Evaluation of the double skin façade in Warm and Humid climate, Mumbai

Case study: ICICI TOWER, Jet Airway HQ

Afsanehsadat Omidiani

College of architecture, Bharathi Vidyapeeth University, Pune

Abstract- Energy today as one of the major factors in the formation and development of industrial societies known. Reduction of energy consumption requires a new solution approach for sustainable architecture .So the choice of double skin facade is as a way to efficiently use energy resources. The method of research in this paper was based on data collected in the form of Case Study Method. This paper calculates the energy saving by Double Skin Façade in two case studies, ICICI Tower and Jet Airway H.Q, in Mumbai. The aim of the research was to evaluate the total quantity heat gain in two case studies according to solar intensity and surface area of building as a reduction in energy consumption and an increase in occupant comfort. Double Skin Facade and combining it with an HVAC system that besides the positive aspects of aesthetic studies and examples of actual results in 30% savings in energy consumption. Additionally, natural ventilation, building dependence natural light plays an important role in the reduction of noise reduction and Resistance to wind energy.

Index Terms- sustainable architecture, Double Skin Facade, solar intensity, surface area, energy saving.

I. INTRODUCTION

This paper discusses a building element known as double skin façade. The motivation for using the double skin façade concept in building mainly comes from the encouragement for sustainable design. In recent years, the building community has integrated sustainable design concepts that can improve indoor air quality while conserving energy in buildings.

Double skin façade concept is a construction element that is intergraded in buildings to achieve several properties that can increase the performance of a building. It is a European architectural trend that is currently gaining momentum throughout the whole world. The basics of the system are that an additional skin is applied to the building with cavity between the external wall and the outside façade.

The outer layer of the double skin façade is constructed with glass panes mounted on a structural grid. The façade has to be close to fully glaze to optimize the function of the system. There is often intergraded a shading device in the system to gain control over the solar radiation [1].

1. Sustainable design:

In the view of sustainability, recently DSF has received much attention as opposed to the more typically glazed curtain wall. Naturally a ventilated Double-Skin Facade seems very interesting from an energy point of view, but a good design and the proper operation of the system are crucial to improve the energy savings. The design of the DSF involves decisions on geometric parameters, glass selection, ventilation strategy, shading, daylighting, aesthetics, wind loads, and maintenance and cleaning cost expectations [2].

Most researchers, that take interest in the double skin façade, attempt to identify the performance and the energy efficiency of the double skin façade. Buildings contribute for roughly around half of all the energy consumption from cities. In modern times sustainability is becoming one of the most challenging tasks for designers to consider, especially when it comes to buildings. Today there is a worldwide stimulation to have buildings as energy efficient as possible to contribute to the today's demand on sustainable environment.

In many minds sustainability means simply that a building is as environmentally friendly as can be. But sustainability also includes living and working environment for people and economic aspects. To be fully considered as a sustainable design, a building has to consider all of these elements and the design has to try to incorporate as much of these elements as possible.
One of these potentials was that the double skin façade is contributing to the idea of sustainable building by decreasing the energy use and at the same time increasing indoor climate quality. But there are some skeptical drifts about the consequences of utilizing the double skin concept [1].

2. Double Skin Façade:

The form and construction of facade systems have a strong influence on both the energy consumption of a building and the comfort level of its occupants. A double window system (DWS) is an energy-efficient envelope system in which a cavity is placed between the inner and outer layers to provide natural ventilation, solar radiation control, and enhanced insulation [3-9].

According to the Source book of the Belgian Building Research Institute [BBRI] [10] "An active façade is a façade covering one or several stores constructed with multiple glazed skins. The skins can be air tighten or not. In this kind of façade, the air cavity situated between the skins is naturally or mechanically ventilated. The air cavity ventilation strategy may vary with the time. Devices and systems are generally integrated in order to improve the indoor climate with active or passive techniques. Most of the time such systems are managed in semi-automatic way via control systems."

Harrison and Boake [11] in the Tectonics of the Environmental Skin, described the Double Skin Facade system as “essentially a pair of glass “skins” separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes”.

Uuttu [12] describes the Double Skin Facade as “a pair of glass skins separated by an air corridor (also called cavity or intermediate space) ranging in width from 20 cm to several meters. The glass skins may stretch over an entire structure or a portion of it. The main layer of glass, usually insulating, serves as part of a conventional structural wall or a curtain wall, while the additional layer, usually single glazing, is placed either in front of or behind the main glazing. The layers make the air space between them work to the building’s advantage primarily as insulation against temperature extremes and sound.”

Saelens [13] defines the multiple – skin facade as “an envelope con- struction, which consists of two transparent surfaces separated by a cavity, which is used as an air channel. This definition includes three main elements: (1) the envelope construction, (2) the transparency of the bounding surfaces and (3) the cavity airflow.”

According to Claessens and De Herde [14] “a second skin façade is an additional building envelope installed over the existing façade. This additional façade is mainly transparent. The new space between the second skin and the original façade is a buffer zone that serves to insulate the building. This buffer space may also be heated by solar radiation, depending on the orientation of the façade. For south oriented systems, this solar heated air is used for heating purposes in the winter time. It must be vented in order to prevent overheating in other periods.”

Compagno [15] describes the Double Skin Façade as “an arrangement with a glass skin in front of the actual building façade.’’ Solar control devices are placed in the cavity between these two skins, which protects them from the influences of the weather and air pollution a factor of particular importance in high rise buildings or ones situated in the vincity of busy roads [16].
The aim of this facades is masimize of energy efificiency, decreaese of energy lose. Double skin facades on building, are arelaive new technolologies in constructon field. This façades are significantly more expensive to install than the installed facade. This research is increasing every day and it will also increase rapidly in the future [17].

3. The Double Skin Façade Concept:

The BBRI [10] includes in the Source book a satisfactory description of the structure of a Double Skin Façade System. The layers of the façade are described below:

1. Exterior Glazing: Usually it is a hardened single glazing. This exterior façade can be fully glazed.

2. Interior glazing: Insulating double glazing unit (clear, low E coating, solar control glazing, etc can be used). Almost always this layer is not completely glazed.

3. The air cavity between the two panes. It can be totally natural, fan supported or mechanically ventilated. The width of the cavity can vary as a function of the applied concept between 200 mm to more than 2m. This width influence the way that the façade is maintained.

4. The interior window can be opened by the user. This may allow natural ventilation of the offices.

5. Automatically controlled solar shading is integrated inside the air cavity.

6. As a function of the façade concept and of the glazing type, heating radiators can be installed next to the façade [18].

4. CLASSIFICATION AND TYPOLOGY:

There are many ways to classify different types of a double skin facade. The most common way of categorizing different types of the system was made by Oesterle *etal.* In fact, Oesterle's [19]. definition is used by almost all researchers to classify the system.

• **Box window type:** In this case horizontal and vertical partitioning divide the façade in smaller and independent boxes.

• **Shaft box type:** In this case a set of box window elements are placed in the façade. These elements are connected via vertical shafts situated in the façade. These shafts ensure an increased stack effect.

• **Corridor façade:** Horizontal partitioning is realized for acoustical, fire security or ventilation reasons.

• **Multi storey Double Skin Façade:** In this case no horizontal or vertical partitioning exists between the two skins. The air cavity ventilation is realized via large openings near the floor and the roof of the building [20].

5. Considering these points, we can improve the performance of the second skin:

- Select the correct type of glass on both facade
- Percentage of transparent and opaque surfaces
- Use sun block levels (Louvre)
- Depth of cavity
- The type and location of inlets and outlet air
- Use air intake systems (Mechanical ventilation)
- Use appropriate systems for air exchange with the room.

II. CASE STUDIES

1. ICICI Bank Towers Mumbai

1.1.Building summary:

ICICI bank towers located at Bandra Kurla Complex in Mumbai, has an area of about 631476 ft. The building was completed in 1998 and it incorporates the green building materials and concepts.

Building was supported with IBMS (Integrated Building Management System), which has helped in our efforts to conserve energy. The system has demonstrated that energy savings can be achieved through efficient energy management strategies. The buildings original design includes numerous energy efficiency features, including day lighting, green rooftops, and double glazed, low-emissive windows. In addition to this, constant up gradations were carried out with energy efficient system and equipment [21].

In high-rise buildings, especially in situations where the upper floors are subjected to wind pressure and noise pollution, use of Double Skin Façade using natural ventilation features are very efficient and effective. Factors such as noise insulation required, air flow velocity in the cavity, exterior building condition, type, number and location of the external and internal openings in each layer, have a direct impact on the design of these facades.

In view of the design and evaluation of double skin only economic factors should not be considered. Other issues such as thermal comfort of occupants and beauty should be equally considered. Specifically, the second skin is designed for the reconstruction of an old building. In addition, performance improvements of the exterior facade, new perspective of buildings is presented.

Fig. 1: ICICI Bank Towers, Mumbai

1.2.Features of ICICI Bank Towers:

- Two Towers: Each G + 11 floors
- Lifts: Mitsubishi make, 12 passenger, 2 Capsule, 2 Freight (total 16 nos.)
- HVAC : 5 X 307 TR + 1 x 250TR Carrier, Air cooled chillers, 99 AHU's, 44 FCUs & 60 Ventilation fans
- For data center : 90 TR Chiller Separately
- Electric Supply : BSES -11 KV, 4 x 1500 KVA Dry
- z Green tops and over deck insulation
- Structural Glazing : 6mm soft coated Double Glazed Units from VIRACON
- Sewage Treatment Plants [21].

1.3.Analysis of building:

The Prevailing wind direction is West & South — West, so the ICICI Tower is oriented North East — South West.

The maximum Area of the building is exposed to west side. Usually in warm & humid climates the orientation should be exposed to wind direction, but due to buildings security reasons it's sealed from all sides by glass envelope the orientation will maximizes heat gain. Due to orientation it shades path way on Road sides in morning & evening. Also they Control all lights by zoning the office area and operation of the same through lighting control system.

1.4. Occupancy in the building:

During recent years the occupancy in the building has reached its maximum. Average working hours at ICICI Bank Tower is 14 hr/day. As the interface between interior space and exterior environment a building's skin plays a crucial role in heat and light exchange. Its performance in that role affect occupant comfort and productivity, energy use and running costs [21].

1.5. Wall Envelope:

Wall envelope consists of the Structural Glazing, Aluminum cladding, White color luster paint inside, and with internal walls of Gypsum block. Structural Glazing systems are a brilliant, cost effective solution for contemporary glass design. Structural Glazing systems consist of a fully or partially framed internal finish, with the glass structurally glazed/adhered to the outside face. In the ICICI Bank the Structural Glazing is consist of 6mm soft coated Double Glazed Units from VIRACON and this can minimizes radiation.

The SHGC is a ratio between 0 and 1. SHGC = 0 that means none of the incident solar gain is transmitted through the window as heat and SHGC = 1 means all of the incident solar energy is transmitted through the window as heat [22].

Table 1 Dimensions at the typical floor plate

Floor Plate Area	**2500 sq. m**
Height	**Height= 48 M**
1 Tower Surface Area	
North	**1680 m^2**
South	**1680 m^2**

East	**1680 m^2**
West	**1680 m^2**
Total built up area	**30,000 sq.m**

We calculate the Heat Gain of the South facing wall for, month of May at 4 pm.
Q=A*I*O, where:
Q= QUANTITY OF HEAT, A= AREA OF WALL, I= INCIDEANT ON SURFACE, O= SOLAR GAIN FACTOR.

AREA OF WALL = 1680 SQM,

Table 2 Incident on Surface, SHGC and Area of Wall for Single floor

Area of Wall for Single floor	**35*4=140 sq. m**
Incident on Surface	**91.7**
SHGC	**0.37**

As the above, Area of wall for single floor is 140 sq. m and the Incident on surface is 91.7, and the Solar Heat Gain Coefficient is 0.37, so:

THERE FOR QUANTITY OF HEAT = 140* 91.7* 0.37 = 4,750 WATTS HEAT GAIN THROUGH WALL PER SQ M OF FLOOR AREA,

THERE FOR, QUANTITY OF HEAT = 140* 319.59* 0.37 = 16,554 WATTS HEAT GAIN THROUGH WALL PER SQ M OF FLOOR AREA,

THERE FOR, QUANTITY OF HEAT = 140* 491.74* 0.37 = 25,472 WATTS HEAT GAIN THROUGH WALL PER SQ M OF FLOOR AREA,

Where:
FLOOR AREA = 1250 Sq. m (1 TOWER - SINGLE FLOOR)
So:
Heat Gain in South Facing Wall= (4,750 / 1250) = 3.8W/SQM
Heat Gain in South- West Facing Wall= (16,554/ 1250) = 13.2W/SQM
Heat Gain in West Facing Wall= (25,472/ 1250) = 20.37 W/SQM

Table 3 Surface area, Solar intensity, Total quantity of heat gain and Heat gain calculation in different facing walls:

	SURFACE AREA	**SOLAR INTENSITY**	**TOTAL QUANTITY OF HEAT GAIN**	**HEAT GAIN/M2**
SOUTH FACING WALL	**140 sq. m**	**91.7 w/m2**	**4,750 watts**	**3.8 w/m2**
SOUTH WEST FACING WALL	**140 sq. m**	**319.5 w/m2**	**16,554 watts**	**13.2 w/m2**
WEST FACING WALL	**140 sq. m**	**491.7 w/m2**	**25,472 watts**	**20.3 w/m2**

2. Jet Airway HQ, Mumbai:
3.

Fig. 2: Jet Airways HQ, Mumbai – SOM

2.1. Analysis of building:

The Prevailing wind direction is West & South — West, so the Jet airways HQ is oriented East — West direction. Maximum Area of the building is exposed to south - west side. exposed to wind direction, but due to buildings security reasons it's sealed from all sides by glass envelope the orientation will maximizes heat gain.

2.2.Wall Envelope:

The Wall Envelope is Double Skin Façade, it can minimizes the radiation.
Parameters of glazing system

1) **Eternal double pane glazing:**

Outer layer: VE 2-2M with 6mm thickness.
Eout=0.84, E1n=0.04, Reflectance=0.05 Transmittance=0.28
Air gap: 13mm thickness.
Inner layer: clear glass with 3mm thickness
E out=0.84, E in= 0.84, Reflectance=0.08, Transmittance=0.76 2)

2) Internal single pane glazing

Clear glass with 3 mm thickness
E out=0.84, E in=0.84, Reflectance=0.08, Transmittance=0.76 (ENVIRONMENTALLY RESPONSIVE BUILDING SKINS)

Tale 4 Dimensions at the typical floor plate:

Floor Plate Area	**3800 sq. m**	
Height	Height = 48.0 M	**268 m² (single floor)**
North	3216 m²	**196 m² (single floor)**
South	2352 m²	**216 m² (single floor)**
East	2592 m²	**224 m² (single floor)**
South-West	2688 m²	
Total Built up Area	30000 sq.m	

2.3. Envelope Study:

Fig. 3: Jet Airway HQ, Mumbai plan

The Heat Gain of the South facing wall is calculated for month of May at 4 pm.
Q=A*I*O, where:
Q= QUANTITY OF HEAT, A= AREA OF WALL, I= INCIDEANT ON SURFACE, O= SOLAR GAIN FACTOR.
AREA OF WALL = **2352 SQ M,**

Table 5 Incident on Surface, External Skin SHGC and Internal Wall SHGC of Wall for Single floor

Area of wall for Single Floor	**49*4 = 196 sq. m**
Incident on Surface	**91.7**
External Skin SHGC	**0.32**
Internal Wall SHGC	**0.84**

THERE FOR, QUANTITY OF HEAT,

- Ext. = Solar incident x SHGC = 319.5 * 0.32 = **102.2 watts.**

Qs = 196 *1022 = 20,031 WATTS.
(20031 / 3800) = **5.27 W/SQM**

- Int. = Solar incident* SHGC = 102.2* 0.84 = **85.90 watts.**

Qs = 224*85.9 = 19,242 WATTS.
HEAT GAIN THROUGH WALL PER SQ M OF FLOOR AREA, FLOOR AREA = 3800 SQ.M (SINGLE FLOOR)
(19242 / 3800) = **5.0 W/SQM**

Table 6 Surface area, Solar intensity, Total quantity of heat gain and Heat gain calculation in different facing walls:

	Surface Area	**Solar Intensity**	**Total Quantity of Heat Gain**	**Heat Gain W/ m^2**
South Facing Wall	196 sq. m	91.7 W/m^2	4830 Watts	**1.27 W/m^2**
South-West Facing Wall	224 sq. m	319 W/m^2	19243 Watts	**5.0 W/m^2**

Table 7 Comparative analysis of case studies; South-West wall heat gain:

NAME	D.G.U	D.S.F	%
ICICI TOWER	13.2 W/M2	9.6 W/M^2	27%
JET AIRWAYS HQ	9.96 W/M2	5 W/M^2	28%

III. CONCLUSION

- The aim of this investigation is to evaluate the economic and environmental impact produced by a DSF (Double Skin Facade System). The results shows that in the ICICI TOWER, the 27% of the energy, and JET AIRWAY HQ, 28% of the energy can be saved in order to arrive at increased transparency combining acceptable indoor environment with reduced energy use.
- According to our results, cooling and heating load reduction can be achieved by adopting the DSF. Regardless of the implementation of natural ventilation, the DSF offers a better performance than Single Skin Facade. With natural ventilation, the performance of the DSF can be maximized.
- The performance of the facades were evaluate in terms of total energy demand, the individual energy demand for heating, cooling arterial lighting, and also the amount of daylight in terms of day light factor.
- The heat gain calculation resulted on the South, South-West, and West facing in the month of May at 4 pm is considered to show quantity of heat.
- The great performance of the double skin facade was emphasized by a U-Value, Solar Heat Gain Coefficient, and Incident on the window's surface according to the floor area.
- Using suitable glazed utilization for double skin facade is a good solution in order to have the maximum energy to save.
- The double skin façade can increase the indoor climate resulting in increase productivity of the occupiers.

REFERENCES

[1] Hilmarsson, J. G. Double Skin Facade, Evaluating the Viability of the Component. Copenhagen Technical Academy. October 2008.

[2] M.A. Shameria, M.A. Alghoulb, K. Sopianb, M. F. M. Zaina, O. Elayebb, Perspectives of double skin facade systems in buildings and energy saving, Renewable and Sustainable Energy Reviews 15 (2011) 1468–1475.

[3] Da Silva, F.M.; Gomes, M.G. Gap inner pressures in multistory double skin facades. Energ. Build. 2008, 40, 1553–1559.

[4] Roth, K.; Lawrence, T.; Brodrick, J. Double skin facade. ASHRAE J. 2007, 49, 70–73. Sustainability 2014, 6 7332

[5] Safer, N.; Woloszyn, M.; Roux, J.-J. Three-dimensional simulation with a CFD tool of the airflow phenomena in single floor double-skin facade equipped with a Venetian blind. Solar Energ. 2005, 79, 193–203.

[6] Hamza, N. Double versus single skin facades in hot arid areas. Energ. Buildings 2008, 40, 240–248.

[7] Baldinelli, G. Double skin facades for warm climate regions: Analysis of a solution with an integrated movable shading system. Build. Environ. 2009, 44, 1107–1118.

[8] Kim, S.Y.; Song, K.D. Determining photosensor conditions of a daylight dimming control system using different double-skin envelope configurations. Indoor Build. Environ. 2007, 16, 411–425.

[9] Ghaffarian, H.A.; Beradi, U.; Makaremi, N. Intelligent facades in low-energy buildings. Br. J. Environ. Clim. Change 2012, 2, 437–464.

[10] Belgian Building Research Institute (BBRI). Source book for a better understanding of conceptual and operational aspects of active facades. Department of Building Physics, Indoor Climate and Building Services, Belgian Building Research Institute. 2002. Version no 1. Web address: http://www.bbri.be/activefacades/index2.htm

[11] Harrison, K., & Meyer-Boake, T. The Tectonics of the Environmental Skin. University of Waterloo, School of Architecture. 2003. Web address http://www.fes.uwaterloo.ca/architecture/faculty _projects/terri/ds/double.pdf

[12] Uuttu, S. Study of Current Structures in Double-Skin Facades. MSc thesis in Structural Engineering and Building Physics. Department of Civil and Environmental Engineering, Helsinki University of Technology (HUT), Finland. 2001. Web address: http://www.hut.fi/Units/Civil/Steel/SINI2.PDF

[13] Saelens, D. Energy Performance Assessments of Single Storey Multiple-Skin Facades. PhD thesis, Laboratory for Building Physics, Department of Civil Engineering, Catholic University of Leuven, Belgium. 2002. Web address: http://envelopes.cdi.harvard.edu/envelopes/content/ resources/pdf/case_studies/PhD_Dirk_Saelens.pdf

[14] . Claessens, J., & DeHerte, A. Active Solar Heating and Photovoltaics. Solar Energy in European Office Buildings. Energy Research Group, School of Architecture, University College of Dublin, Ireland. Web address: http://erg.ucd.ie/mid_career/mid_career.html

[15] Compagno, A. Intelligent Glass Facades (5th revised and updated edition). Berlin: Birkhäuser. 2002.

[16] Poirazis, H. Double Skin Façades for Office Building. Report No EBD-R--04/3. 2004.

[17] Eren, Ö and Erturan B. Sustainable Buildings with Their Sustainable Facades. IACSIT International Journal of Engineering and Technology. December 2013, Vol. 5, No. 6, p730.

[18] Poirazis, H. Double Skin Facade. A report of IEA SHC Task 34 ECBCS Annex 43. 2006.

[19] Oesterle, E., Lieb, R-D., Lutz, M., & Heusler, W. Double Skin Facades – Integrated Planning. Prestel Verlag: Munich, Germany. 2001.

[20] Hilmarsson, J. G. (October 2008). Double Skin Facade, Evaluating the Viability of the Component. Copenhagen Technical Academy .

[21] http://www.emt-india.net/eca2006/Award2006_CD/36OfficeBuildings/ICICIBankTowersMumbai.pdf, n.d.

[22] Gregg D. Ander, F. (2010, 06 18). National Institude of Building Sciences. Retrieved from http://www.wbdg.org/resources/windows.php.

AUTHORS

First Author – Afsanehsadat Omidiani,
College of architecture, Bharathi Vidyapeeth University, Pune
E-mail: soara_barin@yahoo.com