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Encouraging Indigenous Architecture for Sustainable Urban Growth – case of Kolkata

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Abstract

Over the last few decades, urban centers have experienced a steady environmental degradation, contributing to an overall lack of comfort in them. Kolkata, a prime urban megalopolis in the Eastern Gangetic plain of India, is no exception to this phenomenon. In today's city-centric development, urban centres have turned into heat sinks. This rise in temperature is instigating the citizens to use more of mechanical cooling devices, which in turn increase the external temperature by throwing out the inner heat of the building outside, thus creating an endless cycle. Sustainable development approaches of Smart City initiative have recently encouraged planners and architects alike to think and act in order to break this cyclic climatic degradation.

The first part of the paper intends to inspect these critical climatic conditions on a tangible measurable platform, thus establishing the need for a planned intervention into it. This paper then intends to tap a non-conventional solution to the problem. It hypothesizes the comparative supremacy of old indigenous buildings of the existing urban fabric of Kolkata over its newer buildings, and then inspects and tests the hypothesis through climatic measurements carried out in both indigenous and newer buildings.

Analysis and inferences drawn from the climatic measurements would prove the hypothesis to be right or wrong. If the supremacy of indigenous structures is proven, it would then be the onus on the lawmakers to incorporate the unique design inputs of the old buildings into the newer architecture judicially in order to achieve a better thermal performance of the latter.

Key words

Indigenous Architecture, Thermal performance, Sustainability

1. INTRODUCTION

The climatic zoning map of India reveals most of it falling under hot regions having extreme summer conditions. These zones, during the three long months of summer in India, suffer from the extreme heat conditions that becomes further unbearable when coupled with high humidity levels. For last few decades, the hot metropolitan urban centres of India are getting warmer, and future predictions by the end of the century portray a very grim future for their residents [1].

This increasing thermal discomfort is increasing the use of air conditioning in built environment by those who have the affordability to do so. Ironically, the use of air conditioning is further contributing to the urban heat sinks, making micro-climatic zones having higher temperature than their surroundings [2].

The income disparities of Indian population has grown drastically, where the top 1% of the population (in terms of their wealth) has seen a steady increase of over 5% since the turn of the millennium, whereas the bottom 50% in the income table has seen a sharp fall of almost the same 5% during the same tenure [3]. The constant rise in thermal discomfort of the urban centres affects this lower 50% of the population, who mostly has to undertake tertiary sector jobs and thus can afford no better than the minimum comfort of basic housing – circumstances that deny the indoor comfort of conditioned houses. A solution must have to be sought to arrive at an acceptable solution – a solution that would be equitable to all economic strata of the society, and would be sustainable even till the distant future. Research has shown that vernacular and indigenous houses, by virtue of being developed over prolonged period of time and thus respecting the local climate to a larger extent, are frequently found to be more climate responsive and thermally comfortable. This paper thus turns toward the old climate-friendly architecture of yester-years, seeking solution from their indigenous knowledge.

Kolkata, erstwhile capital of British Indian Empire as Calcutta, has a legacy of indigenous buildings that blend the traditional Indian architecture of medieval Bengal along with the European architecture brought in by the colonial British rulers. The paper explores these indigenous houses of Kolkata and assesses their thermal comfort against their modern counterpart to seek solution to counter-balance the growing thermal discomfort condition of Indian cities.

2. AIM AND OBJECTIVE

The paper aims at assessing whether indigenous architecture of Kolkata performs better than the contemporary style of architecture in the residential sector. This assessment was based on comparison of outdoor climatic data vis-à-vis thermal comfort data inside various residential buildings sampled in the research.

The research had an objective to record climatological data for sample number of indigenous as well as contemporary residential buildings, and then find out, through analysis, which one performs better under the same climatic condition during summer months in Kolkata, India.

3. KOLKATA & INDIGENOUS ARCHITECTURE

The city of Kolkata was historically founded by a British merchant by the name of Job Charnock in the year 1690 on the bank of river Hooghly, a branch of river Ganges in India [4]. Although chronology of establishment of British Calcutta is dated as 1690, major building activities started after the East India Company defeated the Nawab of Bengal in 1757 in the Battle of Plassey. Indian Independence, in 1947, however gave wake to a new typology of buildings that followed the American architectural practice as well as the post-War European architecture to a great deal. The architectural typologies of the city, therefore, have been divided into three distinct temporal groups as follows:

(a) Pre-Colonial Period (from antiquity till 1757)

• Original mud and bamboo houses of Bengal

• Brick and stone houses of Muslim Bengal

(b) Colonial Period (1757 – 1947)

• Brick and iron (later steel) houses of British colonial Calcutta

• Indigenous *pucca* houses of local rich landlords, merchants and well-off citizens

(c) Post Independence Period (since 1947)

• Post-world war and post-independence american influence on architecture

• Recent “international” style houses of kolkata – RCC and Glass Facades

In the following section, brief introductions on the three typologies have been given.

3.1. Pre-Colonial Architecture of Kolkata

Calcutta, before the advent of British East India Company, was a hamlet – full of flora and marshes located in the buffer area of Sunderbans Forest, the largest mangrove forest of the world. The settlement had the traditional built form of northern Gangetic plain of India – mud house with bamboo support and sloped roof covered with either tiles or thatch [5]. Pukka houses belonging to the wealthy used terracotta bricks, small in size, or stone for constructing their mansions. The design of these mansions followed the medieval building typologies having various layers of privacy [6].

3.2. Colonial Architecture of Kolkata

Under the British rule the city of Calcutta grew as one of the largest urban centre of Asia. Being the capital of the empire, the city not only housed important government buildings or mansions for the ruling class, it also accommodated the Indian administrative class of kings, nawabs, zaminders and merchants, along with their beautiful palaces. These buildings owed their design legacy from various sources –

(a) The traditional courtyard-centric house-forms of rural Bengal [7]

(b) The medieval socio-economic lifestyle of the Bengal and their design similarity with Haveli of northern India [8], and

(c) The British architecture and construction from the time of Renaissance and post-Industrial Revolution Europe [9].

The amalgamation gave birth to two distinct genre of architecture, viz. the British Mansions designed and meant for the rulers and the Indigenous Palaces and Houses, meant to accommodate the Indians [10]. Primary building material of this era were burnt bricks, timber, iron steel, glass and stone (for cladding) [11]. The paper, in its study, considers the latter as one of the prototypes.

3.3. Post Independence Architecture of Kolkata

The end of the Second World War saw a steady influx of population into the city from its hinterlands. The fear of Japanese aggression on the eastern border of British India and the devastating famine of Bengal attributed to this. As a result, a new resident design typology emerged that put more importance to utilization of space than luxury of abundance. This design approach initially borrowed from the American free plan of the early 20th century, but soon turned towards the more utilitarian way of steel or RCC frame and brick and glass skin structures, colloquially called the International style of architecture [12].

3.4. Climate Condition of Kolkata

Figure 1: Climatic zone map of India as per Koppen's classification

Climate data for Kolkata (Alipore) 1971–1990 [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	32.8 (91)	38.4 (101.1)	41.1 (106)	43.3 (109.9)	43.7 (110.7)	43.9 (111)	39.9 (103.8)	38.4 (101.1)	38.9 (102)	39.0 (102.2)	34.9 (94.8)	32.5 (90.5)	43.9 (111)
Average high °C (°F)	26.4 (79.5)	29.1 (84.4)	33.5 (92.3)	35.3 (95.5)	35.4 (95.7)	34.0 (93.2)	32.3 (90.1)	32.1 (89.8)	32.4 (90.3)	32.3 (90.1)	30.3 (86.5)	27.0 (80.6)	31.7 (89.1)
Daily mean °C (°F)	20.1 (68.2)	23.0 (73.4)	27.6 (81.7)	30.2 (86.4)	30.7 (87.3)	30.3 (86.5)	29.2 (84.6)	29.1 (84.4)	29.1 (84.4)	28.2 (82.8)	24.9 (76.8)	20.8 (69.4)	26.9 (80.4)
Average low °C (°F)	13.8 (56.8)	16.9 (62.4)	21.7 (71.1)	25.1 (77.2)	26.0 (78.8)	26.5 (79.7)	26.1 (79)	26.1 (79)	25.8 (78.4)	23.9 (75)	19.6 (67.3)	14.5 (58.1)	22.2 (72)
Record low °C (°F)	6.7 (44.1)	7.2 (45)	10.0 (50)	16.1 (61)	17.9 (64.2)	20.4 (68.7)	20.6 (69.1)	22.6 (72.7)	20.6 (69.1)	17.2 (63)	10.6 (51.1)	7.2 (45)	6.7 (44.1)
Average rainfall mm (inches)	11 (0.43)	30 (1.18)	35 (1.38)	60 (2.36)	142 (5.59)	288 (11.34)	411 (16.18)	349 (13.74)	288 (11.34)	143 (5.63)	26 (1.02)	17 (0.67)	1,800 (70.87)
Average rainy days (≥ 1.0 mm)	1.2	2.2	3.0	4.8	8.7	14.7	20.5	20.2	15.7	8.1	1.5	0.9	101.5
Average relative humidity (%)	66	58	58	66	70	77	83	83	81	73	67	68	71
Mean monthly sunshine hours	203.9	201.2	225.8	235.4	227.1	123.1	93.1	104.9	116.2	182.6	190.8	203.4	2,107.5

Figure 2: Climate condition table of Kolkata [https://en.wikipedia.org/wiki/Kolkata]

Kolkata has Tropical Wet and Dry climate, having humid to very humid climate for most of the year and a relatively dry winter (Fig. 1). Temperature can go up to 43.9°C during summer in June, and a simultaneous high humidity condition further aggravates the situation (Fig. 2).

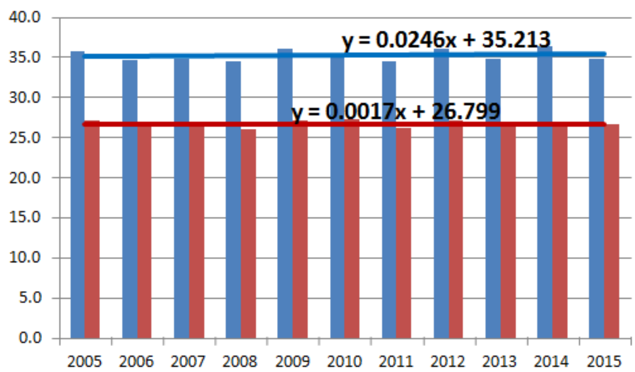

Figure 3: Fluctuation of Maximum and Minimum Temperature across years from 2005 till 2015

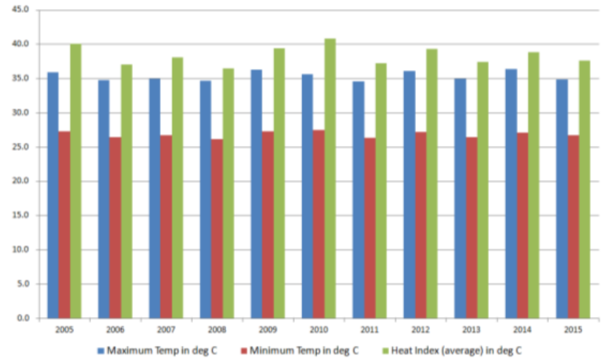

Figure 4: Kolkata – Climate Trend during 2005 - 2015

The above figures, derived from the meteorological data recorded during 2005 – 2015 shows the present condition of climate of Kolkata during the summer months. Whereas figure 3 shows a steady rise, both in the maximum as well as minimum temperature, figure 4 shows us how, except 2009 and 2010, the composite Heat Index of Kolkata is also on a rise.

This particular phenomenon, inherent mostly in urban centers of India, is due to building up of heat sinks in cities. These localized heat sinks necessitate an increased use of air conditioning to enhance the indoor thermal comfort [13]. The air conditioners, on the other hand, 'throw' the heat outside – thus contributing and aggravating the heat sinks. The climatic scenario of summer months in Kolkata thus states an un-deniable fact that solutions to attain better indoor thermal comfort must come from some alternate path of creating building envelopes that would be more 'insulating' and those which 'breathe' better than the present day solutions.

4. RESEARCH METHODOLOGY

The research thus aimed at selecting certain buildings from the city of Kolkata that became its case samples. These buildings were chosen from two major types –
(1) Old indigenous residences, the criteria for selection being residential buildings older than 1947 and not more than 4 storey high. For the purpose of study 2 buildings were chosen as follows –
(a) Chakraborty House at Nebu Bagan By-lane, Bagbazar, Kolkata

(b) Lahiri House at Khidirpur, Kolkata

(2) New residential buildings, preferably not more than 30 years of age and not more than 4 storey in height. For the purpose of study, three new buildings were chosen as follows –
(a) Roy Residence at Bangur Avenue, Kolkata

(b) Datta Residence at Kombuli Tala By-lane, Bagbazar, Kolkata

(c) Mitra Residence at Bangur Avenue, Kolkata

Brief description, along with plans and photographs of these study houses are given below for perusal.

4.1. Chakraborty House, Bagbazar

This house, built between 1890 – 1900, is a three storied building designed to enclose a courtyard as an L-shaped mass (Fig. 5). The structural system of the house is load bearing wall and cement concrete slab, with steel joists used for spanning the long living rooms. Originally built as a double storied residence, the third floor was added after independence.

Figure 5: Floor plans of Chakraborty house

4.2. Lahiri House, Khidirpur

Built between 1870 – 1875, this house was originally designed for a wealthy feudal *zamindar* family. After independence, a portion of the double storey mansion was acquired by the Lahiris (Fig. 6), descendants of whom stay in the house now. The house suffers from dereliction due to want of adequate repair and maintenance. Originally meant to enclose a courtyard on all three sides, partial acquisition of the mansion by different owners has resulted into loss of identity for each part. Independent and non-coherent repair and modification has also contributed to this. However, much of the original massing and construction is retained in the portion under study and hence, the spatial and thermal originality is also ensured.

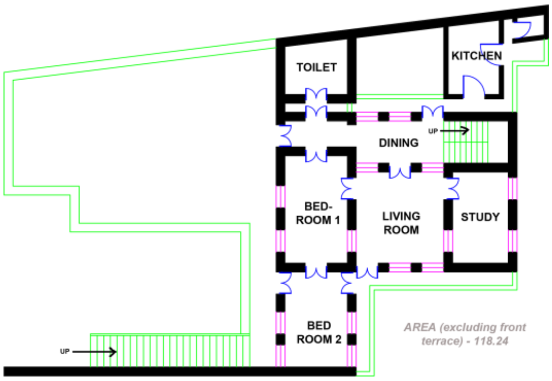

Figure 6: Plan of Lahiri house

4.3. Roy Residence, Bangur Avenue

The residence of Roy is a dwelling unit in a multiple unit apartment building. These types of residential buildings are now most common in Kolkata. Because of the design restrictions, these dwelling units, in most cases, remain deprived of openings on any 2 – 3 cardinal directions. The building housing the Roy family has been built during 1985 – 90, and is a G+3 storied house. The Roy residence is in the 2nd floor (Fig. 7).

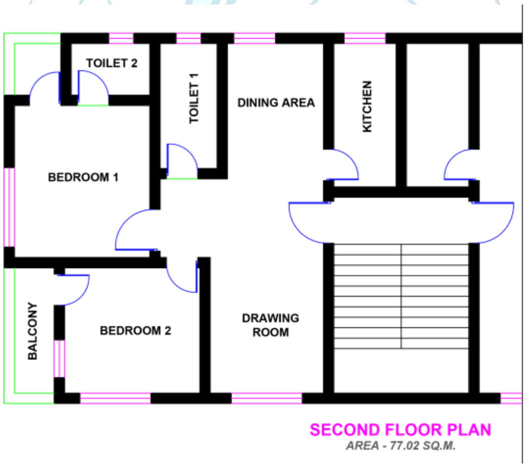

Figure 7: Plan of Roy residence

4.4. Datta Residence at Kombuli Tala By-lane, Bagbazar

The residence of Dutta family is housed in the 2nd floor of a G+3 storied house that has been built in 2014 (Fig. 8), and is the latest of all the three new houses studied. It actually comprises of two dwelling units fused together, and is therefore open on all sides, unlike other study units.

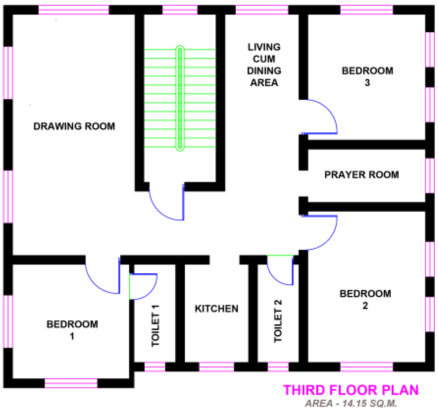

Figure 8: Plan of Dutta residence

4.5. Mitra Residence at Bangur Avenue

The Mitra residence is the smallest and most constricted of all 5 buildings studied as part of the research. It is a unit located in the first floor of a G+3 storied building. Only very small portion of it enjoys external openings on the south and west side. Unlike other houses studied, this unit is shaped elongated (Fig. 9).

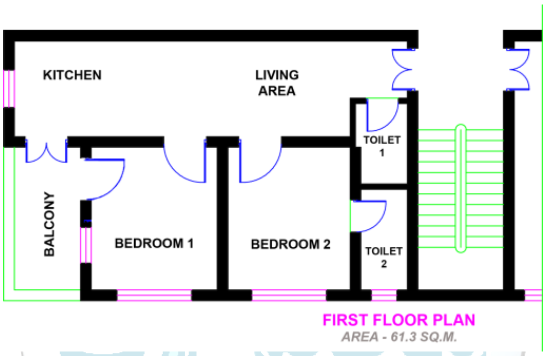

Figure 9: Plan of Mitra residence

5. DATA COLLECTION AND ANALYSIS

The temperature and relative humidity data are collected with the help of Data Loggers simultaneously in all the 5 residence in the end of May, 2017 for continuous 48 hours (2 days) at an interval of 30 minutes. Hence, each dataset is comprised of approximately 200 observations.

On the basis of these data, the value of thermal perception in the form of Heat Index is calculated as per the following equation (given by NOAA National Weather Service website) [14]:

HI = -42.379 + 2.04901523t + 10.14333127r - 0.22475541tr - 0.00683783t2 - 0.05481717r2 + 0.00122874t2r + 0.00085282tr2 - 0.00000199t2r2

where,

HI = Heat Index (in degree Fahrenheit)

t = Ambient Dry Bulb Temperature ((in degree Fahrenheit)

r = Relative Humidity (percentage value between 0 and 100)

The findings have been put into line diagram charts, and the diagrams and their respective observations are discussed in the following section.

5.1. Chakraborty House, Bagbazar

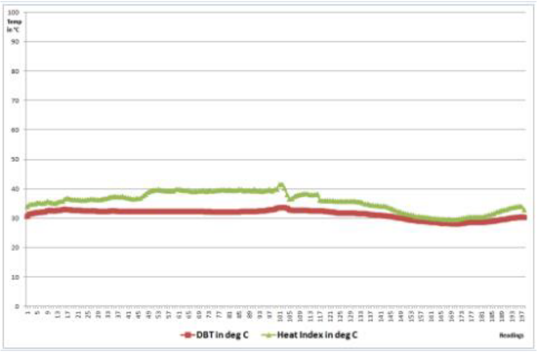

Figure 10: DBT and HI curve for Chakraborty house

Figure 11: Relative Humidity curve for Chakraborty House

5.2. Lahiri House, Khidirpur

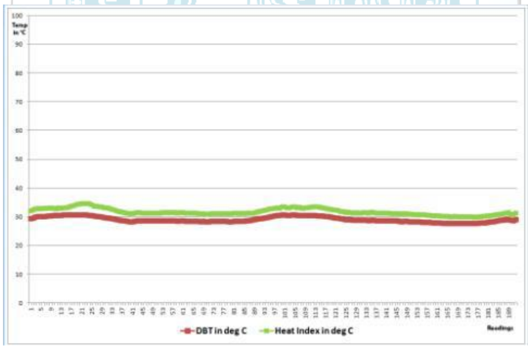

Figure 12: DBT and HI curve for Lahiri house

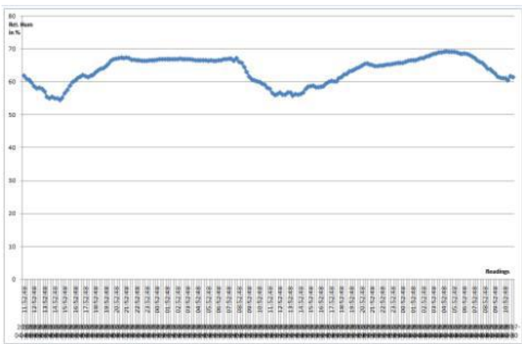

Figure 13: Relative Humidity curve for Lahiri house

The heat index values for the old building of Chakraborty family (Fig. 10) as well as that in the old building of Lahiri families (Fig. 12) show a trend running parallel to the dry bulb temperature, with almost no fluctuation in its value.

5.3. Roy Residence, Bangur Avenue

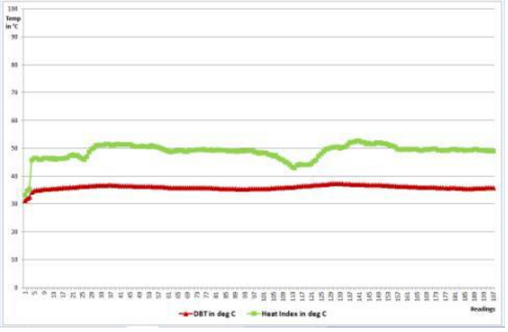

Figure 14: DBT and HI curve for Roy residence

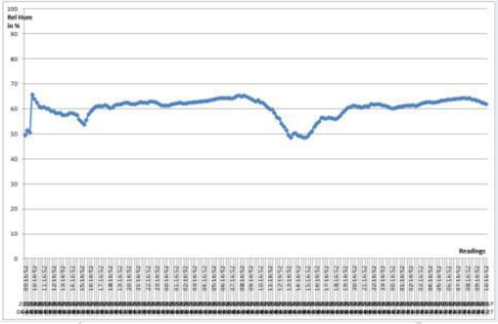

Figure 15: Relative Humidity curve for Roy residence

5.4. Datta Residence at Kombuli Tala By-lane, Bagbazar

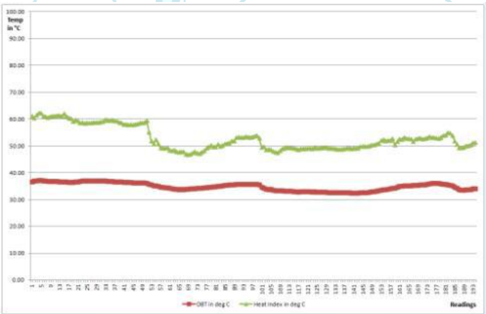

Figure 16: DBT and HI curve for Dutta residence

Figure 17: Relative Humidity curve for Dutta residence

5.5. Mitra Residence at Bangur Avenue

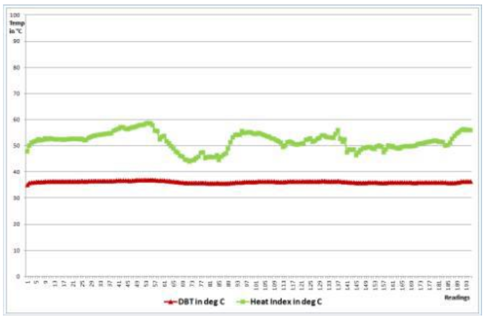

Figure 18: DBT and HI curve for Mitra residence

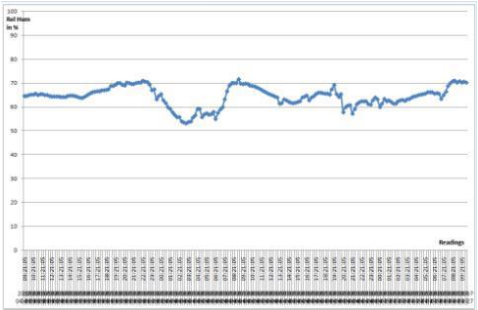

Figure 19: Relative Humidity curve for Mitra residence

The graphs showing variation of temperature in the residences of Roy (Fig. 14), Dutta (Fig. 16) and Mitra (Fig. 18) shows a sharp rise from the trend shown by the recorded DBT. This can be attributed to the fluctuations of RH in the new buildings (Fig. 15, 17 and 19).

5.6. Comparative Analysis

A comparison of the findings show that while in the old buildings the trend of Heat Index does not shift much from the DBT curve, in the new buildings the HI curve has fluctuated considerably. As Heat Index is the factor responsible for the actual comfort condition of the inmates of the houses, a sharp rise in its value grossly deteriorates the overall comfort condition of the house. Further analysis of the data recorded and computed therein in Table 1 below also shows this wide gap between the average values of DBT and HI in the new buildings (*column 4*), especially in comparison to the conditions in old buildings.

Table 1: Comparison of Average Temperature condition in Surveyed Houses

Building Name and Type	*Average Dry Bulb Temperature (DBT) in °C*	*Average Heat Index (HI) value in °C*	*Difference in °C*
(1)	*(2)*	*(3)*	*(4)*
Chakraborty House, OLD	**32.30**	**36.67**	**4.37**
Lahiri House, OLD	**29.94**	**32.56**	**2.62**
Roy House, NEW	**36.89**	**49.51**	**12.62**
Dutta House, NEW	**35.65**	**53.65**	**18.00**

A vertical comparison along column (2) of Table 1 also shows that while the average DBT in the old buildings is 31.12ºC that for the new buildings is 36.27ºC, with a considerable difference of over 5ºC. However, a comparison of column (3) of the table shows a difference of almost 17ºC between the HI of old buildings being 34.62ºC and that of new buildings being 51.58ºC.

6. CONCLUSION

Thus the collected and analysed data indicates to prove the hypotheses "Old Indigeneous Houses are Thermally More Comfortable than Newly Designed and Constructed Houses" to be CORRECT.

This may, however, be contributed to many factors, such as

- Higher thickness of wall.
- Better cross ventilation due to strategic location of windows.
- Existence of courtyard in house – leading to more of stack effect.
- Shading devices outside openings, locally known as chajjas.
- Use of local materials such as burnt bricks, lime, mud etc over non-indigenous materials such as cement and glass.

The paper thus concludes with a note to further the research to establish, in due course of future studies, concrete relationships between various contributing components of a building to its thermal comfort. This will, the authors envisage, propagate a guideline to create more suitable building design guidelines arising out of the actual climatological and geographic context of the city of Kolkata.

BIOGRAPHY

Sanmarga Mitra is an architect from Jadavpur University, Kolkata and a planner from IIT Kharagpur. He is Assistant Professor in the Department of Architecture, SPA Bhopal, INDIA and has been teaching architecture and planning in Birla Institute of Technology, Mesra and its International Centre at Ras-al-Khaimah, UAE for a decade previously. His interests are in history of architecture and structural behaviour of buildings. He is presently pursuing research on thermal behaviour of indigenous and traditional buildings.

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