Summer in Ahmedabad: Pol House Performance
A thermal analysis of three Ahmedabad pol houses

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CARBSE Article Series

Architecture in India today is exploding. With the rise of material availability and access to ever-increasing platforms for information dissemination, the built environment seems to running further ahead and faster afield to try out new technologies and follow up fresh trends.

Alongside feverish growth and experimentation, increasing energy demands add pressure to systems running at capacity to feed the electronic hunger of the nation. In the face of these issues, research in building performance plays an ever more important role in discovering, testing and innovating better ways to use and save energy as we move toward the future. It is a balance of finding what is new and drawing value from traditions, building up a toolbox of strategies and methods to address the state of energy in contemporary India.

This series of articles uses the research of the Centre for Advanced Research in Building Science and Energy (CARBSE) at CEPT University, Ahmedabad, to look at aspects of energy research in the built environment through a variety of lenses—in studies that analyze traditional pol houses with scientific rigour, examine the optimized possibility of stone jaali performance, and explore simulation to assess courtyard effectiveness, among others.

As an interdisciplinary research hub for the building profession, CARBSE advances the use of technically sophisticated methods to assess the built environment, from traditional architecture to contemporary buildings, and shares these findings for the benefit of both practice and research. These inputs also support the Centre's objective of improving future building practices, both through better-informed design, and through the influence of policies for the built environment.

- Melissa K Smith

Introduction:

Pol houses are collected inside Ahmedabad's walled city, named for the gates that formed the entrances to neighborhood clusters embedded like cells within the city's labyrinthine network of streets. Typical of a hot dry climate, the courtyard based house form, structured by a system of party walls, evolved to create a comfortable indoor environment that responded to the local lifestyle, as well as to seasonal and diurnal changes in temperature, humidity, solar radiation and daylight.

Now, the character and composition of the physical and social structures of the city's neighborhoods is changing. Cars, motorcycles and mopeds increase congestion, noise, and air pollution, yet provide access to areas farther away. The lifestyle of the people that have evolved with this city and this climate is changing under the pressures of contemporary conveniences and global comparison. At this juncture, when high tech systems are replacing passive ones, it is useful to evaluate the thermal performance of these traditional building typologies, to determine the degree to which they respond to the local climate, and how well they achieve thermal comfort for their occupants. With this information, we can assess not only how well the buildings are performing, but also begin to make recommendations for how they might perform better for a contemporary lifestyle.

Toward that end, this study examines the impact of courtyards on the thermal characteristics of residential vernacular buildings in Ahmedabad, and its relationship to occupant use, through a comparative case study of three pol houses.
movable furniture and bedding would allow for room migration, ensuring thermal comfort during different seasons.

Background
Ahmedabad's walled city is made up of cellular neighborhood pols. Each pol contains a series of closely-knit row houses set along narrow lanes. The lanes' thin section keeps the sun off of the surface of the buildings for most of the day, which maintains a cooler, steady breeze within the streets. The densely packed houses also prevent gusts of wind, undesirable in the dusty atmosphere of Ahmedabad and in hot summer months, from disturbing the air in the residences.

Pol houses are typically built over the entire plot, with minimal street frontage. They are structured by a series of parallel, shared, load-bearing brick walls, with wooden column and beam spanning systems that also act as rigid shear elements. Floors are constructed with wooden joists, clad with wooden planks, upon which brickbat lime concrete and then stone flooring are laid. Pitched roofs of galvanized iron sheets or, traditionally, clay tiles, vary in height, catching wind that moves above the houses. The attic spaces formed by the pitched roofs shade the slab below. Semi-open multipurpose spaces are organized around the primary axis: a deep, well-shaded courtyard, which reduces the overall length of the house, and provides both ventilation and lighting to adjoining spaces by allowing hot air to rise out of the house, drawing in cooler air through the house's shaded street-level openings.

The courtyard also programmatically connects the two or three floors of the house. It is used for washing clothes and utensils, as well as for social gatherings and festivals. Most internal spaces within the pol house originally tended not to contain a particular function, like bedroom or living room, but instead were flexible in use. Easily

Case Studies: Moti Hamam ni Pol
Three houses in Moti Hamam ni Pol were selected for study. All are located near the center of the block on alleys that run from slightly southwest to almost northeast.

Hourly dry bulb temperature and relative humidity measurements in each of the houses were monitored for three continuous months, April, May and June 2011, through the strategic placement of data loggers in spaces that represent typical conditions in this type of construction. The average dry bulb temperature of all spaces increased until the end of May, and then gradually decreased. The relative humidity increased throughout. Three critical days, twenty-second to twenty-fourth May, which faithfully represented typical hot period and building usage pattern in Ahmedabad, were selected for detailed analysis.

These readings were compared with criteria from the Indian National Building Code for thermal comfort relative to dry bulb temperature, relative humidity and wind speed. Simply put, the higher the wind speed, the fewer uncomfortable hours.
attic space primarily used as store and remains closed most of the time
courtyard shaded by pitched roof, which minimizes solar radiation
at top of courtyard, opening on west allows light to enter, and enables wind-driven and stack ventilation
semi-open spaces around courtyard are used for different activities, depending on time of day and year

single bay construction of wooden post and beam spanning between two shared brick walls

west façade, constructed of wood, contains big openings for ventilation
north and south and east walls load-bearing brick north and south are shared walls with no openings
east façade contains smaller windows
courtyard used by residents for washing clothes and utensils
toilet and kitchen sit around the courtyard, which allows air circulation and ventilation

House A
1203 Moti Hamam ni Pol

Built up Area: 120 m²
Plot size: 14.2 m x 3.2 m
Total Height: 8.2 m
Age: 70 years
Residents: 7
Ownership: Occupied by same family since built
small, unused attic space at the back of the house acts as a buffer space for the four rooms on the first floor behind the courtyard.

courtyard is partially shaded at top by overhang of the pitched roof, which minimizes direct solar gains.

largest of the three houses, with largest courtyard.

makes use of interior walls to cut the span of the wooden beams, so that along the length of the house, the number of rooms varies from two to three.

central courtyard flanked on either side by ancillary rooms.

west facing entrance.

courtyard used for washing both laundry and dishes.

semi-open spaces around it hold multiple functions.

toilet and kitchen, also around the courtyard, take advantage of its ventilation.

House B
1213 Moti Hamam ni Pol

Built up Area: 201 m²
Plot Size: 14.0 m x 7.2 m
Total Height: 6.8 m
Age: >100 years
Residents: 6
Ownership: Occupied by same family since built
second floor room above first floor bedroom is primarily used for long term storage, and generally remains closed
both of the other rooms on first floor have roofs which are directly exposed to the outside
courtyard is partially shaded by eaves of the pitched roof
two brothers live on the ground and first floors with their families
follows the typical construction pattern
entrance faces east
remaining rooms fill the full span of the house

House C
1250 Moti Hamam ni Pol
Built up Area: 190 m²
Plot Size: 15.4m x 5.8m
Total Height: 8.8m
Age: >100 years
Residents: 10
Ownership: Occupied by same family since built, two brothers live on ground and first floors with families
Within the pol house, four types of space were monitored: courtyards, ground floor and first floor rooms under a flat slab, and first floor attic spaces. The variation in temperature was greatest in the attic spaces, and smallest in ground floor rooms, particularly those located furthest inside the thick walls of the house. Minor differences among the three cases indicate advantages of orientation, configuration, material and use, while major differences among types of room confirm the performance of the pol house as a climatically responsive structure, when used according to its traditional design. However, the study also found that changes in use have affected the thermal performance of the houses.
Courtyards

Courtyards principally operate as semi-open ventilation shafts within each house. Cutting through two or three floors, extensive eaves shade the surfaces that surround them. Air that enters through openings at the ground and first floor levels is flushed out through the open courtyard.

The study found that temperatures are higher during the daytime than other ground floor spaces, but nighttime temperatures are similar. For the courtyard to work, it is expected that the diurnal variation is greater than in the rooms, with higher temperatures during the day, and lower temperatures at night. This implies that in these courtyards, something is impeding optimal performance. It could be, as in courtyards A and B, that solar radiation from the sun in the peak of the day excessively heats interior surfaces. Though its diurnal variation is similar, courtyard C is slightly cooler, perhaps because on the eastern side of the house it receives little solar radiation through the large eaves that cover much of the opening.

Nighttime temperatures highlight a more critical issue. Current problems of functionality stem from blocked air inlets at the ground floor, covered courtyard surfaces, and broken ventilation paths, which reduce nighttime ventilation that could offset solar gains and improve courtyard performance.

Because the courtyard is enclosed, adjacent rooms and ground level openings throughout the house become integral to its success as a ventilating space. However, at present fear of theft tends to keep windows of unoccupied spaces closed at night. Furthermore, air-conditioned sleeping spaces cut off the path of air from the street to the courtyard. For example, the windows in ground floor bedroom C have been sealed, because it is often used as an air-conditioned space. This means that courtyard C cannot receive ventilation from the west. The only inlet for courtyard C is through the living room. But since all occupants now sleep in closed rooms, the security of the living room windows are also closed. Therefore heat is not exhausted and replaced with cool air, and courtyard C does not cool the house as designed. In addition, courtyard shades reduce solar radiation during the day, but also reduce the outlet area, which reduces wind driven and stack ventilation. Finally, decreased surface area open to sky also reduces radiant cooling at night.
Ground & First Floor Rooms

Rooms in the houses are located in the deepest recesses of the plan, hidden furthest from the sun. In ground floor rooms, particularly those nestled inside three thick walls, the temperature remains constant. During the day, this is an advantage, because it reduces the heat inside. But because the nighttime temperature in Ahmedabad summer stays above a comfortable level, the thermal mass of the thick walls that improved the temperature during the day releases warm air at night, which makes the rooms thermally uncomfortable. So despite cooler daytime temperatures, the number of uncomfortable hours is always higher than other rooms, because rooms are unable to cool down at night. This implies that it is better to use the spaces during the day and not at night.

Adjacent rooms exhibit variations that describe the importance of location with the structure. In house B, the bedroom could cool faster than the living room because of its east-facing external wall, which receives only morning sun. However, the bedroom is also helped by artificial cooling during sleeping hours, which is evident from the drop in temperature around two in the afternoon.
House C's ground floor bedroom has the lowest average daily temperature. It is air conditioned during afternoon hours and sometimes for a few hours at night as well. But this is not the only factor working to cool this room. Even during unconditioned periods, the rate of change in hourly temperature is very low, due to high thermal mass from the thick external wall and ground floor location, as well as no windows that allow direct solar radiation when the outdoor and indoor temperatures are high.

**Attics**

Attics play a critical role in performance. With thin roofs and large openings, they shade the lower floors during the day, and flush hot air out at night.

All attics recorded very high daytime temperatures for all the three months. This extremely uncomfortable condition comes from a great deal of solar radiation at a high angle of incidence from the high altitude summer sun, which rapidly heats the thin metal roof. Without any insulation, the heat is conducted as well as radiated inside, raising both the ambient and mean radiant temperature.

The attics also have lower minimum nighttime temperatures than other monitored spaces, which indicate quicker cooling. The cooling occurs for two reasons. First, a considerable drop in outside temperature at night (approximately 13-15°C) combined with big operable windows flushes out heat gained during the day. Second, the sky remains clear for most of the summer, providing excellent nighttime radiant sky cooling. The galvanized iron sheet exposed to night sky quickly reradiates the heat from the house, and cools the surrounding space. This justifies the tradition of using such roof spaces (and not bedrooms) in pol houses for sleeping during summer nights.

The diurnal temperature variation is high in these spaces, though small differences can be linked to the position of the particular room in the house, and its solar orientation. All the spaces below the attics benefit from lower temperatures during the daytime, which indicates that these ventilated buffer spaces are indispensable for providing thermal comfort to occupants on lower floors.
Conclusions: How comfortable is the pol house, and how can it be updated for contemporary living expectations and habits?

In the pol house, adjacencies are important. Air movement is important. Shade is important. These three principles work together to perfect the climatic performance of the house, and even in cases where air conditioning is preferred, they can increase its effectiveness and thereby reduce its use.

The measured data collected in these three cases supports traditional construction practices, and many of the material choices, given the limitations of availability and budget. However, the performance of the pol house is also dependent on appropriate use by its inhabitants. Shifting space usage throughout the diurnal cycle requires flexibility. Privacy, security, and cleanliness all play a role in changing expectations for the house. As habits change, parallel to advances in technology and increased expectation of both comfort and privacy, the design must also change.

This suggests that efforts should be made to increase the temperature differential within the house, which in turn naturally increases air movement. A hot attic adjacent to the courtyard can be tuned to drive stack ventilation, and used as a daytime buffer space with nighttime occupation. Focus should be on improving the insulation of the room beneath. Remaining attic areas can be cooled by improvements in reflectivity or emissivity of roofing materials.

To take advantage of the temperature driven stack ventilation, air must enter the house at lower levels. Windows should stay open at night, and rooms adjacent to the courtyard should remain connected and open. Operable and lockable jalis can address security concerns while still allowing air to flow. Even if air-conditioning is used, it should be used only in inside rooms which are the last to receive ventilation, so that it blocks a minimal path of air. However, unless the bedroom does not occupy the house’s entire breadth, air conditioning does cut off the path of cross ventilation. Where air-conditioned room cuts the overall airflow, a duct could allow air to bypass. And these spaces should still be periodically ventilated, because restricting ventilation inside the room can become an issue for indoor air quality.

At night, radiant cooling can increase the temperature differential by decreasing the house’s nighttime low temperature, which requires as big an outlet as possible for the exposure of maximum surfaces to the night sky. Because the courtyard also lets a lot of sun, any shade structure for the courtyard should be easily retractable, so that for nighttime radiant cooling, the courtyard can perform its best.

Finally, most rooms already have ceiling or table fans. This provides additional wind speed where air movement through natural ventilation is not sufficient, so even warmer conditions feel comfortable. Since fans are required anyway, they should be used not only for sensible cooling, but also organized to improve the house ventilation by means of exhaust. Typical ceiling fans push hot air down, which through air movement creates localized and perceived cooling, but does not necessarily improve the overall condition of the house. Rather, wall fans and window or door fans could be used to improve airflow as well as provide localized cooling.

Inserting contemporary strategies and technologies into the pol house can improve its performance both absolutely, and relative to changing standards and habits that contemporary residents bring to these old structures. Some architectural interventions certainly bring improvements, and reduce energy consumption. But the practices of the people living there must also be held accountable, as flexibility, particularly in regard to the use of daytime and nighttime spaces, can take best advantage of the climatic performance for which these houses have been tuned.

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