of the different residents in the house on the basis of their age and work.
9. Are there times when there is a family gathering? _____ Yes _____ No
10. Which part /room of the house is mostly used for family gatherings?
11. Are there security issues related to the courtyard houses? If yes, how do you address them?

Courtyard Form and Functions:

12. Is the courtyard used for daily activities? Yes No
13. If yes, do you regard the courtyard as a private or a public space?

    _____Public _____ Private _____ Both

14. What are the most common activities in the courtyard?

    (i)

    (ii)

    (iii)

    (iv)

    (v)

15. Which family members would you suggest uses the courtyard the most?
16. Do you use the arcade around the courtyard?

17. What are the most common activities in the arcade?

    (i)

    (ii)

    (iii)

    (iv)

    (v)

18. Which is your most preferred time in the courtyard? Why?

    Morning Afternoon Evening Night

19. Which is your most preferred season in the courtyard? Why?

    Summer Monsoon Winter

Courtyard Comfort:

20. Which part of the day is the courtyard most comfortable to use? Please explain why.
21. Which part of the day is the courtyard most uncomfortable to use? Please explain why.
22. When are the following rooms used the most during a typical day-

    a. Living room

    b. Master Bed room

    c. Kitchen

    d. Dining room

    e. Puja room

Evaluative and Reflective questions:

23. Are there any advantages in staying in an old courtyard house?
24. Are there any disadvantages in staying in an old courtyard house?
25. Given a choice would you like to keep living in a house with a courtyard or move into a modern day high rise apartment? Clarify your preference.

Permission for measurement and enquiry if there are any architectural drawings available for this house.

CONTENT CHECKLIST **TIME OF VISIT:** **DATE:**

HOUSE NO: **ADDRESS:**

Schematic drawings will be made of the house with respect to the neighborhood and building plan, elevation and section for answering most of the questions.

Neighborhood Scale:

1. How is the house located with respect to the neighborhood and as per the solar orientation? Describe the impression of the neighborhood.
2. Describe the street connecting to the house. Is it only pedestrian, only automobile or both? What are its width and orientation?
3. What are prominent street activities in the neighborhood?
4. Is there a visible entry to the house?
5. Is there more than one entry to the house? If yes, how many?
6. Is any courtyard visible from the street?
7. Are there any other buildings adjoining the selected house?
8. Are they courtyard houses too? If not what kind of structures are these.
9. Are the adjoining buildings higher or lower than the selected house?

10. Photographs:
    a) Neighborhood
    b) Position of the selected house with its surroundings
    c) Entry of the house

Building and Courtyard Scale

1. How many courtyards are there in the house?
2. If there is more than one courtyard, can one of them be identified as the main courtyard?(maximum usage by occupants)
3. Is the courtyard regular in shape?
4. What are the proportions of the courtyard?

   Length

   Breadth

   Depth

   Height of south wall
5. Which direction is the entry of the house with respect to the courtyard?

   North South East West
6. Is the courtyard directly connected to the street?
7. Is the courtyard the only transition from the street to the interiors of the house? If not, describe the other transitional space.
8. Are the courtyard and the surrounding rooms at the same level?
9. If not, is the courtyard above or below from the surrounding rooms' level?

   Above Below
10. Does the courtyard have rooms on all sides?
11. Is there an arcade in between the courtyard and the rooms?
12. Is the arcade deep or shallow? Is the arcade shaded adequately?

13. Are the rooms housed in the same continuous structure or are there structural breaks between the rooms?
14. Is there a floor height difference in the structures surrounding the courtyard?
15. If yes, in which directions are the heights maximum and minimum?

    North South East West

16. Where is the living room in position with the courtyard?

    North South East West

17. Is the courtyard connected to the living room?

    Physically Yes No

    Visually Yes No

18. What are the cooling techniques used inside the living room?
19. Where is the master bedroom located with respect to the courtyard?

    North South East West

20. Is the courtyard connected to the Master bed room?

    Physically Yes No

    Visually Yes No

21. What are the cooling techniques used inside the master bed room?
22. Where is the kitchen located with respect to the courtyard?

    North South East West

23. Is the courtyard connected to the kitchen?

    Physically Yes No

    Visually Yes No

24. What are the cooling techniques used inside the kitchen?
25. Where is the dining room located with respect to the courtyard?

    North South East West

26. Is the courtyard connected to the dining room?

Physically	Yes	No
Visually	Yes	No

27. What are the cooling techniques used inside the dining room?
28. Where is the puja room located with respect to the courtyard?

North	South	East	West

29. Is the courtyard connected to the puja room?

Physically	Yes	No
Visually	Yes	No

30. What are the cooling techniques used inside the puja room?
31. Where are the toilets located with respect to the courtyard?

North	South	East	West

32. Is the courtyard connected to the toilets?

Physically	Yes	No
Visually	Yes	No

33. What are the cooling techniques used inside the toilets?

Element and Detailing Scale

1. Materials used for the following:
    a) Courtyard floor
    b) Surrounding walls
    c) Arcade floor
2. What are the colors of the surrounding walls?
3. How many windows are there in the exterior of the building and how many are there in the interiors?
4. What types of windows are there in the surrounding rooms? Height of windows.

5. Are they mostly open or closed during the time of visit?
6. What types of shading devices are used in the house?

Does the house have a second floor? If yes, what types of balustrades are used in the second floor?

7. Is the detailing used in the house typically light or heavy?
8. Does the plan and architectural details facilitate cross ventilation?
9. Are there plants and trees in the courtyard?
10. Are there fountains or sculptures in the courtyard? Why?
11. Are the inner courtyard walls lighter/ darker colors?
12. What kind of material had been used for the courtyard floor?
13. Is there any kind of heavy / light ornamentation around the courtyard in the arcades?

Personal Scale

1. How would I rank the different functions of the courtyard? Describe why.
2. If the level of the courtyard and the surrounding rooms are not same, does that design have any bioclimatic significance? Describe the thermal experience in the courtyard at the time of visit. Is the experience in different parts of the courtyard?
3. Which is the hottest and coolest part of the courtyard during visit?
4. If the level of the courtyard and the surrounding rooms are not same, does that design have any socio-cultural significance? Describe any social interaction in the space

EXAMPLE OF DETAILED SURVEY FORM

Purpose of detailed questionnaire

The detailed questionnaire should follow from the answers given in the short questionnaire. It must continuously refer to questions that had been asked and build on respondent's earlier views. The intention of the detailed questionnaire is to provide thick information regarding the building and confirm implications of information recorded through dataloggers.

Possible Survey questions:

Demographic and general information:

1. Do you have any other relatives living in Calcutta?

   In this neighborhood In another part of Calcutta Outside

2. How often do your relatives visit you in this house?

   Once a week or more Once in a month Once a year More than a year

3. Are there times when there is a family gathering? If yes, please describe.
4. How many festivals are held in or around the courtyard?
5. What are the different kinds of celebrations in the house?

   Religious (different Pujas)

   Social (wedding, poite)

   Family (birthday parties etc)

6. Is there any particular time when the house is open to public?
7. Which part of the house is given maximum public access?
8. Are there security issues related to the courtyard houses?
9. Which is your most preferred activity in the courtyard?
10. Which family members would you suggest uses the courtyard the most?

Courtyard Comfort:

1. Is the courtyard a comfortable space for daily activities?
2. Which part of the year is the courtyard most comfortable? Please explain why.

3. Which part of the year is the courtyard most uncomfortable? Please explain why.
4. How would you locate the different family members around the courtyard on typical day? (provide a plan of the courtyard)
5. Does the courtyard serve as an outdoor room?

Thermal, Ventilation, Daylighting:

1. When is the courtyard hottest during the day? Do you have to use the courtyard during that time?
2. If yes, why? If not, where do you stay during those times?
3. When is the courtyard coolest during the day? Do you have to use the courtyard during that time?
4. If yes, why? If not, where do you stay during those times?
5. Does the material of the floor of the courtyard provide any thermal relief?
6. Do you water the floor often to keep it cool?
7. When are the following rooms used the most during a typical day-
    a. Living room
    b. Master Bed room
    c. Kitchen
    d. Dining room
    e. Puja room
8. Do you use the ventilation controls of the rooms to allow cross ventilation?
9. If yes, when do you typically open or close the windows of the rooms? Why?

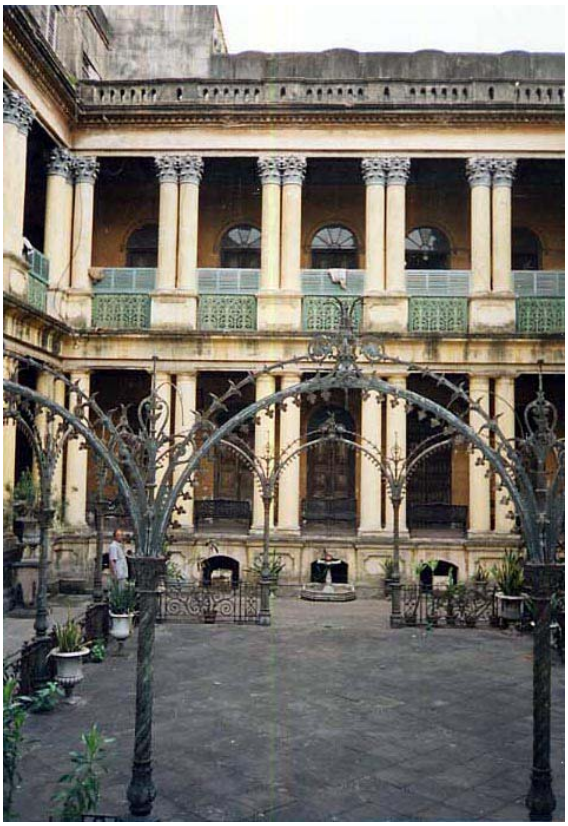
Evaluative and Reflective questions:

1. Suggest 5 ways in which you think the courtyard would have been more comfortable.

2. Our lifestyle has changed dramatically over the years. Do you feel this is true? If yes, do you think we should build courtyard type houses today?
3. Is the courtyard house economical to build and maintain?
4. Is the courtyard religiously significant?
5. Does the courtyard house have historical importance?
6. Does the courtyard have any traditional values?
7. Is there anything particular that you feel would help to make the courtyards work better?
8. Given a choice would you like to keep living in a house with a courtyard? Clarify your preference.

PHOTOGRAPHS OF THE SURVEYED COURTYARD HOUSES

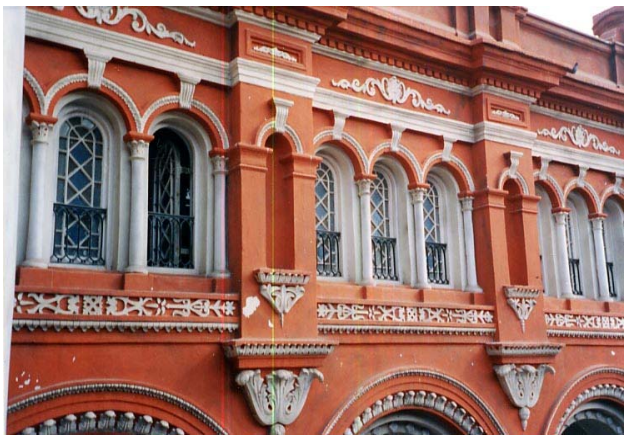
HOUSE 1



HOUSE 2

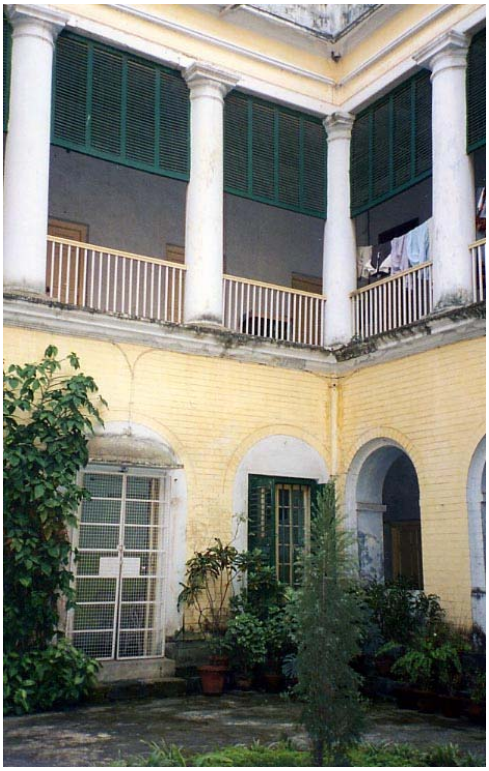
HOUSE 3

HOUSE 4

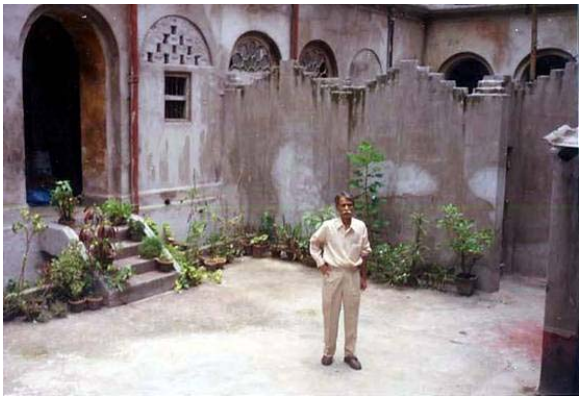


HOUSE 5

HOUSE 6



HOUSE 7



HOUSE 8

HOUSE 9

HOUSE 10