690: Form Follows the Sun: Hill County SEZ Office Complex

Varun Kohli*

*Skidmore, Owings & Merrill LLP, New York, USA**
varun.kohli@som.com

Abstract

The paper discusses a rigorous and methodical environmental analysis process and its successful integration into the design process for the Hill County SEZ office complex in Hyderabad (HC SEZ), India by Skidmore, Owings & Merrill (SOM, New York). The project involved designing over a million square feet of class 'A' office space for Maytas Properties and specifically for catering to the burgeoning IT industry of India. From the onset of the project, design decisions for orientation, programme, massing and façade articulation were informed by a continuing environmental analysis. Based on climate studies, the building design aimed to minimize direct solar radiation and enhance daylighting using passive strategies. The resulting 1.2 million sq.ft. of IT office buildings achieve increased energy efficiency and enhanced indoor environment, whilst adhering to restrictive budget by utilizing local materials and technologies.

1. Background

In the construction environment of India, where an energy guideline (ECBC, 2007) has only recently been introduced in 2007, a large stock of existing office buildings consume tremendous amounts of energy. This paper discusses a rigorous and methodical environmental analysis process and its successful integration into the design process for the Hill County SEZ office complex in Hyderabad, India (HC SEZ) by Skidmore, Owings & Merrill (SOM). The project involved designing over a million square feet of class 'A' office space. An energy simulation mimicking a typical glass office building of similar size as HC SEZ, with 3,700 sq.m floor plates and single pane tinted glazing was performed (EDS, 2007). The results show energy consumption of approximately 450 kWh/sq.m/yr (lighting & HVAC only). Also, with a growing need for office spaces, these buildings have large floor plates with high occupancy density (under 7sq.m/ person) resulting in indoor spaces with no daylighting and poor air quality.

2.1 Climate

At 17º27'N latitude and 78º28'E longitude, Hyderabad lies in the composite climate zone of India, as defined by ECBC, 2007. Summer months, between March and May experience a diurnal temperature range from 25ºC to 42ºC. South-west monsoons bring concentrated rains between the months of June and September. Average relative humidity levels reach 85% during the monsoons. Post-monsoon season through the months of October and November have high humidity with minimal precipitation. Winter months from December through February experience milder temperatures ranging from 20ºC to 32ºC.

Of significance is high level of solar radiation, especially during peak summer months. Direct solar gains can contribute significantly to cooling loads if the façade is not designed carefully. Insolation studies show higher levels of radiation on the horizontal surface followed by east and west facades during summer months (Fig 1.)

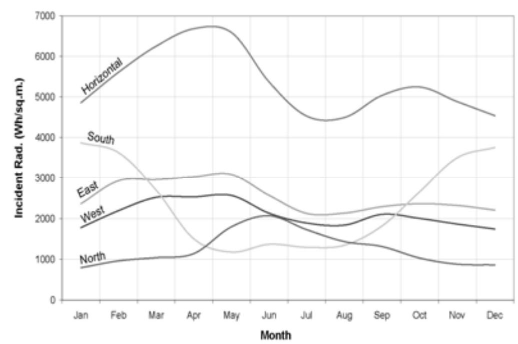

Fig 1. Incident Solar Radiation on Various Facades (Source; Meteonorm)

2.2 Architectural Expression

The building forms and site walls take advantage of the unique site by carving itself into and out of the dramatically contoured and rocky site. The building elevates as extensions of site contours themselves. As these contours rise, the ribbon forms wrap around to form courtyards which have been integral to the local vernacular.

Fig 2. Courtyard shaped building rising out of the site contours

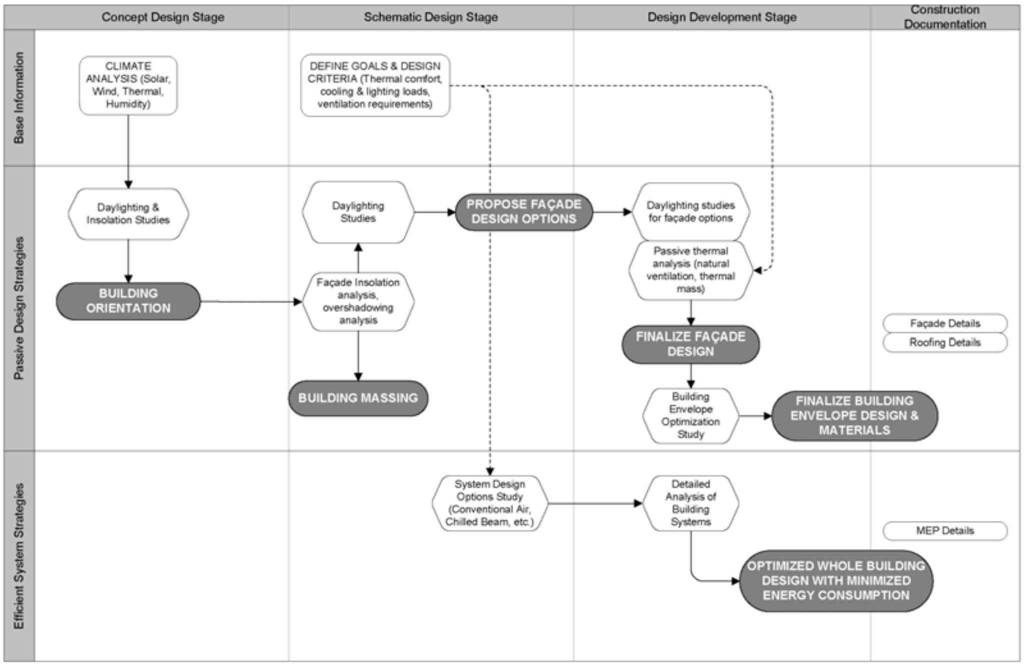

Fig 3. Environmental analysis process flow-chart

3. Analysis & Design Process

In a project of this magnitude, it was imperative to streamline a process which is embedded in the overall project schedule. This would ensure the availability of analysis results in time and corresponding to the appropriate stage of the design process.

Fig 3. outlines a linear process, although within each major step a reiterative analysis process can take place. Starting from the bigger picture, climate analysis, orientation and building massing studies are done by the early phase of schematic design. More detailed passive design analysis for the facades along with active system optimization is carried out towards the end of design development stage.

With a restrictive budget on this project, passive design strategies with minimal or no capital cost increments become all the more significant.

3.1 Building Orientation & Lease Spans

With ever increasing needs for larger floor plate areas in the Indian IT industry, most new building programmes require accommodating 3,500 sq.m or larger floor plates. Many buildings do so using a continuous rectangular plate with lease spans as deep as 40-50 meters. Such a floor-plate layout limits the use of natural daylighting to a small percentage of perimeter office space. In addition, with inappropriate façade design in terms of aperture orientation or low quality glazing, with inferior SHGC and u-values, even the perimeter spaces can not be occupied.

Understanding that the climate of Hyderabad is dominated by cooling season and that the main contributor to the heat gains is direct solar radiation (Fig 4.), it was made a priority to minimize direct solar radiation transmission through fenestration.

Furthermore, since lighting loads can also contribute at least 30-40% of energy consumption (IEA, 2008), solar control would have to be balanced with appropriate apertures in order to optimize daylight levels inside the office space.

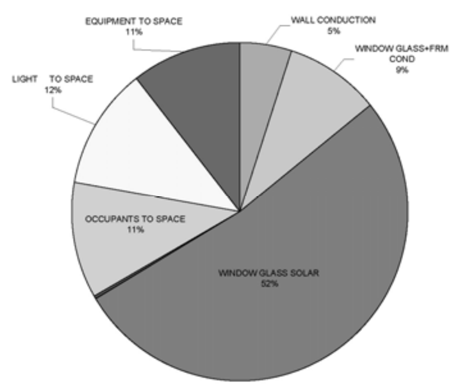

Fig 4. Typical office building cooling loads breakdown (Source; EDS, 2007)

Insolation studies show that the fenestration is most apt in the north and south oriented facades which experience the least amount of incident solar radiation during summer months. Furthermore, with higher VSAs in these orientations, it is far easier to shade an aperture than the ones on east and west oriented facades. A courtyard type building was proposed in order to minimize the lease span and thus achieve the necessary daylighting levels. Simple comparative daylighting analysis diagrams using *Ecotect* by Square One and *Radiance* by LBNL were sufficient to inform the clients of the advantages of a shallow lease span (Fig 4.). The building cores, comprising of elevator banks, toilets, riser shafts and other amenities where daylighting is a low priority, occupy the west and east facing bars of the courtyard building. The office spaces are located on east-west oriented bars with fenestration on its north and south facades (Fig 8).

These simple initial design decisions help lay the foundation for an architecture that is not only sensitive to its environment but also responds to it cleverly.

3.2 Building Massing & Insolation Studies

Once the building orientation and general programme layout was defined, opportunities were explored to further control insolation by manipulating the massing. A simultaneous massing study to understand insolation levels were performed while the massing geometry was being designed by other members of the team.

Initial analysis showed that most radiation was received on east-west facades followed by south facade. Since the building orientation and programming had already minimized exposure of office spaces to east-west and since the north façade receives minimal radiation, a strategy to further control radiation on the south façade was analysed.

It was found on the south facade that with minimal tilting or stepping out in the upward direction (0.5m per floor), a reduction in insolation levels of approximately 30% could be achieved (Fig 5). Once again, this was due to high solar altitude angles (high VSAs for the south façade) for most part of the year owing to lower latitude location of Hyderbad. Such stepping on the east and west facades had minor impact on insolation levels due to low altitude angles (low VSAs).

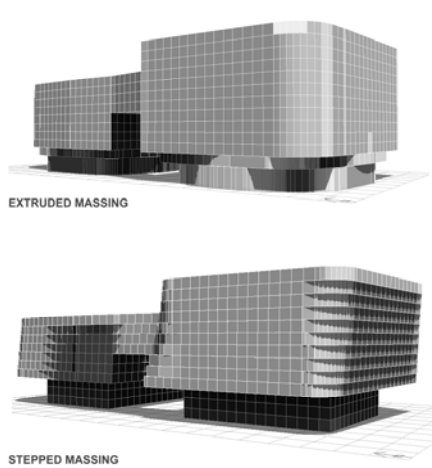

Fig 5. Insolation studies for extruded massing compared with stepped massing

This analysis provided a clear direction in terms of performance advantage of stepping the building massing in one direction over another.

3.3 Façade Articulation

Towards the middle of schematic design, as the massing of the building began to formalize, more detailed analysis and design began for the facades. A method was adopted by which a standardized panel system would create a small palette of window wall ratios (WWRs). This was based on an established module of 1.2m (Fig 6.). Each module was divided in three parts which would then vary between glazing and opaque panels giving us four panel types and WWRs; 1) Type A with 100% WWR (all glazed panels), 2) Type B with 66.7%, 3) Type C with 33.3% and 4) Type D with 0% (all opaque panels). Although this palette created only four varying WWRs, a combination of two could possibly create a different WWR. For example, types 'B' and 'C' together could create a WWR of 50% (Fig 6).

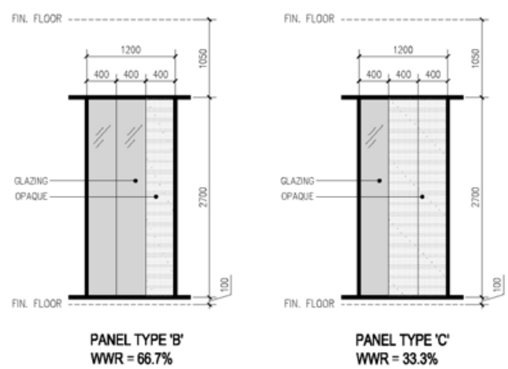

Fig 6. Panel types 'B' & 'D'

Different WWRs would then be applied to various facades guided by two key parameters; orientation of the façade and corresponding internal programme. For example, a west facing exterior wall with internal core space would only have 25% WWR (panel types 'C' + 'D'), whereas a west facing wall with internal office space would have 33.3% WWR (type 'C'). Using this method, the building has an overall WWR of approximately 30%.

Once all facades were associated with appropriate panel types, adequate shading device would be designed to maximize average annual shading percentage. The last step would be to evaluate an appropriate glazing type based on energy simulation results (Fig 7).

As a design decision it was decided to utilize vertical shading fins throughout the external wall. These fins would mirror their angles on every floor giving the building a more horizontal feel, keeping in sync with idea of contours rising out of the site (Fig 2). Also, these fins would be designed with a pattern inspired by traditional 'jalis'.

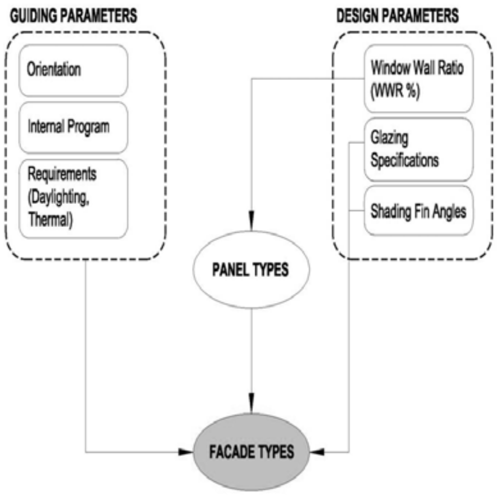

Fig 7. Façade design process

The first step in optimizing shading devices was to designate a unique nomenclature to every façade with a different orientation angle and/or different internal programme (Fig 8). A pre-determined size of the shading fin 'jali' of 850mm was kept as a constant while the rotation angle of the fins was a variable to be determined. In a first set of analysis, every façade was analysed for average annual shading percentage (using *Ecotect* software) with fins rotated every 10 degrees, both clockwise and counter-clockwise. The data generated was used to determine the angle to achieve maximum shading. In a second step, a slightly more detailed model was analysed for shading results. The results when compiled together show an overall average annual shading of over 88% (Fig 9). With already reduced WWRs and minimized shading, direct solar gains were significantly cut down. In fact, as a result of the shading input into the energy model, the reduced energy loads allowed the removal of two 800 ton chillers from the original HVAC design. It should be noted though that the WWRs and shading fin angles were further tweaked in response to daylighting studies and aesthetic considerations.

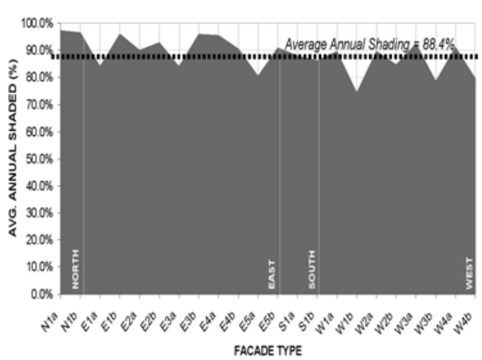

Fig 9. Overall average annual shading data (%)

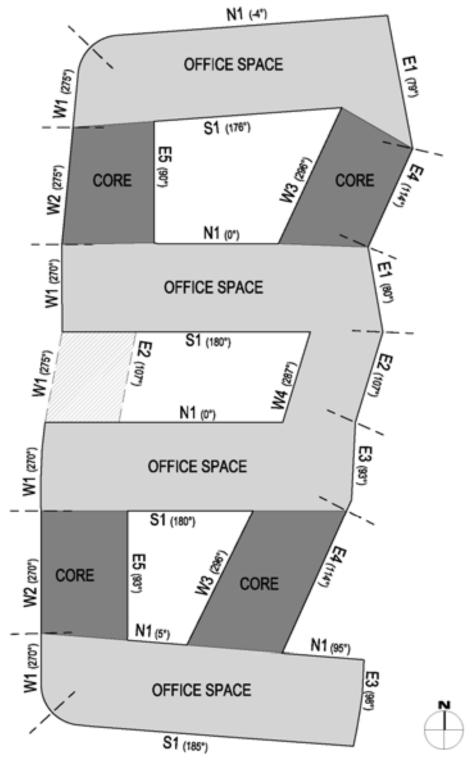

Fig 8. Façade types are uniquely designated based on orientation and programme

At the most detailed level, the selection of glazing was carefully analysed not only to fit the budget, but also for its properties in terms SHGC and u-values. Energy model analysis was used with different glass types that were economically viable and also available in the Indian market. This data (Table 1) helps the team collectively make a decision on an acceptable choice whilst evaluating all aspects of the product, as well as create a resource for future use.

4. Energy Efficiency

Throughout the process of design development, energy model analysis was run to evaluate energy consumption and reiterative models were run to understand individual components such as the glazing used on exterior facades.

Three primary energy models were used to run energy simulations. At the onset, an arbitrary model was built representing a typical glass office building in India. The model replicates a fully glazed building with SHGC values of 0.6 and no shading. In the absence of any mandatory energy code in India, many new buildings constitute similar low performing glazed facades. The second energy model was built to represent the design more closely and comply with the basic requirements of both ASHRAE 90.1 2004 and ECBC, 2007. This model was used as a base case to compare to the proposed Hill County design. The third and final model represented the proposed design accurately with

Table 1: Comparative data for different glazing products

	Company	Description	Color Shade	Code	Light Factors			SF	SC	SHGC	u-Value	Energy	Cost
					VLT (%)	Ext. Reflect. (%)	Int. Reflect. (%)	(%)			(w/m²K)	Savings over ASHRAE (%)	(Rs./m²)
1	Saint Gobain	DGU (Outer: 6mm with coating face 2 - 12mm Air - Inner: 6mm clear)	Pristine White	PLTT	70	11	11	64	0.62	0.53	1.77	3.2	[illegible]
2	Saint Gobain	DGU (Outer: 6mm with coating face 2 - 12mm Air - Inner: 6mm Planitherm Total, Low-e coating on face 3)	Pristine White	PLTT	71	9	6	61	0.59	0.50	1.7	3.8	[illegible]
3	Saint Gobain	DGU (Outer: 6mm Clear - 12mm Air - Inner: 6mm clear)	Clear	[illegible]	76	14	14	72	0.83	0.71	2.8	1.8	[illegible]
4	AGC	DGU (Inner Sunergy Clear pos.2 - 12mm Air - 6mm Planibel Clear)	Clear	Sunergy Clear	61	12	10	60	0.57	0.49	2.2	3.4	[illegible]
5	China Southern Glass	DGU (Outer: 6mm heat strengthened w/ coating on face 2 - 12mm Air - Inner: 6mm Fully tempered clear)	Clear	SCED12-76S+12A+6C	68	11	12		0.46	0.41	1.8		[illegible]

shading devices and glazing as specified in the design.

The results show that an ASHRAE or ECBC compliant building has drastically improved performance with roughly 60% savings over a fully glazed building of same size. The proposed Hill County design is roughly 18% better than the base case energy model. This reduction in energy consumption is mostly attributed to reduced WWRs and enhanced shading. It should be noted that the energy savings through office daylighting could not be taken into account as these are tenant controlled spaces and no mandatory requirements could be made to provide for daylight sensors. Furthermore, the COP for air-conditioning equipment remained at minimally compliant with ASHRAE guidelines to maintain budgetary limits and the fresh-air intake rates were increased 30% over minimum ASHRAE requirements.

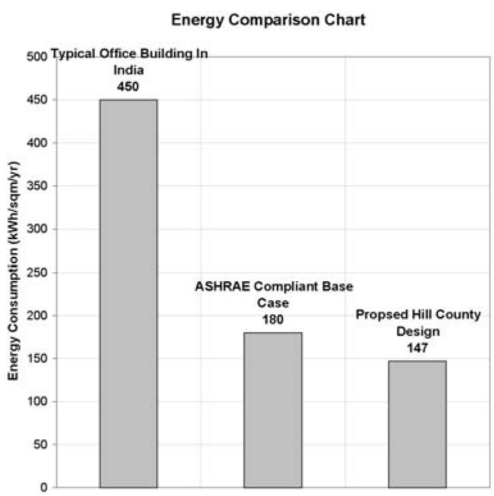

Fig 10. Comparison of energy models

5. Conclusion

In order to achieve a well performing building design, it is important to start environmental analysis at the initiation of the design process. It is all the more imperative to devise a process to do so, especially in large projects with multiple and large design teams. This process must be integrated into the overall project schedule. Studies and analysis in sync with the design development help inform the entire design team of the critical environmental issues of a given stage of design.

Some basic design moves, as were made initially for Hill County design helped create a well performing building with minimal or no capital cost increments. With additional SOM projects, the author aims to further streamline a process to seamlessly integrate environmental studies within a project development process, making it a standard procedure.

Fig 11. Perspective rendering for HC SEZ – view from north-west

6. Acknowledgements

Key design team members include;
SOM New York design team – Roger Duffy, Anthony Vacchione, Mark Igou, Peter Fajak, Alfredo Munoz and Richard Hall.
Environmental Consultants – Environmental Design Solutions, New Delhi (India)
HVAC Consultants - Spectral Services Consultants, Noida (India)
Client – Maytas Properties, Hyderabad (India)

7. References

1. Energy Conservation Building Code 2007
2. International Energy Agency (IEA), [Online], Available: http://www.iea.org/textbase/work/2006/buildings/krishan.pdf [14 June 2008].
3. Energy modelling done by Environmental Design Solutions (EDS), New Delhi (India) as consultants to SOM, 2007-08.