Shashwat

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A GRIHA Council Publication

FEATURE ARTICLES

- Environmental Impact of Solar Photovoltaic Installations on Urban Heat Island Effect
- Skilling for Green Construction
- Transit-Oriented Development

IN CONVERSATION

- Peter Head
- Rolf Disch
- Eugene Pandala

Shashwat

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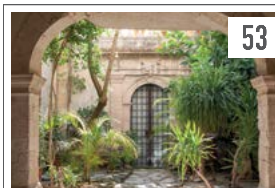
Sustainable living is our target and we are all exploring ways to live and work in a manner that helps us to be in synchrony with nature and coexist with the environment without disturbing it.



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The importance of the Sustainable Development Goals (SDGs) have never been more acutely felt. Designed to improve climatic conditions and our way of life, SDG 11, especially aims at striking the much-needed balance between the economy, environment, and various human needs.

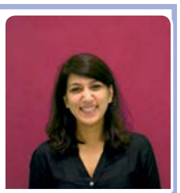
FEATURE ARTICLES

TESTIMONIALS

Passive Façade Design for Energy-Efficient and Cost-Effective Envelope

It is now a well-established fact that our resources are limited; however, our demands are not. The architectural industry, one of the biggest contributors towards GHG emissions and waste, is taking adequate steps to face the challenge and is deploying passive strategies to address these issues. In this article, **Sonali Rastogi**, **Isha Anand**, and **Aarushi Juneja** discuss the ways in which sustainability and affordability issues are closely linked vis-à-vis issues, such as identity and liveability parameters.

Sonali Rastogi, founder–partner at Morphogenesis, has written extensively in diverse areas, ranging from architecture to urban design, landscape, and interior design. She can be reached at: media@morphogenesis.org



Isha Anand, associate at Morphogenesis, has 11 years of experience with specialization in sustainability and environmental design.

Aarushi Juneja, architect at Morphogenesis, has a master degree in sustainable environmental design.

Hamdard, a research-based health and wellness charitable trust, commissioned the design of their 4,000-sq. m administrative and R&D office in New Delhi, India. This was to imbibe their vision and values of innovation, progression, and humility. The budgetary constraints were imposed by the charitable nature of the company where most of the company's earnings are diverted towards humanitarian activities. Therefore, every penny invested in the creation of this project had to be justified. Morphogenesis set out to achieve a cost- and energy-efficient envelope through an integrated design approach, illustrated through the design of this administrative office, set in a composite climate.

The Integrated Design Approach

The matrix of SAIL (sustainability, affordability, identity, and liveability) governs the philosophy of an integrated design approach.

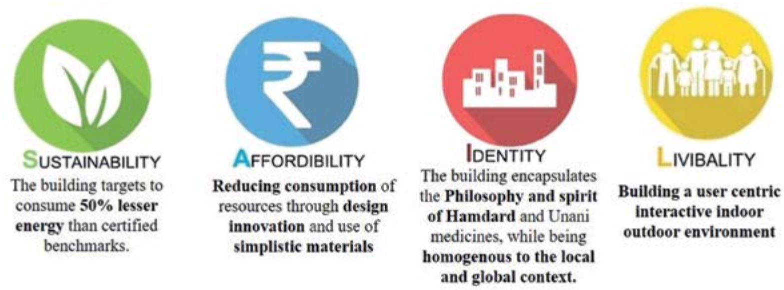


Figure 1: Key parameters for an integrated design approach (SAIL)

Sustainability

The approach of 'No is More', that is, imagining one has no resources at one's disposal, becomes an inspiration for creating truly optimized built-spaces responding to present-day issues of stress on resources.

The implementation of passive strategies at the site level (thermal banking and evaporative cooling) and at building level (thermal mass, glazing optimization, and façade shading), as guided by historical precedents, combined with modern-day techniques, strongly influenced the optimization of the built form making it sustainable.

The overall site comprising 15,000sq. m area for the administrative office and an existing factory in New Delhi explored the potential of being net-zero in terms of water consumption and energy.

The carrying capacity calculation for the site suggested a potential of rainwater collection at 4,695 cu.m/year. This, along with recycling of grey water through a bio-digester was sufficient to meet the water demand for the entire office comprising 200 people. The annual energy of this building has been targeted at an EPI of 45 kWh/m^2/year (HVAC, lighting and equipment load). As compared to a conventional building, passive methods are known to result in reducing the electricity demand. Further, the integration of renewable resources to offset the energy demand, presented a requirement of a 2,100 m^2 solar farm to be net-zero on energy.

Affordability

Affordability in terms of capital investment was a key component of the brief that led to the use of simplistic materials (brick and concrete), along with locally skilled labour to ensure cost control. Site optimization by working with the existing site levels into the built form led to material reduction. Passive design methods and resource optimization led to cost optimization of both construction and operation cost, thereby further enabling an economized investment in renewable resources.

Identity

Historical precedents in the region suggest that the architecture itself was a response to the harsh climate and a lack of availability of resources. Delhi and the immediate site context continue to inspire designs since precedents suggest that the architecture itself was a response to the harsh climate and a lack of resource availability.

- *Baoli* (stepped well)

A dipped site filled with trees presented the possibility and potential of using sunken courts for creating spill-out spaces for the office. An N-S oriented rectangular volume was formulated to minimize the exposed surface area which was raised above the ground making use of the existing excavated area to create an underbelly. This is banked with earth on all four sides and shaded by the building above thus creating a microclimate

Section the building with a series of stepped sunken courts.

Plan of the Building showing the workspace punctured with courtyards.

Figure 2: As compared to a conventional building, passive methods are known to result in reducing the electricity demand in courtyard planning

with reduced perceivable temperature inspired by Agrasen's baoli. Further, the use of water bodies explore the potential of evaporative cooling in the hot and dry summer months to enhance outdoor comfort, and double up as an amphitheatre when these are to be drained out (warm–humid monsoon months).

Courtyard plan has been a predominant and prevalent microclimate control feature of the historic Mughal architecture in hot–dry regions of the country which in turn influences the architectural planning of the office. The central courtyard concept has been taken to the next level to create a pixelated plan format with greens and workspaces.

The two-storeyed main office block with a 71 × 31 m footprint has been broken down resulting in creating alternating solids and voids. The solids become work halls while the voids provide visual breaks which allow for daylight and air penetration. This also helps in generating a healthy working environment for users in terms of daylight and indoor air quality, thus increasing their productivity. The series of courts have been optimally punctured into the work hall with a span of not more than 6 m from the work space and with no work desk more than 10 m away from an accessible court with operable windows. The end result is that the entire floor plate is 90% naturally lit. The office has been planned in an open format with collaborative zones to encourage team interaction. It has been designed for a modular efficiency using a 7.5 × 10.5 m structural grid that not only accommodates the multiple workstation modules and departmental organization while being adaptable to future changes, but also optimally fits the car parking bay below the main office block, thereby ensuring minimal wastage in a resource-intensive yet relatively non-contributory area. The internal self-shading courts with a resultant modified microclimate act as an extended workspace, thus reducing the need for enclosed areas.

- *Jaali*

The jaali or the *musharabiya*, a perforated skin inherent to Mughal architecture, is used to moderate the incoming natural light, which could be harsh most of the time, allowing proper ventilation. Thereby it becomes a second skin which acts as a thermal buffer between the building and its surroundings.

Liveability

Building a user-centric environment is extremely critical in making a design successful. As discussed above, the precedents so interpreted in the project along with modern-day techniques link to the liveability and well-being of employees.

Fresh air, daylight, minimal noise, and a steady temperature are the four main factors for a productive work environment,[1] and yet many people spend their working week sitting in sealed up, stuffy offices that are dim and dingy thus severely affecting their productivity and increasing the absenteeism rate. The design aims to develop a strong indoor–outdoor connect which is deeply rooted in the Indian social psyche, but often does not find expression in the workplace. Nowadays, with blurred boundaries between our work and private lives, the aspect of making our workplace more liveable gains utmost importance.

Façade Strategy

Value engineering is a harsh reality, particularly in the context of emerging economies such as India where projects are highly cost-sensitive and can manifest at any stage of a project. Bearing this in mind, the façade treatments are integrated as an extension of the structure of the building. This integrated façade design approach ensures that the vision of the architect is followed through till the completion of the project.

Energy Efficiency

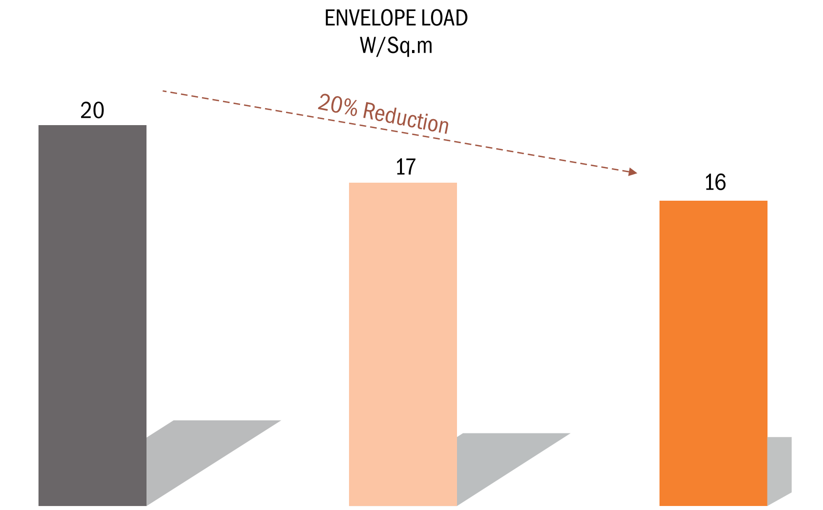
The application of passive strategies through façade design targets the reduction of solar heat gain by the envelope whilst providing a 90% day-lit workspace and reducing its operational cost for lighting and air conditioning. An optimum balance between solar control and daylight has been achieved to design a user-efficient built environment.

Shading, glazing area (WWR, i.e., window-to-wall ratio), and building materials determine the performance of the façade. These three elements are analysed and optimized to determine the best solution for the project. For shading the external façade, the vertical fins and horizontal overhangs need to be optimally spaced as per the various orientations. A solar analysis determined the optimal width to depth ratio (1:1) of shading devices for maximum solar control during the hottest period for all the four orientations.

As per ECBC,[2] the WWR should preferably be ≤ 40% for this climate. The cumulative heat gain from the envelope was calculated to assess its thermal efficiency with a 40% and 30% WWR and

1 Henley J. 2014. *The Secret to Healthy, Productive Workplaces, Human Spaces-Spaces Designed with the Human Mind.*

2 Energy Conservation Building Code-2007. 2008. Bureau of Energy Efficiency (BEE), New Delhi.



CASE 1: WWR 40%

U values	
Walls	044 W/m2.K
Glazing	1.8 W/m2.K

CASE 2: WWR 30%

U values	
Walls	044 W/m2.K
Glazing	1.8 W/m2.K

CASE 2: WWR 30% +Shading

U values	
Walls	044 W/m2.K
Glazing	1.8 W/m2.K

Figure 3: Thermal efficiency of façade

façade shading parameters at an indoor operative temperature of 24 °C. The solar heat gain from the envelope was seen to drop by 4W/sq. m by the dual strategies of reduction in the glazing area and façade shading.

The humble brick is expressed in a cavity wall format to provide insulation as well as internal and external thermal mass.

Cost Optimization

- Wall and glazing

Cost constraint being an extremely critical criterion, the potential of cheap, local, and easily accessible materials and strategies, were explored to achieve the desired performance. The high thermal mass façade was achieved by using a double-exposed brick cavity wall which is economical and low on maintenance. Additionally, it absorbs ambient heat during the day while radiating lesser amounts of heat overnight. An exposed cavity wall with insulation is only about 10% higher in cost as compared to a regular 230 mm-thick brick wall with external plaster and paint.

The 30% WWR has been distributed as long vertical strip windows punctured into the façade, optimized as per the orientation on the outer perimeter, and maximized around the internal courts as they receive diffused sunlight. High-performance glazing can add significant cost to a building, especially when required in larger spans. Therefore, to reduce cost, the panel has been divided optimally in alignment with the interior arrangement of desk height and within standard available spans.

- Shading devices

The jaali, as highlighted above, has been used as a façade strategy to reduce direct heat gain through fenestrations, yet allowing diffused daylight. Brick as a material for jaali proves to be economical with low maintenance and has flexibility to be arranged in various patterns as per the required perforations.

Jaali along with the exaggerated concrete roofs are the primary shading devices. Use of these simplistic and climate-responsive strategies and building materials enable envelope optimization

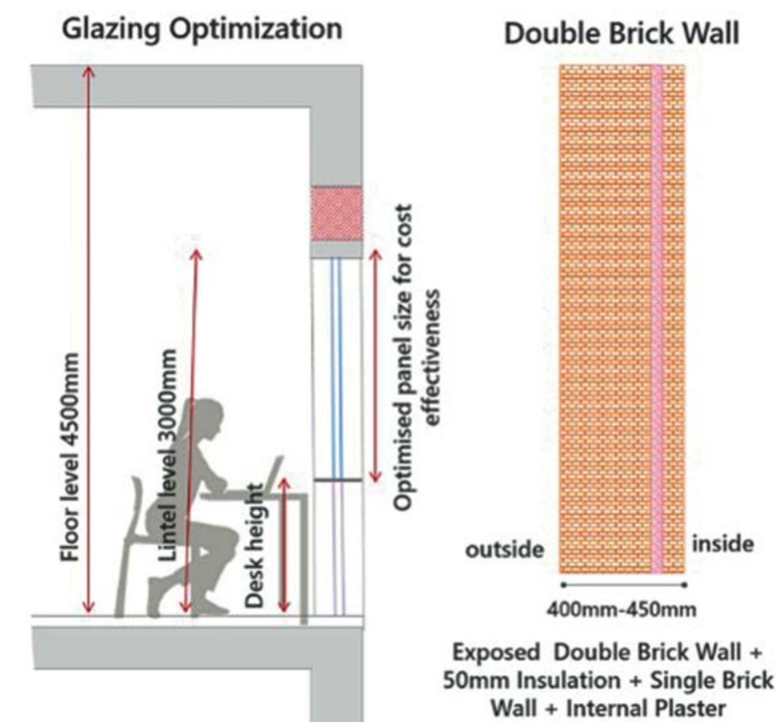


Figure 4: Wall and glazing section

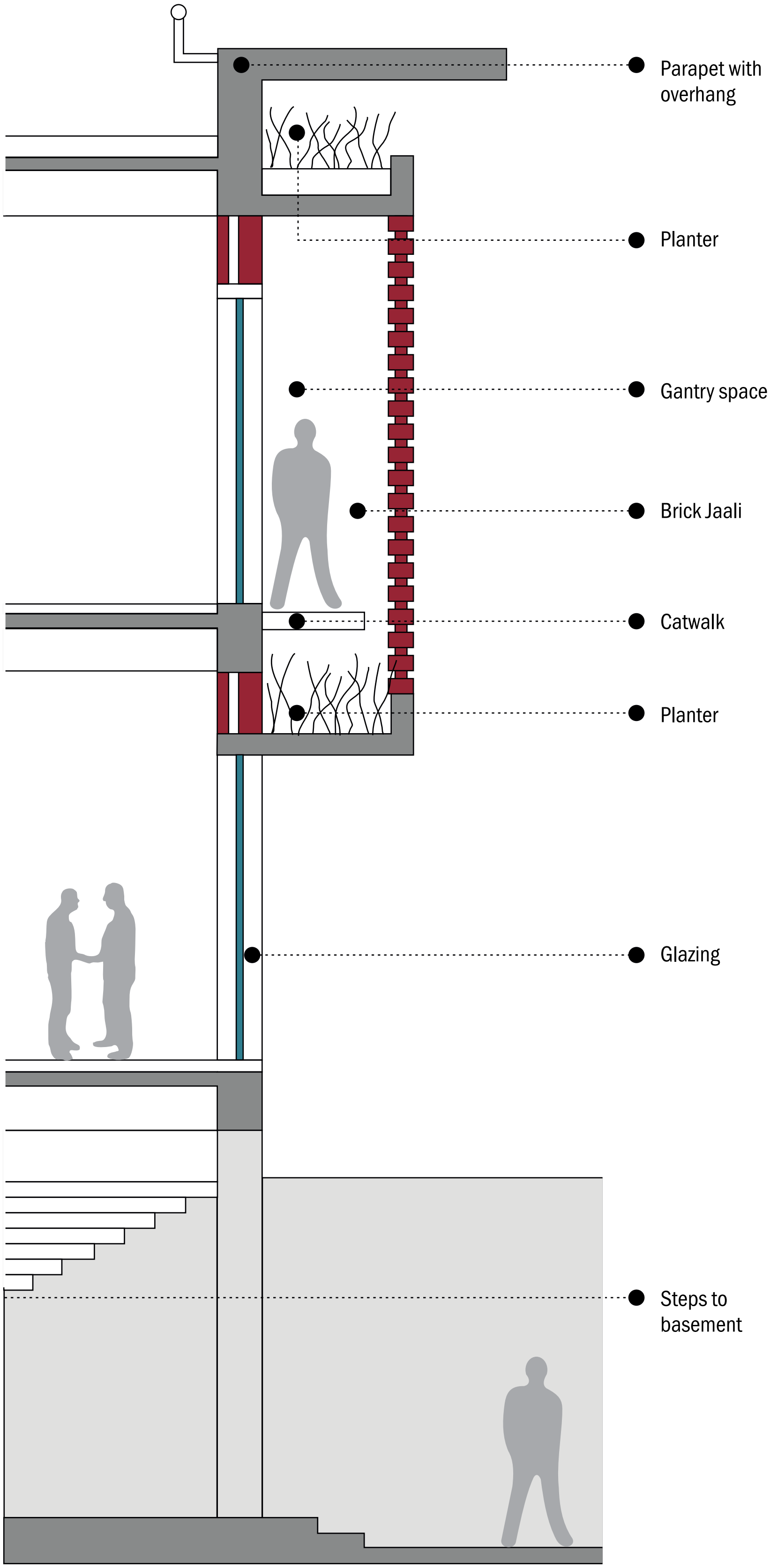


Figure 5: Typical wall section

not only in terms of energy but also in terms of construction cost (260 €/sq. m).

Overall Energy Performance

The built form and façade optimization together help in reducing the energy demand of the building. According to the GRIHA baseline, the EPI (energy performance index) for an air-conditioned building of this typology is 90 kWh/m²/yr.[3] Passive strategies, explore the potential of reducing the demand load and, therefore, lowering the EPI to 45 kWh/m²/yr., that is 50% better than the GRIHA baseline leading to a significant reduction in the cooling demand of the building.

A comparative analysis between the energy demand of the building and the area required for PV panel installation, highlights that the reduction in energy demand also reduces the space required for installing PV panels, thus reducing further investment as land is an expensive resource too. With an EPI of 45 kWh/m²/yr., the annual energy demand of the building is about 270,000 kWh, which needs a PV system over 2,100 sq. m. of 210 kWp. The south-facing existing factory terrace has been explored to plant this system. The analysis done by the solar energy consultants also clearly stated that 23% of the investment cost could be recovered within the first year of installation of the system and the total investment could be recovered in less than 6 years.[4]

3 Application. 2010. *Green Rating for Integrated Habitat Assessment (GRIHA) Manual, Volume-3*. New Delhi: The Energy and Resources Institute.

4 Solar Feasibility and Savings Report for Hamdard Administrative office. 2017. Sunfund Renewable LLP.

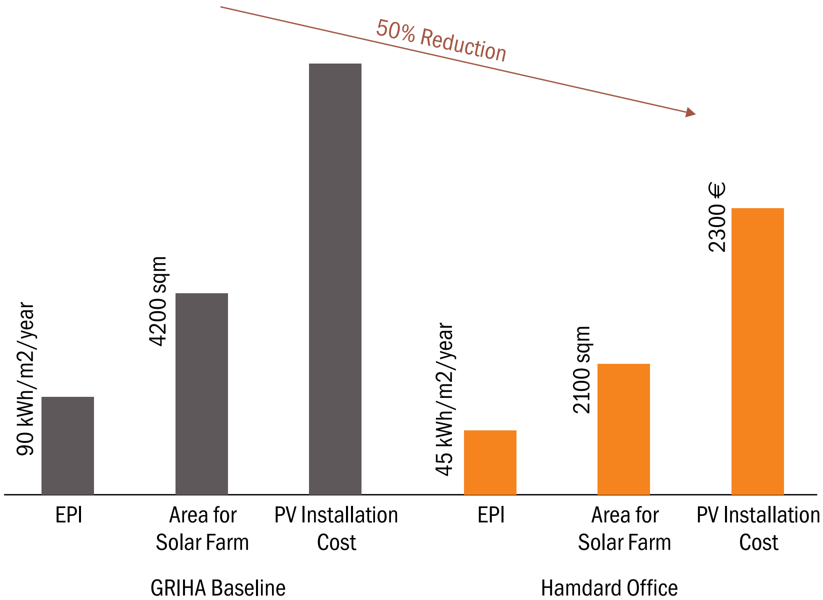


Figure 6: Comparative graph between the GRIHA baseline and Hamdard office targets

Conclusion

This comprehensive design process concluded with an overall cost of construction (civil and façade) at 260€/sq. m. As they say, 'necessity is the mother of all invention', the limitations set by the client in the design brief were used as an opportunity to create a design with an integrated approach of SAIL.

Acknowledgements
The authors would like to thank Ms Rashmi Mandal, Mr Sajid Ahmed, and Mr Shamshad Ali from Hamdard for their support.

Figure 7: A visual of the Hamdard administration office

> Access to food, clean water, sanitation, education, technology and healthcare are all underpinned by affordable and clean energy.
> — **Fuso Nerini**

The Economics of Sustainable Design in the Indian Context

In Affordable Segment

Practicing environmental architecture in a developing country such as India has unique advantages as well as challenges. While vernacular architecture is deeply rooted in passive design, urbanization has led to highly populous cities with 60% of the urban population living in metropolitan cities, such as Delhi, Mumbai, etc. This has resulted in overcrowding, lack of space, and, consequently, skyrocketing real estate rates equivalent to any other metropolitan city in developed nations. In this article, **Manit Rastogi**, **Nitin Bansal**, and **Piya Gupta** discuss the importance of design efficiency for the built environment.

Manit Rastogi, founder partner of Morphogenesis, is known as an architect who consistently pushes the boundaries of sustainable design. He can be reached at: media@morphogenesis.org

Nitin Bansal, a senior associate at Morphogenesis, has 11 years of experience in architecture with a specialization in sustainable environment design.

Piya Gupta, an associate at Morphogenesis, has over 4 years of experience. She specializes in sustainable architecture.

Sustainability and affordability come together to create contemporary and global architecture while responding to the local climatic conditions and, subtly, to our-deep rooted, socio-cultural instincts. This process of integrated design has been illustrated through an IT-office project in the hot–humid climate of Hyderabad.

Climate

Analysing the climate is the first step towards understanding the possible passive strategies applicable to the site. This process is critical in setting the project parameters for comfort and usability of open spaces.

The prevalent tropical climate in India demands a combination of passive strategies for year-round comfort. High intensity of solar radiation adds to the challenge of creating a glare-free, 100% day-lit working environment while ensuring effective solar control (for reducing cooling loads).

The Indian Model for Adaptive Comfort Study[1] addresses the thermal adaptability of people living in tropical climate typologies inherent to the country.

Sustainable Design Brief

Historical precedents suggest that architecture itself was a response to a lack of availability of resources and response to climate, the principle being that nothing was ever wasted. The approach, 'No is More', that is imagining one has little or no resources at one's disposal becomes an inspiration for creating truly optimized built spaces catering to present-day issues of stress on resources.

Based on an approach that began

1 The Indian Model for Adaptive Comfort Study. 2015. *Green Rating for Integrated Habitat Assessment* (GRIHA)-Appendix-1. New Delhi: The Energy and Resources Institute.

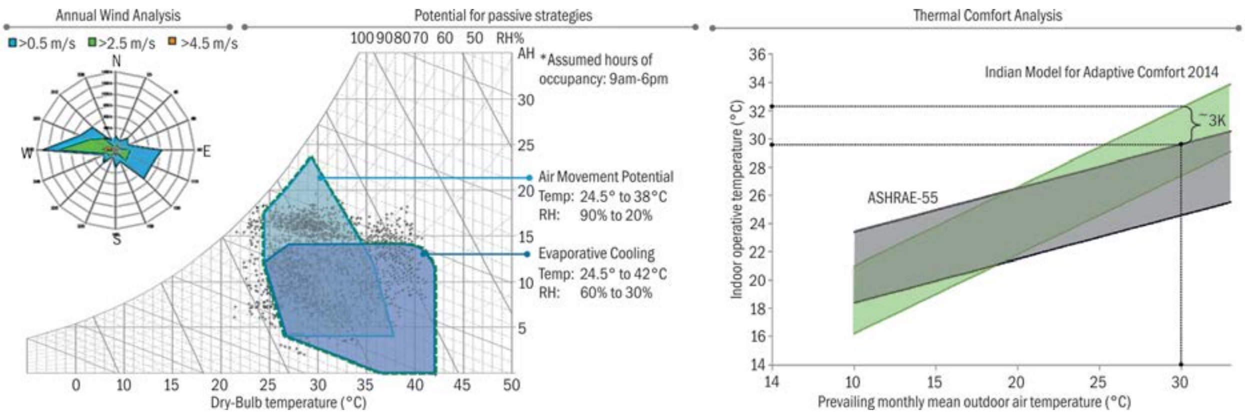


Figure 1: Climate analysis and thermal comfort standards in Hyderabad

with the carrying capacity of the land, the 100-acre site for an IT campus in Hyderabad was found capable of serving the conventional water demand of 14,400 persons. A 3 m-deep water reservoir of approximately 14 acres was designed to be located in the low-lying section of the site. The annual energy consumption for the project was targeted at 60 kWh/m^2/yr. with primary energy consumption estimated at 35 kWh/m^2/yr. and 25 kWh/m^2/yr. being the load from the equipment.

Integrating renewable resources to offset the energy demand presented a requirement of a 13-acre solar farm. Comparable spatial requirements allowed the solar farm to be planned on top of the water reservoir expected to significantly reduce evaporative losses while cooling the solar panels at the same time.

Urban Design and Masterplanning

Designing tor utilize prevailing winds, visual comfort through daylighting, and solar control resulted in a series of urban design solutions. Six schemes were generated without imposing any preconceived notions of aesthetics, responding purely to the density and environmental performance targets. The schemes were first analysed through the process of Computational Fluid Dynamics to understand the movement of air in open spaces and the potential to naturally ventilate the buildings. The resultant was a master plan translating the sustainable design brief, thereby generating a microclimate of comfortable outdoor and semi-outdoor spaces with the potential of being utilized for the interactive common functions of the programme. In order to maximize the functionality of the courtyards, the effect of introducing a roof, elevated air speeds, and dry mist systems were explored as targeted strategies for open spaces. Direct solar control strategies for the courtyard helped almost double the period of comfort during occupancy hours. Enhancing the air movement by morphology as well as introducing active methods such as fans proved to be successful in increasing the hours of comfort to 60%, annually, and increased the capital cost negligibly by £ 1/sq.ft. Moreover,

Table 1: Carrying capacity for water resources

Site Area	4,09,961 sq. m
Annual rainfall*	0.822 M
Potential annual Rainwater collection (50% run-off, 10% evaporative losses)	1,68,494 cu.m
Water requirement per day per person**	45 lpcd
Carrying capacity of site based on water demand	14,400 persons
Size of water reservoir required(@3M depth)	56,165 sq. m (~14 acres)

Sources: *www.rainwaterharvesting.org, ** National Building Code-2005

Table 2: Carrying capacity for renewable energy

Carrying Capacity (Based on water demand)	14,400 persons
Total Built-up area required @ 9.29sq. m/person (100 sq.ft./person)	133,781 sq. m
Target Energy consumption	60 kWh/sq. m./yr
Total Annual energy consumption	8,026,830 kWh
Area required for installing solar PVs*	53,512 sq. m. (~13 acres)

Sources:*1500kWh energy generated annually per 1 kWp of installed capacity, requiring 10 sq. m/kWp.

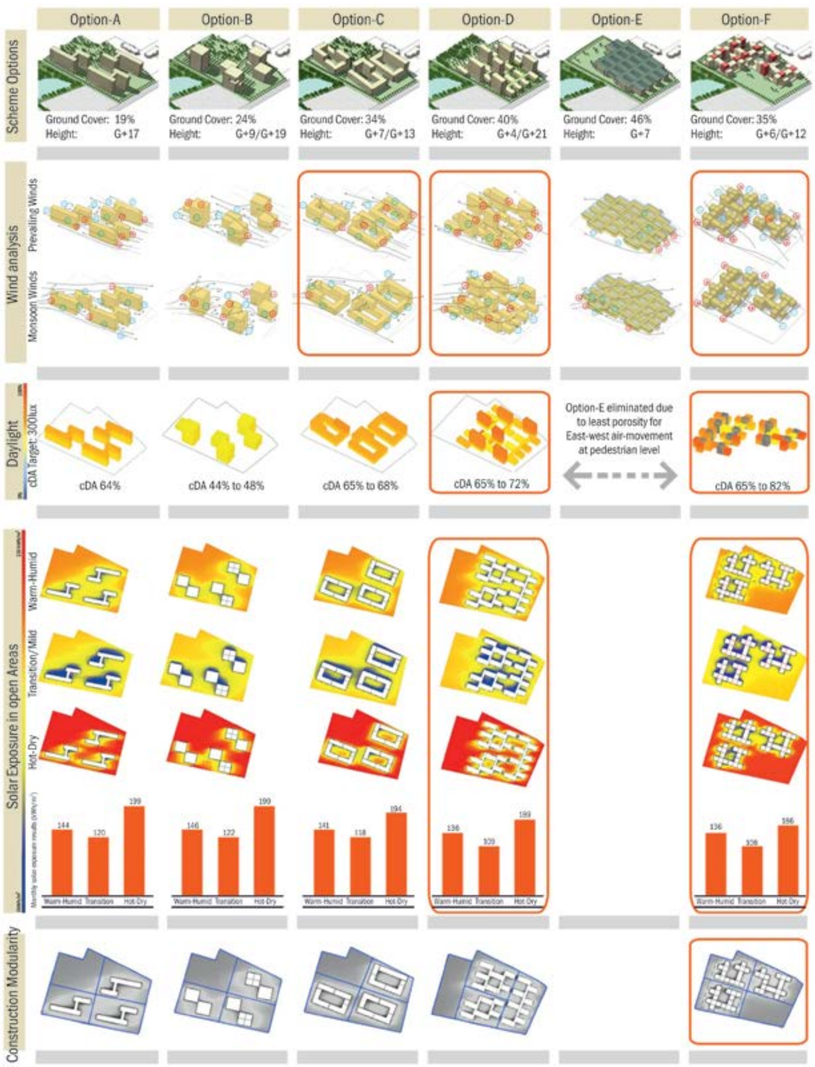


Figure 2: Methodology of urban design and masterplanning for an IT campus in Hyderabad

mist-cooling systems drastically improved the micro climate by achieving comfort in 97% of the occupied hours while adding to the investment by £ 4/sq.ft.

Finally, common functions, such as food court seating and even part of the library were designed as semi-outdoor protected spaces encouraging a dialogue between the natural environment and the users, proving applicability of adaptive comfort strategies in hot–humid climate conditions. Using the above-mentioned processes, over 1,00,000 sq.ft., comprising 9% of the total built up area, was successfully eliminated from the construction requirement. Moreover, in addition to being a grand arrival plaza, the courtyard becomes a multi-functional gathering space at 10% of the conventional capital cost.

Built Form

A modular efficiency involved an inside-out approach using a structural grid of 11.5 m x 8.5 m that could be the multiple of a workstation module as well as the lowest unit of a car parking bay. Workspace efficiencies of up to 45 sq.ft./person were achieved with an overall 85 sq.ft./person on built up area. This further saved 15% of construction area as compared to conventional standards of 100 sq.ft./person.

The design of the built envelope can be governed by balancing shade, glare, daylight distribution, and solar heat gain reduction. Solar control for the external façade involved vertical fins and overhangs spaced according to the different orientations. Shading devices were designed with conscious attention to controlling glare without hampering the daylight distribution. External façade treatments are often eliminated during the course of a typical project as capital cost is generally given more thought over controlling operational costs. Moreover, maintainability of these features becomes more challenging over time due to high intensity of sun and air pollution levels in larger cities. These issues led to an integrated façade designed as an extension to the structure of the building with concrete slab projections and monolithic vertical fins, spaced relevant to the orientation. The façades facing the courtyards were mostly protected by roof coverings and could, therefore, be allowed to open up to the micro climate. Illuminance targets of 110 lux were achieved by effective daylight distribution. The cumulative solar heat gains from the designed façades were calculated to assess the overall thermal efficiency of the envelope. Finally, the solar heat gain for the entire building was calculated and resulted in an overall thermal efficiency of 0.8 W/sq.ft.

Active Systems

Thermal comfort has proven to be crucial in achieving occupant satisfaction as well as workplace productivity. Setting comfort targets when the end

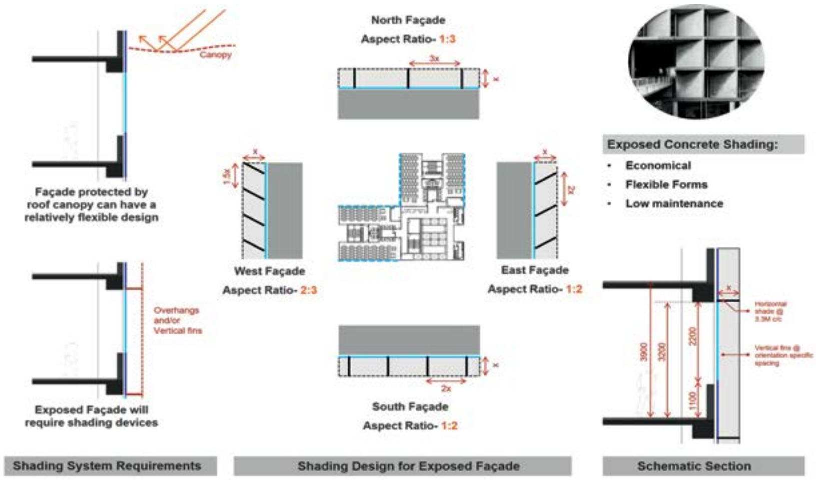


Figure 3: Integrated façade design for reducing solar gains through building envelope

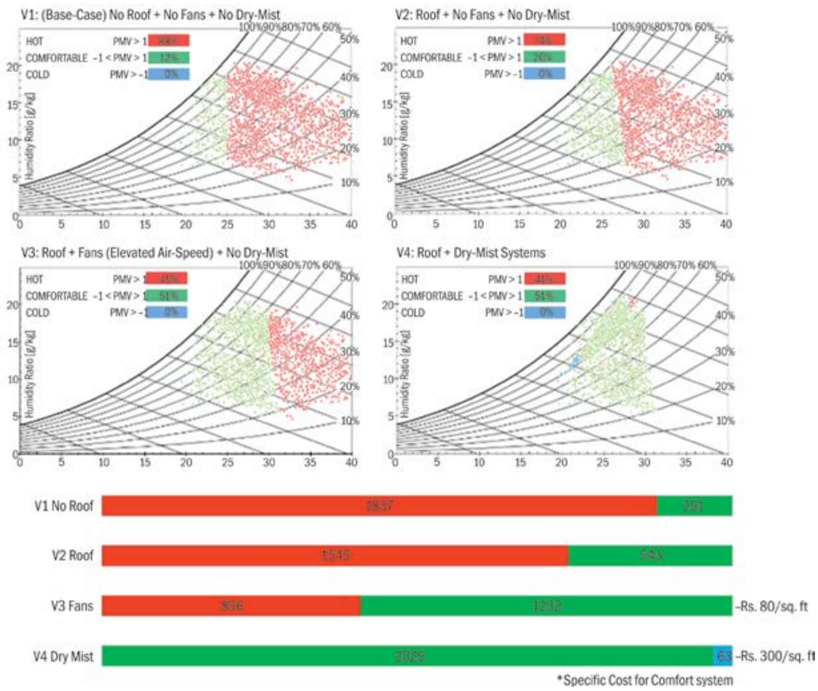


Figure 4:Comfort and cost evaluation for outdoor spaces using the PMV model for adaptive comfort

user is not involved makes it essential to consider not only the adaptive factor but also expectations of comfort which may vary for different climate typologies. Working spaces demand consistent and controlled indoor environments for minimal distraction during focused tasks. Although minimal, the cooling loads as a result of micro climate creation and robust envelope design needs to be countered with active systems to achieve the desired comfort levels indoors.

Multiple cooling systems were analysed to achieve an optimized solution specific to the project constraints. Feasibility analysis studies concluded with the selection of under-floor cooling system for controlled thermal comfort requirements in working spaces. The primary advantage was that the system offers flexibility in internal layouts enabling any future changes in market standards and user requirements. Under-floor cooling systems are, generally, useful due to the stratification of air in high-volume spaces. Adding air movement at ceiling level is undesirable in such cases as it is expected to counter the process. However, floor heights limited to 3.9 m–4.5 m are unable to benefit from stratification since temperature variations only up to the range of 0.5–1 °C are achieved. Enhanced air movement in such spaces significantly adds to the physiological comfort. The overall advantages offer flexibility to the architecture as well as active systems.

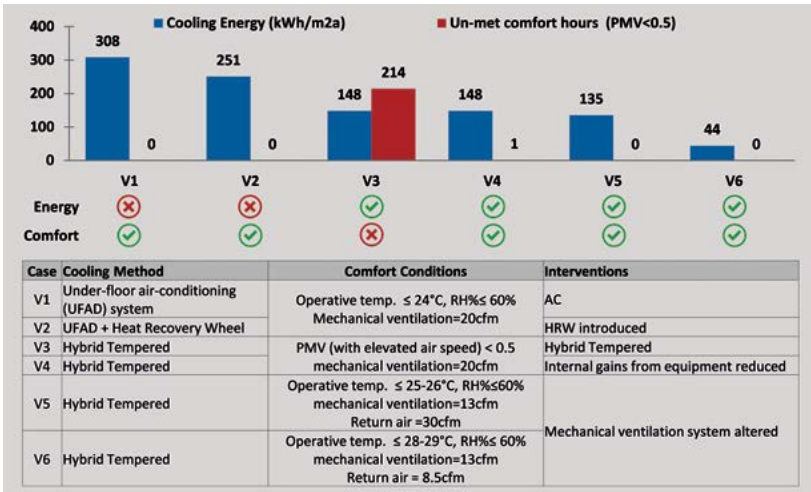
A combination of natural ventilation and evaporative cooling may work for hot–dry conditions but highly humid environments make it difficult to open to the outdoors without adding systems for dehumidification and enhanced air movement. Learning from the analytical studies, where the effect of elevated air speeds on the micro climate was tested through installing ceiling fans in indoor spaces, hybrid systems were created to reduce mechanical cooling loads. A robust envelope design enabled common interactive functions within the built spaces to be opened up for natural ventilation by using the same strategies of dry-mist systems in combination with fans. The basic understanding was that when occupants are not at work or are involved with interactive activities in a work environment, they tend to be more accepting and adaptive to their surroundings. Consequently, the micro climate could be further extended to comfortable transition spaces where another 35% of the total built up area of the office building was made comfortable at half the cooling energy requirement of conventional practices. Combining passive principles of solar control and active systems for cooling proved to save another 50% of cooling energy in fully air conditioned spaces (refer to Table3).

Conclusion

The comprehensive design process discussed above concluded at an overall construction cost falling well within £ 40/sq.ft. This factor was extremely crucial when addressing the budget constraints of projects in developing nations where saving in capital investment is more important than operational costs. Overall, the office project in hot–humid conditions of Hyderabad can be seen as an example of successful application of sustainable principles in hard-core, cost-driven markets like India. Pushing the potential of sustainable design requires expert inputs from multiple contributors, such as architects, climate engineers, structural consultants, mechanical, electrical, plumbing consultants, etc. Designing optimized systems and low-energy consumption starts making commercial sense only when complemented by spatial efficiency. Energy consumption per capita becomes a crucial factor in analysing the efficiency of sustainable architecture in high-density markets. Similar applications of integrated design across the various tropical climate typologies have proven to be equally effective as can be seen in Figure 7.

Table 3: Relative savings in construction area and cooling energy consumption

Area Distribution	Use	Measures Considered	% age Area	Cooling Energy Savings
Air conditioned spaces	Workstation areas, meeting rooms	Under-floor cooling + Fans	56%	45%–67%
Naturally ventilated spaces	Cores, library, food court, gym, lobbies, discussion areas	Natural ventilation + Fans + dry-mist systems	35%	50%
Shaded outdoor areas	Outdoor open cafeteria seating, recreation, library, arrival plaza	Tensile roof + fans + dry-mist systems	9%	49%



Case	Cooling Method	Comfort Conditions	Interventions
V1	Under-floor air-conditioning (UFAD) system	Operative temp. ≤ 24°C, RH%≤ 60% Mechanical ventilation=20cfm	AC
V2	UFAD + Heat Recovery Wheel		HRW introduced
V3	Hybrid Tempered	PMV (with elevated air speed) < 0.5 mechanical ventilation=20cfm	Hybrid Tempered
V4	Hybrid Tempered		Internal gains from equipment reduced
V5	Hybrid Tempered	Operative temp. ≤ 25-26°C, RH%≤60% mechanical ventilation=13cfm Return air =30cfm	Mechanical ventilation system altered
V6	Hybrid Tempered	Operative temp. ≤ 28-29°C, RH%≤ 60% mechanical ventilation=13cfm Return air = 8.5cfm	

Figure 5: Sensitivity analysis for hybrid systems integrating elevated air speeds

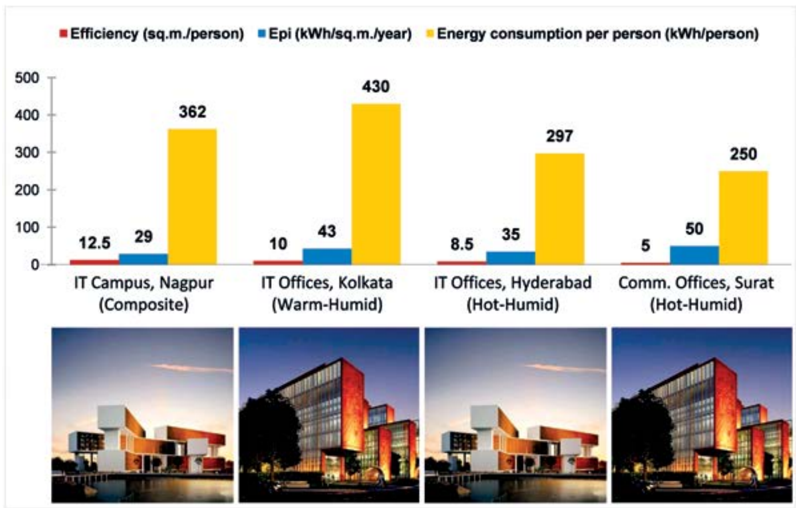


Figure 6: Applicability of integrated design approach across different tropical climate typologies