

Thermal Behaviour of Double Skin Facades: A Case in IT Buildings

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ABSTRACT: The Façade is synonymous with “a boundary and inner face, and a backdrop of streets and urban spaces”. But the façade as a building envelope also stands for intelligent systems, which can be planned and executed perfectly with a broad range of technology and materials. Therefore efficient energy management, interior climatic control and protection from outside influences such as noise, heat, cold or the sun’s rays are the fundamental requirements of a modern building and of the building envelope per se. Hence the main objectives of this paper are (a) to investigate the thermal effect of double skin facades in an IT office building in the warm and humid climate of Chennai and (b) to propose guidelines for their efficient design based on the evaluation as per ECBC by numerical analysis. An effort is made to analyse the IT building under study to investigate the Façade with respect to the thermal gradient across the existing façade section. The main source for the high cooling loads was found to be heat gain through windows and walls. This led to the evolution of a series of façade strategies with the goals of reducing heat gain, providing ventilation and daylighting along with the use of appropriate insulating materials.

Keywords: double skin façade, thermal gradient, energy, cooling strategies,

NOMENCLATURE

Symbol	Description	[Units]
R	Resistance	[m ² degC/W]
U	Transmittance	[W/m ² deg C]
b	Thickness	[cms]
k	Conductivity	[W/m deg C]
1/fo	Internal Surface R	[m ² degC/W]
1/fi	External Surface R	[m ² degC/W]
Rip	R of inner plaster	[m ² degC/W]
Rop	R of outer plaster	[m ² degC/W]

1. INTRODUCTION

If building envelopes are to be truly “functional”, it is important to identify project specific requirements and boundary conditions relevant to the building envelope as early as in the planning phase. In addition, the building envelope, structure, technology and interior must be considered together.

In most of the IT buildings in Chennai, it has been found that an architect applies glazing to a building envelope to express an expansiveness and hi-tech quality through transparency. Except for the selection of colour of the glass, elevation of single and

double glazing units and Aluminium Composite Panel Wall Cladding, there are not many designs specially tailored for the climate of Chennai

Therefore the aim of this paper is to redesign an IT building façade with appropriate double-skin strategies. Each of these strategies was varied according to the layers constituting the façade, the transparency of the façade and the orientation of the façade to which it is applied.

Final comparisons of thermal gradient were made between the proposed options and the base case to find the most efficient strategy and also the factors that affected this efficiency. The double skin was modelled by numerical analysis as per an approximate and simplistic calculation of the U-value and transmissivity properties of the layers constituting the façade.

Based on inferences drawn from these façade design models, a set of design guidelines comprised of goals and parameters were generated for design of double-skin façades in warm humid climate typical to Chennai. It was realized that the double-skin defined typically as a 'pair of glass skins separated by an air corridor' may not be an entirely energy efficient design strategy for hot climates. However, when used appropriately in combination with other materials, in the right orientation and with the right transparency and ventilation, a double-layered façade turns out to be an energy efficient solution. [1]

2. SCOPE AND OBJECTIVES

This paper therefore aims to experiment a double-skin façade for an IT building in Chennai and document its impact and appropriateness in the context of the climatic conditions of Chennai. The focus of the study will be limited to the following features.

Protective features:

Air and Weather tightness and Thermal insulation, Condensation and sound insulation.

The motivation behind this attempt has been the interest to reinforce the role of an Architect as a master planner and to defend the outer surface against the superficiality of its critics. Façade is not what it often means 'mere external appearances'. [2]. Instead the visual and functional character of high-rise facades, often located at the hub of society, play a powerful symbolic and social role as a result of their 'external' appearance. And the art of the façade with concrete, steel, aluminium, glass, timber, paper, earth, water and air knows no bounds. For there is nothing deeper, as long as the overall architecture is coherent, than the surface. [2]

3. DESIGN DETAILS

3.1 Effect of Shading on the Energy Performance of the Buildings

Previous studies have shown that there was a reduction of almost 2-5% in the cooling energy consumption with the introduction of shading devices to the double-skin, where it was 100% transparent. But it is beyond the purview of this paper to quantify the reduction in cooling energy in double-skin facades oriented to any direction with shading devices like verticals and overhangs.

3.2 Effect of Double-Skin Façade on Lighting Loads and Cooling Loads

The breakdown of energy consumption would show a reduction in the energy needed for lighting for the proposed double-skin strategies than the base case.

However, there is a trade-off between the cooling and lighting loads with or without shading devices when comparing the various strategies because in order to reduce cooling loads, one needs to reduce the transparent areas which would then cause the lighting loads to increase as there would be reduced daylighting. This by itself is

another field of research which is beyond the scope of this paper.

4. DESIGN GUIDELINES

A number of factors and issues influence the functioning of a double-skin façade which are discussed as follows.



Figure 1: Detailed Plan



Figure 2: View of NE walls

5. GOALS FOR DESIGN OF FAÇADE

In order to design a façade that is energy efficient and most appropriate for a given context, one first needs to establish a framework of goals that the façade needs to

achieve. These goals would then help generate a sequence of design ideas that can be followed to achieve them. These are broad guidelines which may have to be tailored to specific situations. The primary goals of the façade in a hot climate can be identified as:

5.1 Solar Heat Gain Reduction

The façade is designed in such a way that there is minimum solar heat gain through the façade. Heat gain is minimized by appropriate use of material in the correct proportion according to the orientation of the façade. This would cut down the cooling loads and cooling energy requirement. [3]

5.2 Daylighting

The façade is designed in a way to utilize daylighting, so that lighting loads due to artificial loads can be reduced. Sufficient shading devices are incorporated to avoid excessive heat gain and glare. A balance between daylighting and heat-gain needs is achieved.

5.3 Ventilation

The façade is designed to allow for ventilation for the following conditions

- i) During certain periods of time when the outside air temperature is at a comfortable level and can be allowed inside the space.
- ii) During summer time, ventilation is allowed through the cavity of the glass façade to remove the trapped heat.
- iii) During night time, ventilation is facilitated to happen from within the building to the outside to dissipate heat absorbed through the day. This would bring down the building temperatures considerably and reduce the energy needed to cool the space next day morning.

6. DESIGN PARAMETERS

The key factors contributing to the above mentioned design goals, which in turn would affect the efficiency of the façade, are:

6.1 Materials

In the Indian context of this study, the common construction materials include brick, concrete blocks and stone. Alternate materials include ACP, glass bricks and bricks made of fly-ash. The materials used have a high resistance (R value) so that there is minimum heat gain. But this should not be at the expense of using vast amount of energy to acquire these materials. The glass used are high solar control glass with low e coating manufactured by depositing a coating of metal oxides by magnetically enhanced cathodeic sputtering under vacuum conditions onto clear float glass.

6.2 Glazing Material

In terms of glazing, more than the type of glass that is used in the façade, it is crucial to determine how much of it is used, along which façade it is used and whether it is appropriately shaded. This is because using the locally manufactured glass in two layers (double-skin) for the glazed areas in a façade may be more cost effective than using a highly advanced glazing technology that may have to be imported.

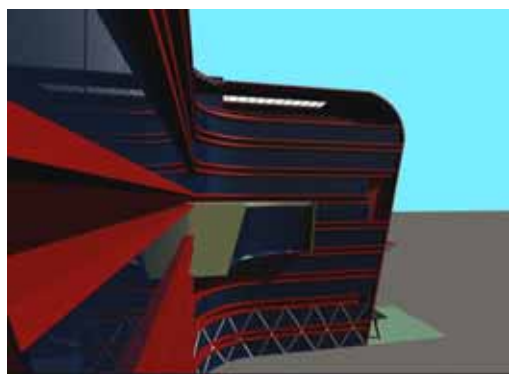


Figure 3: View of NE1 and SE2 walls

7. PHYSICAL DESIGN

7.1 Nature of Layers

The two layers should not be completely transparent on any of the facades except the one oriented to north, if desired this should also be avoided if possible unless aesthetics or any other reason gains priority to have a

completely transparent façade. Both the opaque layers may be of the same thickness or for better insulating effect, the outer layer can be thicker than the inner layer

7.2 Dimensions

The width of the cavity between the two layers may be decided based on available space and also space required for maintenance of the cavity this is because the U-value of the air space is almost constant after 8" of thickness. Hence, the width of the cavity is flexible as long as it facilitates ventilation of trapped air. Some case studies had shown the cavity to include plants and vegetation to cool the air in the cavity. A quantitative analysis of how much insulating effect these plants would have is difficult to simulate.

7.3 Nature of the Cavity

The cavity space between the two layers of glazing can be continuous for low-rise structures. It can be partitioned horizontally at each floor level to allow easy movement of air within each floor for taller buildings.

7.4 U-Value

The overall U-value of the façade should be reduced as much as possible for maximum benefit. From the numerical simulations, for SW wall, it was seen that a U-value of 0.2488 W/m² deg C was more efficient than the existing base case façade's U-value of .4498 W/m² deg C. The U-factor of the glazed double-skin varies between 0.5 -1.2 Btu/h ft² F, which may get further reduced depending on the type of glass used and shading devices within the cavity. Therefore, design the facade to keep the U-value as low as possible of both the opaque and the glazed portion of the façade

7.5 SHGC

The solar heat gain coefficient of the glazed double skin is based on the type of glass used on both the inside and the outside as it is the product of the two layers. The

lesser the solar heat gain coefficient, the more efficient the façade. Thus, the choice of glazing should be made based on this solar heat gain coefficient.

7.6 Transparency and Shading

Façade is designed in such a way that maximum transparency is on the north East façade and minimum transparency is on the south west and NW sides. The North east and North west façade have about half the transparency on the South side. Some horizontal shading devices are provided on the northeast and southeast side and vertical shading devices on the northwest and South west facades to block off direct sun and excessive glare by way of recessed windows.

SE1 and SE2 are cladded with ACP.

7.7 Orientation

The North East façade can have maximum transparency and making it an all glass double-skin façade is more efficient than having a single skin on that particular façade. Though, the difference does not seem very large but with the use of additional shading devices, the solar heat gain can be further reduced. Hence, the northern façade is the most preferred orientation for a double skin.

The South East façade (SE1) is designed with minimum transparency and is essentially an opaque layered wall with ACP. This would increase the thermal mass of the building and the air gap between the layers will have an insulating effect on the building. The overall heat gain and direct sun through the south side is reduced. SE2 has DSF with alternating glass and ACP.

South West façade also cannot be a completely transparent double skin facade because of the intense direct sunlight which it receives especially during the evening hours. It can consist of alternate shafts of opaque and transparent double-skins, with the percentage of glazing being about 40-50% of the wall area. This glazing also needs to incorporate some shading devices to cut off the direct sunlight from entering

the spaces. Therefore the SW façade has recessed windows only.

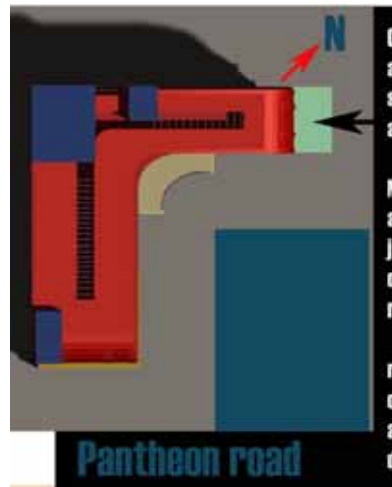


Figure 4: Site Plan showing the orientation

North West facade cannot be a completely transparent double skin facade because of the intense direct sunlight which it receives especially during afternoon and evening. It can be designed similar to the South West façade with alternate shafts of opaque and transparent double-skins. However, the orientation of the shading devices would be exactly opposite to those on the east façade. But the NW façade has been designed with recessed windows only.

Table I: Design Proposals for all the walls

Orientation	Design Strategy
SW	Recessed Box windows
NW	Recessed Box windows
NE 1	DSF with glass shaded by horizontal bands of ACP
NE 2	ACP cladding
SE 1	ACP cladding
SE 2	DSF with glass shaded by horizontal bands of ACP

8. EVALUATION OF THE THERMAL GRADIENT ACROSS AN ASSEMBLY

Total Resistance, R ($\text{m}^2 \text{ degC/W}$)
 $= 1/f_i + R_{ip} + R_{brick} + R_{op} + 1/f_o$
 'U' value ($\text{W/m}^2 \text{ deg C}$) $= 1/R$ [4]

8.1 SW wall- existing and proposed



Figure 5: Existing plan of SW wall.

Table II: Existing values for SW wall across the opaque section for severe exposure

Type	b	R	R and 'U' value of the assembly
1/fi	-	0.123	R= 2.199
ip	1.3	0.10	'U' value=1/R
brk	23	1.80	= 0.4547 > 0.352
op	1.3	0.10	max as per
1/fo	-	0.076	ECBC. [5]
			Unfavourable result.

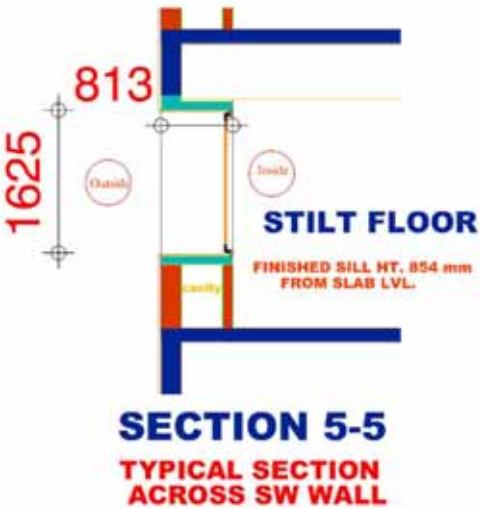


Figure 7: Proposed cavity wall section for SW wall

Table III : Design values for SW wall across the opaque section for severe exposure.

Type	b	R	Total R and U value of the
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assembly			
1/fi	-	0.123	R = 4.043
ip	1.3	0.10	'U' = 1/R = 0.247
Brk	11.5	0.90	< 0.352 max as
C	45.5	0.92	per ECBC
Brk	23	1.80	Favourable result
op	1.3	0.10	
1/fo	-	0.076	

8.2 NW wall –existing and proposed



Figure 6: Existing plan of NW wall

Table IV: Existing values for NW wall across the opaque section for severe exposure

Type	b	R	Total R and U value of the assembly
1/fi	-	0.123	R = 2.155
ip	1.3	0.10	U = 1/R = 0.4640
Brk	23	1.80	> 0.352 max as
op	1.3	0.10	per ECBC.
1/fo	-	0.032	Unfavourable result.



Figure 8: Proposed plan for NW wall



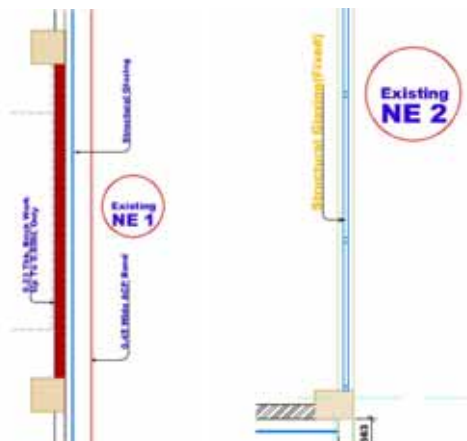
Figure 9: Proposed section for NW wall

Table V: Design values for NW wall across the opaque section for severe exposure

Type	b	R	Total R and U of the assembly
1/fi	-	0.123	R = 3.975
Ip	1.3	0.10	U = 1/R
Brk	11.5	0.90	= 0.2515
C	45.5	0.92	< 0.352 max
Brk	23	1.80	as per ECBC
Op	1.3	0.10	Favourable result.
1/fo	-	0.032	

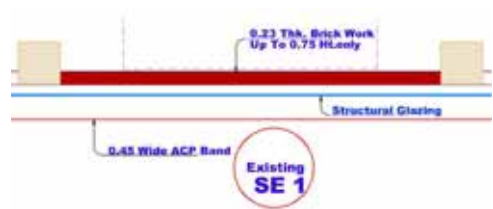
8.3 NE and SE walls

Existing DGU's are from Saint Gobain Royal Blue Glass Laminated
Sound transmission loss required = 97 dB
(car horn) - 55 dB (at high 'f') = 42dB

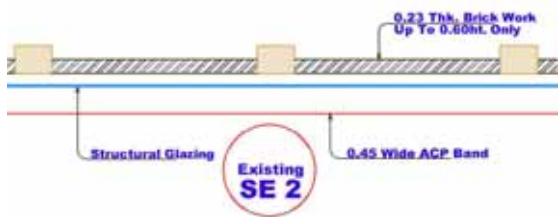


a. Plan of NE1

b. Plan of NE2



c. Plan of SE1



d. Plan of SE2

Figure 10: Existing plans of NE 1, NE 2, SE1 and SE2 walls

Table VI: Existing values of DGU for NE1 and SE2 walls across the vision area.

Type	R	Total R and U of the assembly
6mm glass	1/5.4 = 0.1841	R = 0.3809 U = 1/R = 2.625 < 3.177 max as per ECBC.
+1.52 mm PVB	b/k = 1.52/01038 = 0.015	Favourable result.
+4mm glass	1/5.5 = 0.1818	But sound transmission loss is only 35 dB



Figure 11: Proposed typical plan of NE 1, NE 2, SE1 and SE2 walls



Figure 12: Proposed typical section of NE 1, NE 2, SE1 and SE2 walls with Inner DGU of Asahi India Glass (AIS) Supersilver dark blue Laminated.

Table VII: Design values for **DSF** of NW and SE walls across the vision area

Type and Thickness	R
Inner DGU	
6mm Glass + 1.52 mm PVB(4 layers each .38mm thk)+ 5mm Glass	$1/5.68 = 0.1761$ $b/k = 1.52/.1038 = 0.015$ $1/5.71 = 0.1961$
12mm air gap	0.142
5mm Glass + 1.52mm PV B + 4mm Glass	$1/5.71 = 0.1961$ $b/k = 1.52/.1038 = 0.015$
Total Thickness = 35.04 mm	$1/5.75 = 0.1739$
Air cavity of the DSF (horizontal) 710mm	0.92
Outer single glass	$1/5.60 = 0.1786$
AIS glass FL 8 - 8mm	
R- DGU= 0.9142 , 'U' DGU = $1/R = 1.094$ < 3.177 max as per ECBC. R ac + R outer single glass= 1.098 , 'U' value = $1/R = 0.9107$ R total = 2.01 , 'U' = $1/R = 0.4975$ < 3.177 max as per ECBC, Favourable result, Best solution - high thermal resistance, Sound Transmission loss = 40 dB	

9. CONCLUSION

This paper thus contributes to the potentials for high-rise façade development linked to material selections, technology and adaptive construction processes. We find that these design proposals cut down cooling loads. Ventilation of the cavity has to be allowed to exhaust the hot air in summer by way of openable panels and at night time

ventilation has to be facilitated from the building to the outside. The outer layer of the DSF has to be single glass and the inner can be double glass unit for a better design in the facade. Thus DSF if used makes possible the opening of windows in a windy place and integration of solar protections in the cavity. Protected from bad weather and pollution, blinds keep the effectiveness of external blinds and preserve a completely smooth aspect of façade. Thus facilitates the use of natural cooling strategies. A DSF also facilitates the application of secure natural night ventilation [6] and it can improve acoustic comfort of constructions established in noisy places.

ACKNOWLEDGEMENT

Appreciation is expressed to Mr. Venkatesh, NFC, Ar.Pradeep, Ar. Siddharthan., R.Suresh, Karthick and Vignesh.

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