



# High Performance Building – A Case Study

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## Introduction

The Volvo-Eicher Corporate office is located in the National Capital Region (NCR) at Gurgaon. This ambitious project was conceived as a signature building for the Volvo group to showcase their commitment to the environment and to provide a work culture similar to that of the parent office. The total built area is 9150 sqm, spread over seven habitable floors and two basements primarily used for car park and service spaces.

The project has many innovative design features that make it stand out amongst its contemporaries, and has been recognized by Indian Green Building Council (IGBC) with the coveted Platinum rating under its IGBC LEED NC (New Construction) Rating System. The design team has ensured that the operational objectives of the building, which include not only the lowest energy consumption, but also the highest level of Indoor Environmental Quality (IEQ) for the occupants so that their productivity can be maximized while ensuring the smallest environmental footprint, are met. The highlights of the project are as follows:

- High performance building envelope exceeding ECBC and ASHRAE 90.1 set criterion.
- Passive design strategies for maximizing indoor thermal comfort and facilitating natural ventilation to ensure micro-climate generation.

- HVAC equipment selected to perform at the highest efficiency throughout the load curve.
- Combination of day-lighting and an efficient artificial lighting system with smart controls in order to minimize heat gain within space.

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## About the Author

**Ashish Rakheja** is a B.Tech. in Mechanical Engineering from REC University, Allahabad and M.Tech. in Thermal Engineering from IIT Delhi. He has work experience of over twenty years in design and coordination of multi-disciplinary engineering activities, has worked on writing codes and standards with various Government agencies, and has handled design activities of services for thirty six LEED Platinum rated green building projects in India. He is spearheading the green building movement in India as Chairman, Technical Committee of IGBC and is a certified LEED India Trainer. He heads the sustainability division at AECOM India. He is a Past National President of ISHRAE, and has won several national awards and recognitions.

**Saurabh Goyal** is an Associate at AECOM's Noida office. He has over 11 years of experience in MEP Engineering and Project Management. He has designed the largest number of Green projects in India, and is currently working on several projects poised for LEED Platinum and Gold awards.

**Tushant Suri** has a long experience in providing sustainable building solutions, project management and project facilitation of Green building rating systems. He has a Master's in Renewable Energy & Architecture from The University of Nottingham, UK. He provides green building facilitation services for new and existing buildings.

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- Careful thought to operation strategies through building integrated sensors with a feedback loop designed to minimize human intervention.

Based on recommendation from the design team, the Owners opted for Under Floor Air Distribution (UFAD) System supplemented with a double skin façade, making this building a pioneer in its field. Coupled with optimized internal lighting at Lighting Power Density (LPD) of 0.63W/sq ft, the project has achieved a 35.4% reduction in annual energy consumption over the base case set by ASHRAE 90.1-2004, and an EPI of 86.2 kWh/sqm/year. Table 1 highlights the actual energy performance of the building as captured by the dataloggers installed in the building.

Table 1: Month wise actual energy consumption of the building

Month	Annual Energy (kWh)
October 2013	112792
November 2013	89592
December 2013	71488
January 2014	56200
February 2014	63448
March 2014	57216
April 2014	49144
May 2014	77440
June 2014	89720
July 2014	106664
August 2014	91288
September 2014	139688
<b>Total</b>	<b>1004680</b>

The comparison between designed and actual energy consumption is given in Table 2.

Table 2: Design vs. actual energy consumption

Description	Design Case		Actual Operation Case	
	Annual Energy (kWh)	EPI (kWh/sqm/year)	Annual Energy (kWh)	EPI (kWh/sqm/year)
October 2013	81210	8.88	112792	12.33
November 2013	71674	7.83	89592	9.79
December 2013	57905	6.33	71488	7.81
January 2014	64630	7.06	56200	6.14
February 2014	41930	4.58	63448	6.93
March 2014	50160	5.48	57216	6.25
April 2014	54480	5.95	49144	5.37
May 2014	59170	6.47	77440	8.46
June 2014	66610	7.28	89720	9.81
July 2014	68000	7.43	106664	11.66
August 2014	67220	7.35	91288	9.98
September 2014	106163	11.60	139688	15.27
<b>Total</b>	<b>789152</b>	<b>86.2</b>	<b>1004680</b>	<b>110.1</b>

## Building Envelope Design

From the concept stage, emphasis was laid on minimizing heat ingress through the building envelope and accordingly, after carrying out life cycle cost analysis, specifications listed in Table 3 were adopted, which exceeded both ECBC and ASHRAE guidelines.

Table 3: As-built envelope design parameters

S. No.	Envelope Parameters	AHRAE 90.1-2004 Baseline	ECBC Baseline	Proposed Design	Envelope Specifications
1.	Walls	U-value: 0.7 W/m <sup>2</sup> .°C	U-value: 0.44 W/m <sup>2</sup> .°C	U-value: 0.41 W/m <sup>2</sup> .°C	16 mm thick ceramic tile + 50 mm insulation + 230 mm fly ash brick.
2.	Roof	U-value: 0.35 W/m <sup>2</sup> .°C	U-value: 0.40 W/m <sup>2</sup> .°C	U-value: 0.49 W/m <sup>2</sup> .°C	Broken china mosaic + 25 mm thick plaster + geo textile synthetic membrane + 40 mm polyurethane foam insulation + 25 mm thick plaster+ APP water proofing membrane + 35 mm thick PCC + 160 mm thick RCC slab.
4.	Glazing	U-Value: 6.9 W/m <sup>2</sup> .°C SC: 29% VLT: 59% WWR: 40%	U-Value: 3.3 W/m <sup>2</sup> .°C SC: 23% VLT: 16%	U-Value: 1.6 W/m <sup>2</sup> .°C SC: 37% VLT: 59% WWR: 47%	Double insulated high performance glass
5	Envelope heat transfer coefficient	1.5 W/m <sup>2</sup> .°C		0.75 W/m <sup>2</sup> .°C	Walls + Roof + Glazing

After optimization of envelope performance, the final break-up of the space heat gains from various sources is given in Table 4.

Table 4: Space heat gain summary

S.No.	Description	Heat Gain	Percentage of Total Gains
1	Envelope	139 kW	23%
2	Ventilation air (outdoor air)	103 kW	17%
3	Internal loads	358 kW	60%

Thus, the final building design is dominated by internal heat gains which constitute 60% of the total heat gains. Besides, the skin and non-skin loads were also studied so that the performance of HVAC system could be made independent for two zones to help in optimizing the power consumption further.

A Window Wall Ratio (WWR) of 47% helped to achieve natural day-lighting of over 110 lux in 77% of the floor space. Please

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Photo 1: Actual building image with no use of artificial lighting during daytime



Photo 2: Perforated metal louvers

refer to *Photo 1*, and it may be observed that design optimization has ensured minimal use of artificial lighting during day time. Each façade of the building has been investigated to quantify the intensity of sunlight/solar penetration through the window glazing at different times of the day and year. The sloping blinds are configured and designed to eliminate direct heat gain through radiation. The building façade is complemented with louvers made of a special quality alloy with coating to equip them with self-cleansing finish and long lasting properties. The strategically arranged perforated metal louvers not only make the building appear transparent, but also ensure that it gets indirect light with maximum deflection of direct heat. Please refer to *Photo 2*, highlighting the metal louvers designed to ensure glare free day-lighting and to maximise diffused solar radiation within the building.

A 40mm layer of polyurethane insulation is a vital element of roof assembly to minimise conductive heat gain. The sky facing surface of the roof, finished with white and broken china mosaic tiles with a Solar Reflective Index (SRI) of 108, reflects the sunlight to the sky, enhancing the performance of the building. Thus, an optimized combination of envelope specifications and WWR helped to reduce the overall energy demand, capital cost (by reduction in equipment sizes) and operational cost of the HVAC system, and to enhance the indoor environment for building occupants.

### Outdoor and Indoor Design Conditions

A conventional building is designed for peak ambient temperatures as specified in hand-books and design guides. For

this project, a detailed study was carried out, taking the following parameters into consideration:

- Site wind speed and direction to maximize micro-climate generation
- Solar radiation and orientation to determine shading devices
- Psychrometric analysis of indoor and outdoor conditions
- Skin and non-skin loads
- Equipment and occupancy schedules were drawn in consultation with Owner teams.

ASHRAE Standard 55 was referred to adopt and implement Adaptive Thermal Comfort in the building, which enabled the design team to move beyond the standard practice of designing for low internal temperatures and high peak load cooling system design. The AC load profile was developed for the entire year, which helped in equipment sizing and selection. The system design intended to provide thermal comfort at  $24\pm 2^{\circ}\text{C}$  and maintain maximum relative humidity and indoor air speed equivalent to 60% and 2m/s respectively.

### Lighting Design

Being a day time use building, efforts were undertaken to ensure maximum day-lighting in all regularly occupied spaces so that AC loads are calculated without any impact of heat gain from artificial lighting. Simulation software Integrated Environmental Solutions (IES) was used to evaluate the impact of fenestration sizes, properties and shading devices that ensured a glare-free light in the indoor spaces. The primary objective of the design exercise was to avoid the usage of blinds/curtains on windows. Internal heat loads for cloudy days were calculated with no safety



Photo 3: Image of artificial lighting simulation

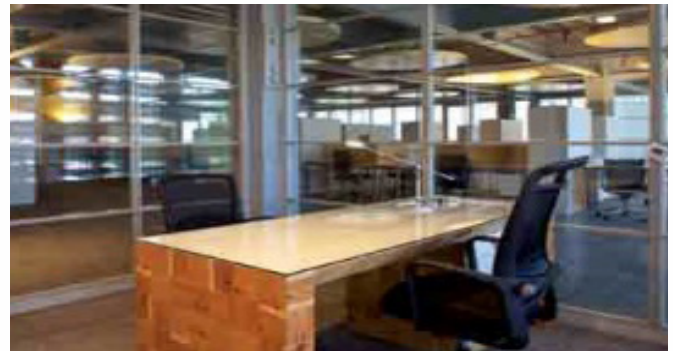


Photo 4: Another image of artificial lighting simulation

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factor, thereby reducing equipment sizes. The approach of task lighting and ambient lighting was adopted for artificial lighting design in the building. The selection and position of lighting fixtures was computed using IES simulation tool. The optimized design resulted in Lighting Power Density (LPD) of 0.63 W/sqft and Unified Glare Rating of 20, thereby enhancing the lighting uniformity within the room and consequently the visual comfort of the occupants. *Photo 4* highlights that shading design optimization has ensured a glare free daylight within the building coupled with minimal use of artificial lighting, enhancing the visual comfort of the occupants. An added benefit is realized in terms of facilitating the external view for the occupants. It is important to note that an extremely low LPD (40% lower than ECBC) is achieved with vented fluorescent T5 fixtures (instead of expensive LED lights), coupled with electronic ballasts to eliminate heat gains from conventional magnetic ballasts. All lighting fixtures are installed with high efficiency digital dimmable ballasts connected to daylight sensors that cut off artificial lighting during daytime and are programmed to gradually build it up as dusk approaches. Lamp selection is based on high efficacy (lumens per watt), color temperature, color rendering index, life, lumen maintenance, availability, switching/dimming capability and cost.

Thus, the combination of day-lighting, energy efficient luminaires and sensors enable the building to achieve 50% efficiency compared to ASHRAE 90.1-2004 base case with the following additional benefits:

- 79% of all regularly occupied spaces in the building have a minimum daylight factor of 2%.
- Glare free space lighting quality.
- Optimized illumination level on work plane to reduce eye strain and fatigue.
- Healthy and productive work environment.

The benefits from day-lighting are further enriched by the integration of occupancy sensors in normally unoccupied areas like stores, toilets, etc. to minimize the use of artificial lighting in non-required areas when they are not occupied.

### Energy Modeling

It is a conventional practice to compute air conditioning loads at peak ambient conditions that occur ranging between 0.4% to 1% times in a year. This leads to over-sized equipment selection and inefficiency in the system due to part-load operation for most of the year. For this project, a whole building energy simulation approach was employed using computer simulation tool e-Quest, thereby creating a year round AC load profile that helped in a better understanding of operating conditions.

The pre-meditated integration of passive strategies and active design features enable the project to achieve total diversified AC load of 200 TR for a built-up area of 9150 sqm. Thus the project achieves a very high 45.75 sqm/TR ratio on gross built-up area.

### Indoor Air Quality and Thermal Comfort

In accordance with LEED requirement, an additional 30%

outdoor ventilation air supply is provided over the benchmark set by ASHRAE Standard 62.1-2013, thereby enhancing the Indoor Air Quality within the occupied spaces. The air quality is monitored in all indoor spaces through CO<sub>2</sub> sensors located at 1.8m height above the floor level. These provide an audible alarm to the operator when the difference between indoor and outdoor CO<sub>2</sub> levels exceeds 800 ppm. Each AHU is installed with a combination of MERV 8 (pre-filter) and MERV 13 (fine filter) filters with an eye to provide a healthy environment for the occupants.

### Innovation

Under Floor Displacement Ventilation (UFDV) with enhanced outdoor air supply is the unique feature of the project, and is a trend-setter for the industry. The previous examples of employing UFDV in Indian projects are limited to Data Centers or small applications in typical spaces without availing benefits of higher chilled water temperatures or optimized skin loads.

Through the under-floor air distribution system, conditioned air is channelized into the space through diffusers set into a raised floor via a plenum. When conditioned air enters the plenum, it is heated by transfer of heat through the floor from the warmer space above. Manually adjustable floor diffusers

deliver the air to the space, allowing occupants to control their individual environment. Variable volume floor outlets as well as booster fans at

select locations connected to a thermostat provide automatic zone control for some spaces such as conference rooms. The cool supply air at the floor rises to the ceiling, taking heat and indoor air pollutants with it. At the ceiling, the air travels through the ceiling plenum and back to the air handling unit. This produces an overall floor-to-ceiling air flow pattern that takes advantage of the natural buoyancy produced by heat sources in the office, thereby efficiently removing heat loads and contaminants from the space.

UFDV also ensures that conditioned supply air is mixed with outdoor ventilation air through the Air Handling Unit (AHU) and distributed through the pressurized plenum at the floor level where occupants are present. The air conditioning ducts, which are normally fitted in false ceilings in a majority of buildings, have been eliminated and natural convective currents (hot air being lighter

**This project was recently declared Runner-up in the System Design category of the 10th Bry-Air Awards for Excellence in HVAC&R, during ACREX 2015.**



*Photo 5: Plenum floor*

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than cold air) help in achieving proper stratification, thereby ensuring that the dehumidified air quantity supplied through the floor is limited to 1.4 cfm/sq ft as against the conventional practice of 2.0-2.5 cfm/sq ft. This further helped in reducing the size of the AHUs, wherein the fans are provided with EC motors for modulation as compared to Variable Frequency Drives. *Photo 5* depicts the plenum that channelizes the air distribution into the building. It is important to note that as per ASHRAE and LEED criterion, the ventilation effectiveness of under-floor supply is 1.2 as compared to 1.0 for overhead systems, thereby providing healthy indoor environment. The swirl diffusers located near or in each workstation control the interior temperature. They also act as a 'user interface' to the system since they can be adjusted by the user to vary the airflow to suit his personal requirement. An added advantage of the system is that the diffusers can also be moved to different positions around the occupant, thus providing more flexibility to the design.

Lastly, the supply and return air temperatures in a UFAD system are 18 deg C and 28 deg C respectively, which are higher than conventional overhead air distribution, thereby extending the use of 100% free cooling through the integration of Dedicated Outdoor Air System (DOAS).

### Maintenance and Operation

In the Indian context, it is a known fact that despite superior standards of design solutions as well as deployment of new technologies, there exists a significant gap in the quality of execution due to unskilled labor. ASHRAE-recommended commissioning methodology has been adopted for the project to ensure that the building is operated as designed. Also, an independent team acted as a third party commissioning agent/ auditor to carry out the following activities based on critical operation parameters identified during design stages:

- Design Phase Commissioning to provide early inputs for the incorporation of a successful monitoring mechanism.
- Construction Phase Commissioning for proper implementation of M&E systems.
- Acceptance Phase Commissioning to ensure that the HVAC contractor demonstrates the operation of equipment as per design intent.
- Occupancy Phase Commissioning to focus on proper operation of the systems by the O&M staff.
- Continuous commissioning for a period of one year to verify operational methods and equipment performance through periodic audit process.

Energy meters are also installed to log data continuously for monitoring equipment performance. This data is compared regularly with the baseline data to determine the actual savings. A daily, weekly and monthly comparison of electricity consumption is carried out for the whole building and individual components like HVAC, lighting and other related areas.

### Environmental Impact

*Table 5* depicts, as designed, peak cooling load (TR), simulated annual energy consumption (kWh), energy performance index

(kWh/m<sup>2</sup>/year) and equivalent greenhouse gases emission (CO<sub>2</sub> emission) as compared to ASHRAE 90.1-2004 baseline case. The final design is estimated to reduce annual carbon emissions by 35.6%, which amounts to reduction of 219 tons (equivalent to annual carbon emitted by 50 passenger cars or 2.5 acre of forest preserved from deforestation). The building performance has been evaluated using DOE 2.0 e-Quest Energy Modelling Software.

*Table 5: Environmental impact parameters of the project*

Parameters	ASHRAE 90.1 2004 Baseline Case	Proposed Case (Energy Simulation)
Air Conditioning Load	275 TR	200 TR
Simulated Annual Energy Consumption	1264 MWh	789.12 MWh
Energy Performance Index	138.1 kWh/m <sup>2</sup>	86.24 kWh/m <sup>2</sup>
Annual Carbon Emission	746 tCO <sub>2e</sub> /annum	465 tCO <sub>2e</sub> /annum
Pollution (Equivalent Cars on Road)	133 cars	83 cars

(Note: 1 MWh=0.58982 tCO<sub>2e</sub>)

The installed HVAC&R equipment operates on environment friendly R134A (for water chilling machines) and R410 (for standby VRF systems) refrigerants respectively. The cooling tower make-up requirement of the building is met through the treated sewage treatment plant water, reducing the potable water requirement by 9.8% – equivalent to 7.6 kl/day.

### Conclusion

UFAD system coupled with double skin façade offers a potential for initial capital savings in the form of reduction of the slab-to-slab height and cooling capacity equipment size due to natural stratification, thermal comfort improvements, minimized ducting and reduced construction schedules. The additional cost of the access floor system got largely offset by savings in wiring and HVAC equipment installation coupled with substantial reduction in the operation cost of the building. An added advantage of under-floor air distribution system is that the diffusers can also be moved to different positions within the proximity of occupants, thereby enhancing their thermal comfort. The access floor system also provided opportunities to explore synergistic combination of the routing building services such as power, voice and data wiring, paving the way for easy maintenance and enhanced management of communication and data infrastructure. The Electro Mechanical design of Volvo-Eicher Corporate Office is yet another leap towards achieving the dream of a Net Zero Energy Building in India. ❁