Performance of Naturally Ventilated Buildings in a Warm-Humid Climate

A case study of Golconde, Pondicherry, South India

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ABSTRACT: Built between 1935 and 1942, Golconde is the first modern reinforced concrete building in India. After 75 years it still remains as one of the most outstanding examples of climate responsive buildings in the country. Though some books have been published on Golconde, it has never been analysed with detailed data logging and scientific analysis. This paper will present some of the various passive design strategies employed to ensure thermal comfort without the use of a mechanical cooling system. Among others, the building's surrounding vegetation, its orientation minimizing solar exposure, the ventilated double roof and the louvers working as solar shading devices are appropriate and efficient strategies for the Indian tropical climate context. The hourly data collected for air temperature, relative humidity and surface temperature over one and half years was used to analyse the impact of those passive strategies on the indoor conditions. This exemplary case study represents a strong case for constructing climate responsive buildings which could address the energy crisis in many countries.
Keywords: Warm-humid climate, Golconde, naturally ventilated building, passive strategies, data logging

Figure 1: Golconde

INTRODUCTION

In today's context, India is facing a formidable challenge in providing an adequate energy supply to one of the fastest growing energy markets in the world. The building sector's energy consumption, accounting for 35% of the nation's energy use, is growing by 8% annually (Climate Works, 2010). As a result of India's rapid economic expansion and urbanization, the floor-space growth in the commercial and residential sector is expected to add the equivalent built area of a new Chicago every year (McKinsey, 2010).

Given the increased intensity of energy use, coupled with the changing lifestyles of 1.2 billion people on a quest for an improved quality of life, India must address competence and efficiency in this sector.

The coming decade provides an immense opportunity to realize, in practice, the potential for significant energy savings through the construction industry. It would be interesting to study good examples from the modernist movement and check their viability in today's context especially for tropical regions. This could advocate environmental sensitivity as a foundation for the design process.

As a part of the five year Indo-US joint research program on the energy efficiency of buildings (2012-2017) named "Centre for Building Energy Research and Development" (CBERD), efforts are being made to provide tangible scientific results that lead to a significant reduction in energy use in buildings in both nations.

This paper will present some of the results of the detailed research being carried out on one of the buildings selected under the CBERD program - Golconde Dormitories of Sri Aurobindo Ashram – a place for disciples and long term visitors, following the integral yoga of Sri Aurobindo and The Mother.

Figure 2: Location of Golconde within the Boulevard area, Pondicherry

It is located in an urban setting within the old city precinct (Boulevard area) in Pondicherry, India, (12°N, 80°E). Designed by architect Antonin Raymond, Golconde is the first reinforced concrete building in India, and is still admired for its outstanding maintenance and thermal performance. By using various passive strategies, this building has been designed to ensure thermal comfort without the use of mechanical ventilation or cooling system. Although built eight decades ago, Golconde still remains as an excellent climate responsive building in a warm-humid climate. This is the first time that such detailed study with extensive data logging over a period of one and a half years has been undertaken.

This paper aims to demonstrate that there is a lot to be learnt from a good understanding of the local climate and use of passive design principles which can pave the path to reduced energy demand.

GOLCONDE: SITE CONTEXT AND DESIGN

The building is oriented with its longer axis North-South, with a tilt of 20° E of South as shown in Figure 3.

Figure 3: Golconde Basement Plan & Elevation

It has 51 rooms across 3 floors and a semi-basement. Both the north and south facades are equipped with individually operating horizontal asbestos louvers which provide protection from the sun, wind and rain, while allowing for ventilation, ensuring the best combination between natural daylight and solar heat gain. Since it is an occupied building, the louvres are manually operated according to the user's needs, mostly being closed during the day and open during the night.

Access to the rooms is through a continuous corridor along the northern side of the building which also acts as a thermal buffer to the internal spaces. Rooms are separated from the corridor by teak wood sliding doors with staggered slats which not only allow air to circulate freely when open but also when the doors are closed. The framed RCC structure has been left unplastered, while the walls which are made of burnt brick (210x100x55mm) have a special "Chettinad" lime plaster, which is still in its original state. The east and west walls contain little or no openings to reduce the solar heat gain. All the furniture is designed by George Nakashima (site architect) and done in Burma teak. The floor is made of polished black Cuddapah stones of 63.5x63.5cm with 5mm butt joints. The carefully landscaped gardens on the North and South side are designed to further enhance the thermal performance.
Golconde's unique ventilated double roof consists of a reinforced cement concrete (RCC) slab covered with precast concrete shells with an air gap of 10-30cm in between.

Figure 4: The Roof

These detailed design interventions keep the insides of Golconde as cool as possible without mechanical ventilation. The comprehensive integration of orientation, structure, interior design and landscaping strategy, adhere to the basic principles of simplicity without being austere, and having a closeness to nature.

A recent case study carried out in the Reunion Island on a building (ENERPOS) which uses similar strategies such as orientation, landscaping, louver system, ventilated double roof, also proves the efficacy of these passive strategies in terms of thermal performance (Aurélie et al., 2011).

CLIMATE CONTEXT

With globalization, our buildings are often standardized and we seem to forget the local constraints and particularities that need to shape them. The bio-climatic concept is one of the pillars of low-energy and sustainable buildings. Consequently, an analysis of the climate context is of prime importance. For this study, the weather station of Auroville, which is the closest to Pondicherry, was used.

The proximity of The Bay of Bengal has a direct impact on the high humidity recorded and the relatively slight temperature fluctuation across the seasons (Figs. 5 and 6) (Auroville Weather Station, 2015).

The annual temperature trend curve is opposed to the annual relative humidity (Rh) trend curve (which is a typical trend between temperature and Rh). During June, the hottest month of summer, temperature peaks reach 40°C. For the same month, the relative humidity average is 65%.Summer is followed by monsoon (i.e. August to November) and marks a clear change in humidity values due to abundant and regular rainfall. The sun path diagram (Fig. 7) shows the sun angles being furthest north during June and furthest south during December (summer and winter solstices).

Based on this analysis and keeping in mind the constraints of this paper, we have concentrated on 21st June (Summer Solstice).

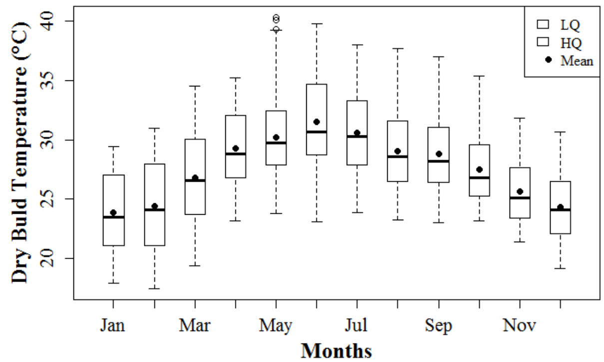

Figure 5: Monthly outdoor air temperature, Auroville, 2014

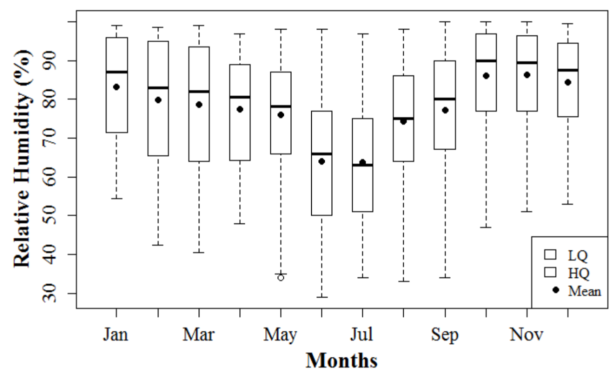

Figure 6: Monthly outdoor humidity, Auroville, 2014

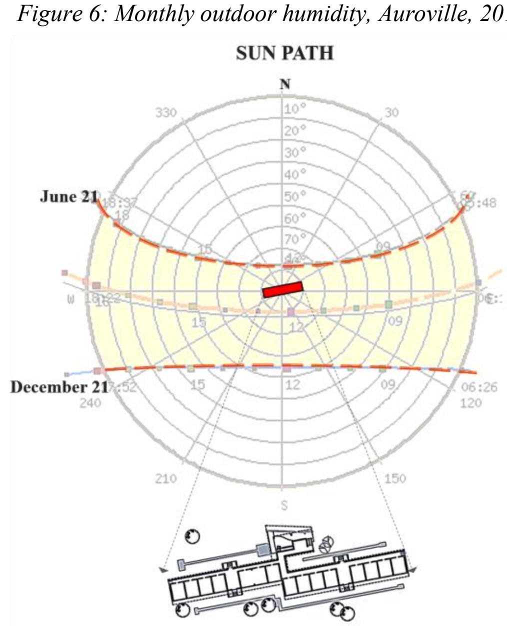

Figure 7: Sun Path Diagram, Golconde, Pondicherry

GOLCONDE, FLOOR PLANS

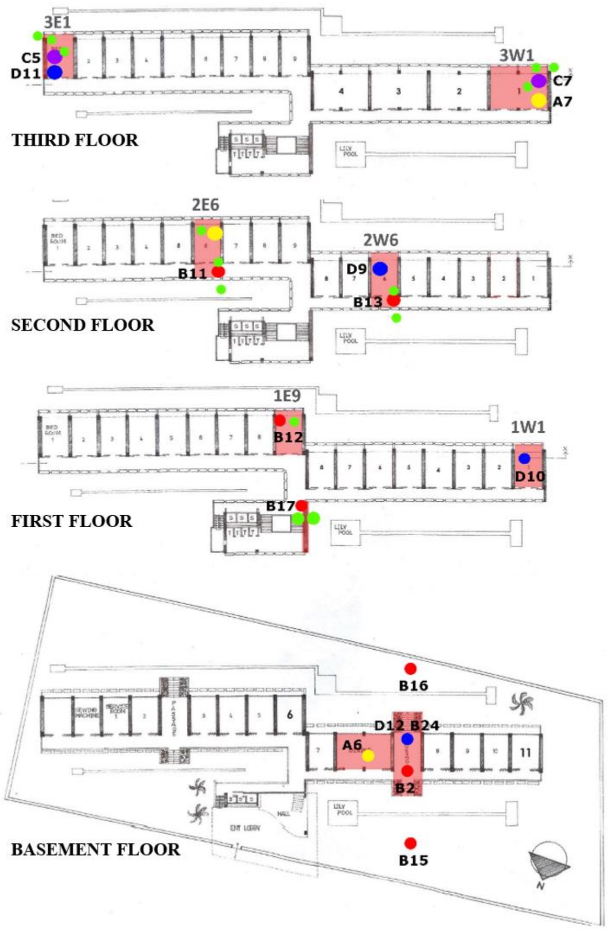

Figure 8: Loggers placement, Floor Plans, Golconde

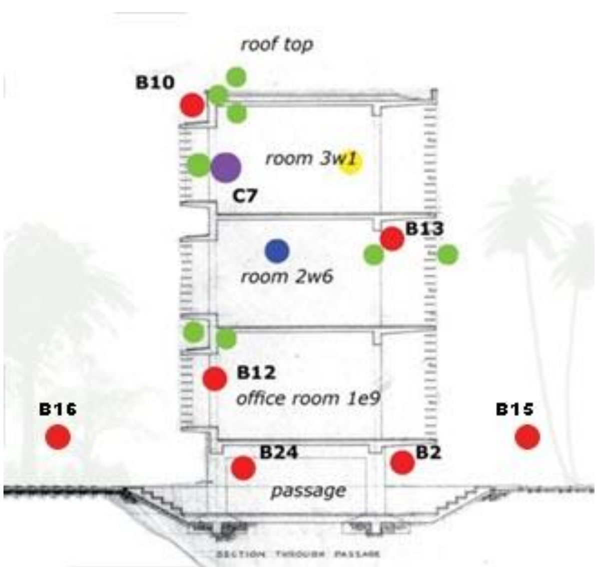

Figure 9: Loggers placement, section, Golconde

MONITORING METHODOLOGY

A market survey was done and the most appropriate loggers / sensors were identified and procured. 17 loggers (with built-in air temperature and humidity sensors) and 17 surface temp sensors were installed in Golconde. In order to verify the accuracy of the measurement, the handheld and logger temperature measurements were cross-checked.

Onset HOBO^{TM} data loggers, Testo 410-2 and Ex-Tech 30 were used to monitor the air temperature and Relative Humidity.

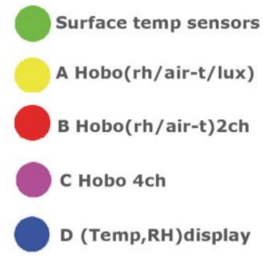

Figure 10: Key for the Loggers placement

VENTILATED DOUBLE ROOF

Golconde's ventilated double roof consists of an RCC slab covered with precast concrete shell and a ventilated air gap of about 10-30cm cm in between (Fig. 11).

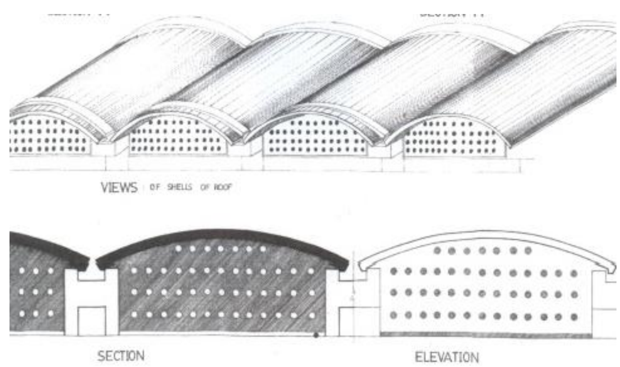

Figure 11: Ventilated Roof

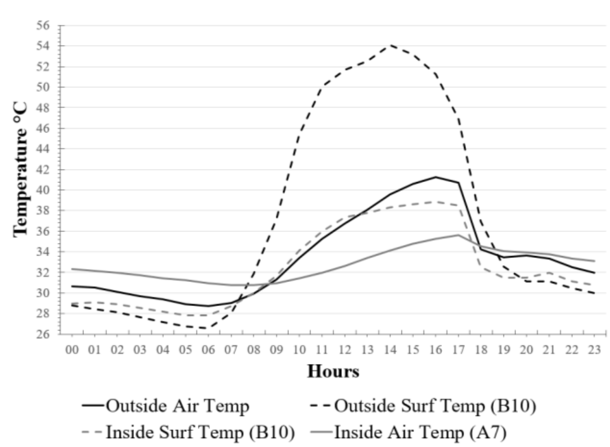

Figure 12: Ventilated roof temperature, June 21st

A large proportion of total heat gain of the building enters through the roof. Efficient roof insulation is crucial to ensure thermal comfort of the room directly below the roof. As shown in Fig. 12 (Logger B10), the efficiency of this ventilated roof allows a reduction by 18°C between the outside and inside surface temperature, occurring under warm and radiant conditions.

Temperature damping (Difference between peak outdoor and indoor temperatures) describes the way in which exterior temperatures affect the interiors of a building. As seen from the graph above, there is a significant amount of surface temperature damping. However, to get a clearer understanding of the indoor conditions the air temperature damping was also mapped across the year 2014 (Fig 13).

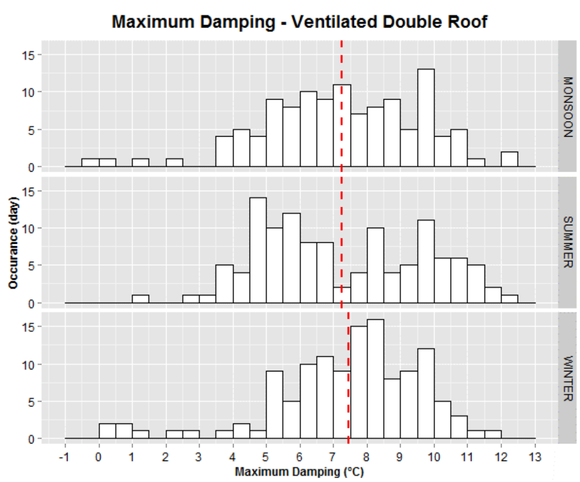

Figure 13: Air Temperature Damping, 2014

The average maximum damping was found to be around 7°C across the year.

INFLUENCE OF LANDSCAPING

Interestingly in Golconde, the Architect has used a simple landscaping strategy to transform the indoor and the surrounding environmental conditions.

Figure 14: North Garden

The North garden has been deliberately designed with sparse vegetation, resulting in lighter and dryer air while the south garden has more dense foliage with large tree cover. These tropical evergreen trees of the South Garden increase natural shading of the building façade, making the air more dense and moist.

Figure 15: South Garden

These gardens are essential to reduce the radiation reflected from the ground (albedo) and prevent hot air from penetrating the building. But more importantly, as shown in Fig. 16, during the morning hours, the temperature is lower and humidity higher in the South garden than in the North garden (Loggers B16 and B15) and vice versa during the noon.

This continual temperature difference creates a constant air flow in the building (as the hot air rises making way for the cooler air), especially in the semi-basement passages (Fig. 17) making it pleasant to sit even in peak summer afternoons without any mechanical ventilation and thus, most of the common areas (kitchen, dining room, laundry), are located in this space.

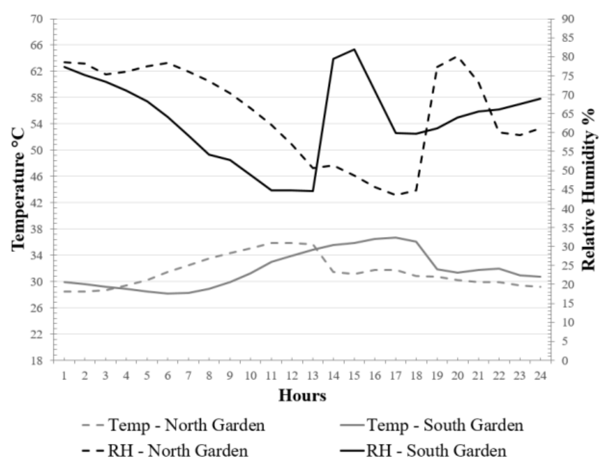

Figure 16: Air Temperature & Relative Humidity, June 21st

This semi-basement area is 1.2 m below ground and takes advantage of the shelter created by the building, the wide open spaces along with the natural ventilation as well as thermal inertia of the surrounding walls and ceiling that don't heat up from solar radiation. This area is the most commonly space used by the occupants during the daytime, validating that this area is the coolest in the building.

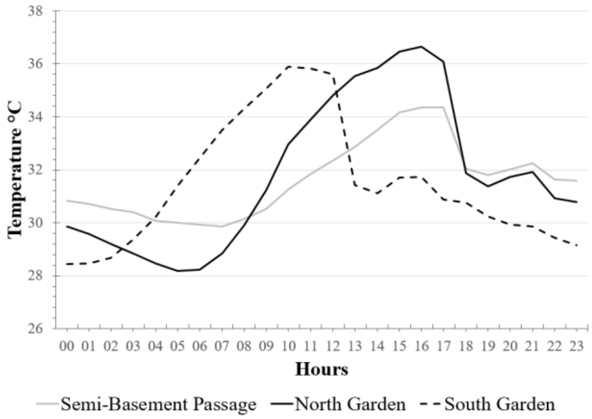

Figure 17: Garden and Semi - Basement, June, 21st

Figure 18: Semi-basement and passage, Golconde

Unfortunately we could not monitor the wind velocity of the passage, due to limited access to plug points and probability to cause damage to the building finishes while logging.

NORTH CORRIDOR – BUFFER ZONE

The North corridor, along with the use of louvers, has the function of blocking the direct solar radiation, the rain and to regulate the ventilation (Fig. 19). Located on the North and South façade, Golconde's asbestos louvers are adjustable. Special, locally fabricated brass levers have been made for the building, allowing the occupants to play an active part in their own thermal comfort. The room and the corridor have permanent air exchange through sliding doors (even when closed) when natural cross ventilation occurs.

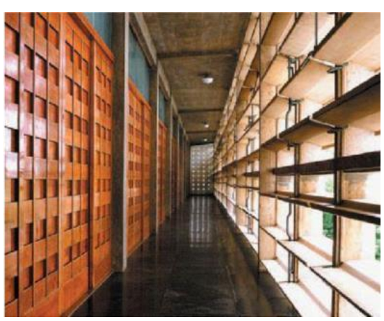

Figure 19: North Corridor, Golconde

This buffer zone located on the northern part of the building is most likely to reduce indoor temperature when the sun is furthest North in summer.

As shown in Fig. 20 (Loggers B13 and D9), the room (2W6) has an air temperature of 0.5°C lower than the North passage at the warmest time of the day. With only a small air temperature difference, it is clear that the air exchange between the room and the corridor is working efficiently. Interestingly, the temperatures inside the room and the corridor are also quite stable with very little fluctuations. The effect of this buffer zone lies in its ability to diminish the northern solar radiation from entering the room.

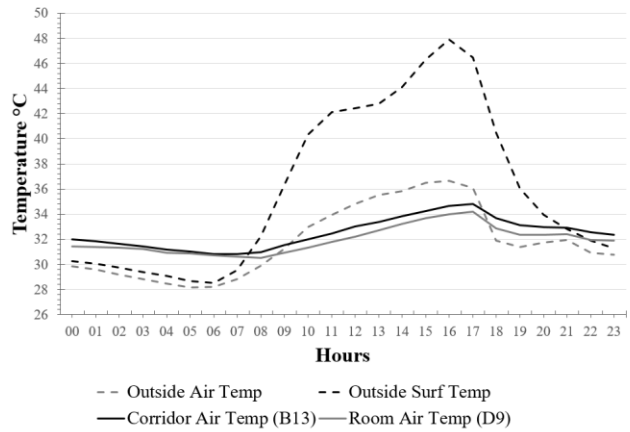

Figure 20: Air temperature in the corridor and Room (2W6), June 21st

CONCLUSION

This investigation has attempted an analysis of the thermal performance of Golconde building by continuously monitoring various passive strategies employed.

1. The **ventilated double roof** acts as a very efficient thermal insulator by reducing about 18°C surface damping from the rooftop to the ceiling surface. On an average there is about 7°C of air temperature damping recorded throughout the year.
2. The basement passage has temperatures significantly lower than the gardens (Outside temperature) during most of the day, making it the most commonly used space for daily chores and relaxing. This is mainly due to the **landscaping strategy** in the North and South Gardens which create the pressure difference and continuous air movement in the passage.
3. The **corridor in the north** which connects the rooms, acts as a very effective buffer zone and

helps in reducing the air temperature inside the rooms even during peak summer.

It can thus be concluded that Golconde has an effective passive and natural control system that is responsible for providing a comfortable thermal environment indoors, during the summer.

Scope for Further Study

This paper presents the first report on the extensive data collected over one and a half years. There is scope for more analysis with respect to performance of the building and individual strategies at different times of the year.

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11. *All the images except Fig. 2, have been generated by the Author.*