Comparative Thermal Performance of Vernacular Houses at Lucknow: A Quantitative Assessment & Dominant Multiple Strategies

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ABSTRACT

This study focuses on the comparative thermal performance of a selection of cases from three distinct generic types of vernacular houses at Lucknow, a culturally & architecturally renowned city in the Gangetic plains of Northern India. The objective of the study has been to evaluate the core urban courtyard houses, colonial adapted bungalows and semi-rural mud houses at Lucknow to ascertain which type(s) have responded to the prevailing climate better than others and what factor(s) or strategies may be contributing for its (their) improved performances. Most significantly it has aimed to search for emergent energy efficient principles applicable to the region’s composite climate characterised by hot-dry summers, cold winters and intermediate warm-humid monsoon season. This has been pursued firstly by an in-depth study of deviant cases within each generic house type with respect to Lucknow’s composite climate assessing their anticipated performances. Later simultaneous monitoring of indoor temperatures and humidity in identified periods of each season has been analysed among these cases followed by their testing against the adaptive model of thermal comfort prescribed by Nicol and Humphreys. Moreover their simulations on Ecotect software have been examined and calibrated making them suitable for extended research. Conclusively, this study has acknowledged the significance of a combined chemistry of varied strategies & sub-strategies functioning together in each house for effective thermal response in this region. Furthermore, it has given a range of multiple tactics to fall back upon instead of a myopic view of just orientation or thermal mass or others & more importantly it has substantiated the role of ventilation & air movement for the favourable thermal performance of a built envelope. As a whole this research has been useful in deriving inexpensive passive strategies useful for Lucknow also resulting in principles and recommendations suitable for the composite climate of the region.

BACKGROUND

The significance of learning from the vernacular has been corroborated by a number of scholarships that have also ascertained that, their responses to prevailing climatic conditions have been favourable. These lessons are even more meaningful in the contemporary Indian context with low energy resources and the unremitting escalating needs of an exploding population. Moreover learnings from the Indian vernacular have also established their effective thermal performances with respect to existing environments especially the hot-dry and warm-humid climates. Lucknow, is a culturally and architecturally rich North Indian city located in the Gangetic plains, experiencing a composite type climate that necessitates varied responses from a built form all through the year. Furthermore the city fabric consists of broadly three vernacular house types comprising of the core urban courtyard type, bungalow type and the semi-rural mud house type, within its precincts, that have not yet been examined for their thermal responses. It is interesting to note that all these generic house forms are distinct and varied from each other and yet seem to be thermally comfortable in the varying composite climatic conditions of the region.

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THERMAL COMFORT: SELECTED MODELS & METHOD:

A review of previous scholarships has acknowledged the role of thermal comfort as most significant within a built form that could be defined as a condition expressing satisfaction with the thermal environment. Moreover the scientific interventions for assessment of thermal comfort have included various models like the steady state (ASHRAE 55), PMV (Fanger) beside other empirical & analytical indices. These have led to the significance of adaptive model of thermal comfort which relates the outside prevailing conditions to the indoors, thus establishing that people have remained comfortable approximately to the average indoor temperature they encountered. Equations for the same have been derived by Humphreys & Nicol as $T_n = 12.1 + 0.534 \times T_m$ and $T_n = 17 + 0.38 \times T_m$ respectively, where $T_n$ was the predicted indoor comfort temperature directly determined by the outdoor temperature of a place, and $T_m$ that was the monthly mean outdoor temperature (Auliciems). These models gave a flexible thermal comfort band of 5°C to 7°C in which a person could become comfortable by short term actions or long term acclimatization validating their utility in the diverse tropical climate of the Indian Subcontinent simultaneously reducing the energy demands created by uniform steady temperature standards. Furthermore, the recognised most controllable factors affecting the thermal performance of a building envelope within the architectural premise include its Siting, Location, Orientation, Form and Massing, Spatial Organisation, Open Built Distribution, Material and Construction Techniques besides special elements responsive to existing climatic conditions. Accordingly they shall assume a significant role in selection of cases for study and the subsequent extrapolation of passive strategies.

LUCKNOW: CONTEXT CLIMATE & SELECTED STUDIES:

Lucknow city is regarded as one of the “finest cities of North India both in the architectural and cultural context” (Siddiqui 27). As a spontaneously accretive grown city, it is more a consequence of the various layers of development added to it by the diverse rules and colonisations due to which the city’s morphology is an amalgamation of organic & geometric parts. Broadly three types of house forms have developed, the most significant of them being the city courtyard houses, inhabited both by Hindus and Muslims; the bungalows that have been colonial adaptations by British; and the semi-rural mud houses present on the fringes of the city. While most of the courtyard houses are introverted and situated in the old city areas accessed by winding streets among mohallas, some later ones have formed part of newly well-defined settlements. The bungalows on the other hand have constituted of more formal well-defined spaces with extroverted arrangements set amidst large secure compounds within well-maintained cantonment or similar precincts. In contrast the semi-rural mud houses have existed as semi-introverted courtyard houses in informal clusters with an agrarian population of informal usage patterns.

All these house types have evolved in diverse contexts and conditions but have co-existed in the city for more than hundred years. Furthermore they have been built after numerous checks and balances making them vernacular in the true sense of the word. The core urban courtyard houses with shared walls have one or two courts with a single bay of rooms around it opening to narrow shaded streets within dense built contexts. Distinctly the Muslim houses have had two courtyards segregated for both men and women while the Hindu houses possessed a single courtyard both utilized for similar informal activities. Of introverted centripetal organisation, with thick lakhori brick, surkhi lime construction their roofs have been made of timber joists or jack arches. Within these, four variations were selected for the study namely Farangi Mahal house, Jannat Ki Khirki, Kaiserjahan house and Narhai house. The colonial adapted bungalows being detached monolithic units have centripetal extroverted configurations well lighted and exposed to the large open environment around them. These are made of thick walls of brick, surkhi, lime mortar and are usually single storied with flat jack arch with varied heightened roofs and verandahs in strategic directions. Within these, three variables in form of Majithia house David house and Rachna house have been selected as cases for examination. The semi-rural mud houses were semi-detached houses in clustered formations on large vegetated sites. Consisting of singly banked rooms around courtyards with transitional verandahs the selected cases consisted of the Pradhan house, Rumesh house, small mud house & Rajmahendar house. It is to be reiterated here that while the three types of
house forms at Lucknow were already generically different in terms of organisation & siting the variables amongst each case varied in terms of shared walls; orientation; fenestration percentage; Courtyard proportions and massing. The objective of the selection of the cases was to ascertain the role of specific factors in the varying thermal performances of houses within one generic type and among diverse types.

TOOLS & TECHNIQUES:

An in-depth critical review of utilised procedures and techniques for assessment of thermal performance of buildings all over the world was done to arrive at a comprehensive methodology for the study. These included theoretical studies without on-site documentation by Nevins & Dabaieh; extensive site analysis with some numerical simulations by Ford & Associates, Vinod Gupta, Ashok Lall and Campos among others; on-site monitoring with extensive site-study by Brian Ford, Kotharkar, Ahmad and Fanchiotti; simulations & site studies by Kanika Agrawal, Antarikananda, Avlokita Agrawal, Haschem and Alanzi; on-site monitoring with simulations by Arvind Krishan, Young and Summers Francoise amid others. The simulating software was selected after assessing the reviews of Crawley, Ling and Summers amid others. Subsequent to the systematic analysis the methodology devised for this study was all inclusive, incorporating a detailed recording of the selected houses being variables of each generic type of house form at Lucknow. The expected thermal performance of each study was evaluated for each case against theoretical parameters after which an onsite simultaneous monitoring by Hobo Data loggers was conducted in the living rooms of all the houses for similar periods all over the year. These results were plotted on the predicted comfort equations by both Humphreys and Nicol for the assessment of recorded data of all selected cases. Concurrently Ecotect models were developed for all cases with simulation for critical discomfort periods and tested for varying parameters. Later the results from monitoring & Ecotect were put together and analysed to assess the performance of each case to establish principles useful for this region.

ANALYSIS OF DATA & DISCUSSION OF RESULTS:

The comparative analysis of the on-site monitoring data of all studies was conducted with respect to the predicted comfort bands by both Humphreys & Nicol formulated on the basis of Lucknow meteorological data. On basis of Aulliciens a comfort band of 7 ºC width was considered as these houses utilised an adaptive informal lifestyle. The scrutiny showed that in summers the variable cases within all generic types of houses lay within the band with a difference of just 3.5°C within the closest and farthest cases. However in this season as per the afore-mentioned analysis, the city courtyard houses (Narhai house closest) generically performed better than the bungalows & mud houses. Furthermore in winters the bungalows as a type showed improved performances (Rachna house closest to desirable comfort temperature) while the city houses with larger courtyards achieved lower thermal performances & the mud houses were even worse. In monsoons generically the city courtyard houses (Narhai house followed by Jannat house) performed better than mud houses & even more so than bungalows.

On a finer analysis of the temperature data of variables within one type it was gathered that there was significant deviation within the thermal performance of one generic type meaning that in the same season one case within the same generic type performed best while another was one of the poorest amongst all cases. Notwithstanding the above, the most important inference was that within all cases the temperature variation was not great while the difference in the indoor relative humidity readings was even more minimal. In summers and winters the difference in maxima & minima was less than 5°C while in monsoons the variation was limited to only 3°C. It was also observed that the bungalows recorded the lowest diurnal variations among all cases. Relative spot readings within the same house indicated a difference of up to 2°C in the temperatures. On close observations it was found that Narhai house- a core urban courtyard house recorded lowest indoor temperature in summers while the Rachna bungalow experienced higher internal temperatures in winters whereas in monsoons Narhai and Jannat courtyard houses noted best inside conditions. These outcomes also led to the understanding that all the
selected cases of vernacular houses were thermally comfortable although the superiority of one type over
the other could not be distinctly established in any season. In fact it was realised that each house utilized
a combined chemistry of varied strategies and sub-strategies for effective responses to varied seasons.

The Ecotect simulations for each case was calibrated on basis on existing data and the
comparative assessment of their cooling, heating loads, monthly discomfort hours & temperature
distribution was made. After which these models were also simulated with varying factors of orientation,
material properties, and fenestration, shared walls, changed massing & varying shading systems. The
implications of analysis by Ecotect revealed that the maximum heating loads were required by the Small
Mud House while Rachna Bungalow and Narhai House needed minimum heating loads. Alternately
maximum cooling loads were used by Pradhan House and minimum by Majithia, Narhai and
Rajmahendar Houses. The living areas of all houses exhibited more constant hourly temperature profile
than the other rooms. Variations in the simulation models also revealed the change in loads with
modifications in upper floors, shared walls, orientation, fenestration, shading and materials that have
been summarised in the coming paragraphs.

CONCLUSION

The most significant inference of the study was that all the generic vernacular house types of
Lucknow were found to be thermally comfortable in the varying seasons of the region due to diverse
multiple passive strategies adopted by them to counter the extremities of outdoor conditions. While the
superiority of thermal performance of one generic type over the other could not be distinctly established
in any season it was evident that the combined chemistry of varied strategies & sub-strategies were
utilized by each case for effective thermal response to the existing climatic conditions of Lucknow. The
architectural study of the selected cases within each generic type and across types revealed the passive
strategies and sub-strategies utilised by the variants for effective response to prevailing climatic
conditions. The core urban city courtyard houses employed siting amid narrow mutually shaded dense
winding streets with minimal fragmented spaces whereas the bungalows comprised of siting in large
open airy heavily foliaged sites. The mud houses on the other hand used a combination of the above
with dense clusters amid large open sites. Furthermore the city houses had multiple shared walls with
staggered massing of over floor to counteract heat gain & provide shade while the bungalows employed
a minimised envelope with shaded verandahs and trees on periphery for the same. The mud houses on
the other hand used partial shared walls and shading from adjoining large trees. Moreover the city and
mud houses have used introverted courtyard plans with minimal outside fenestrations for preventing heat
gain while bungalows have utilised large fenestrations opening into shaded verandahs and high ceilings
with ventilators for enhancing convective cooling & ventilation. The use of high thermal capacity
materials with high thermal lag in all the houses has contributed to constant temperatures all day and
over the year.

It was also quantified by simulations of the selected cases that, the use of high thermal mass in
building elements could improve the performance of the envelope to 70% but would prove detrimental
without night purge ventilation validating the role of ventilation versus insulation. Furthermore it was
observed that the strategy of orientation of vertical facades with respect to sun has been largely overrated
in this region for structures below 3 stories. It contributed to a deviation of only 5 to 10% whereas the
influence of effective mutual shading could improve the performance up to 30%. This study also
substantiated that although solar radiation assumed maximum significance within the tropical Indian
climate the role of wind and air movement had to be taken into account for favourable thermal
performance of built envelope. Moreover Roof shading has shown to be extremely effective in this
climate while effective massing improved the performance of lower floor up to 45%. Effective Shading
of walls & fenestration have shown to reduce heating & cooling loads by 30% while presence of small
courtyards has also indicated usefulness in all seasons. Verandahs as shading devices have exhibited
significance & have a larger role to play built forms at Lucknow to articulate facades provide shading &
prevent thermal shock in extreme outdoor conditions. The recommended Fenestration proportions have
seen to work more effectively in combination of ventilators & doors reducing loads by up to 32%. The study also showed that a non-parochial view of materials was to be required and their role in a combined assembly system should be assessed.

Furthermore Simulative modelling techniques have made visualisation and subsequent design much easier but the study resolves that the unrestrained use of simulation software’s without an assessment of real conditions are a cause of concern because despite multiple configurations they underestimate the role of wind and air movement. Furthermore in simulative models insufficient credence is given to adaptations due to physical actions in actual environments leading in inaccurate results. Especially in the case of naturally ventilated buildings in the Indian climate their role has to be examined more closely and thus selected with extreme care that would need to be calibrated with actual on-site data. India is fast becoming a global phenomenon as a result of which modern living comparatively has become more inflexible with minimal space reallocation even in the extreme conditions. In an age of fast depleting resources and power crisis learning from the adaptive and flexibility principles of the vernacular makes sense to restrict reliance on active systems of cooling and heating loads

REFERENCES