

Performance of Large Glass Facade in Commercial Buildings: Evidence from Greater Noida, India

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Abstract- Glass facade has several functions that coax its sustainability of use such as aesthetical function, solar control, thermal insulation, acoustical function, natural ventilation, structural functions, and security. When not installed appropriately, this material creates unwanted reflection causing glare which is harmful to the users. It creates indoor heat discomfort in summers. This paper has studied these key factors affecting the performance of glass facade in the context of commercial buildings of Greater Noida. The paper argues that in the design of glass facades important parameters like thermal comfort are not given the needed priority. The research includes an empirical study of three popular commercial buildings in Greater Noida with the tools of a thorough design analysis and user perceptions survey of ninety-six respondents based on the recognized determinants. Findings reveal that solar control and natural ventilation are the most critical parameters for the design of glass facades in the commercial buildings of the study region. The study provides an easy framework of seven key elements useful for building design and promotes the integration of good natural ventilation and solar control strategy in the buildings with large glass facades to improve the overall comfort levels of the users and healthy environment.

Keywords: Glass façade, Energy efficiency, Passive architecture, Commercial buildings in India.

1. INTRODUCTION

Today glass façade usage in commercial buildings is unceasingly improving as one of the modern embraced material, as it is one of the building materials that enhanced the spread of modern architecture. This material thus serves as a great inlet for natural light and is popularly used as a cladding material for modern buildings. [1]. The city of Greater Noida is an ongoing project that keeps progressing in terms of populations, and

buildings that explore numerous opportunities alongside the usage of new construction techniques and materials that makes the city a real destination. Greater Noida is considered as an extension from Delhi NCR where some parts of the population from Delhi migrated as a result of the constant influx of immigrants to the urban area. It is positioned adjacent to Noida which shares boundary with the western side with the Delhi NCT. These twin cities continue to receive population from the overpopulated urban areas to reduce the pressure of congestion and pollutions hence, there is an increase in the living standard of these cities through erections of high-rise buildings to promote the livelihood of the cities. [2].

The adoption of glass façade in commercial buildings of our contemporary cities has been something that manifests the picture of the city, and this material is espoused because of its ease of maintenance and durability. Most of these glass facades used are intelligent glasses that respond to acoustic and resistance to solar radiation to shield the building from overheating resulting in upsetting the comfort of the interior spaces. Glass façade morphology varies with the building shapes and the façade design which can either be an intrusion or extrusion of the material through the building, [3]. Most of the commercial buildings façade nowadays are cladded with glazing, because it gives aesthetic effects to the buildings and the surrounding. Building envelopes entail the integrations of walls, roofs, and openings constructed in a systematic process. The solar radiation penetrates the buildings through the glass which increases the indoor heat gain that helps to maintain the comforts of the indoors, or offset it when the radiation intensity is high. [4]. Because of the flexible nature of the frameless glass façade, its use has overwhelmed other glasses for the past three decades due to the high degree of transparency with less support, [5].

1.1 LARGE GLASS FAÇADE

“Façade is a French origin word meaning the front face. The use of glass at the exterior facades provides more of light and good ambiance to the occupant of the building which gives rise to the increasing use of glass” [6] (p. 1). Glass façade is a vital building material serving different purposes in a building such as aesthetics, acoustics, solar radiations control, thermal insulations, light penetrations, structural functions and many more. The energy efficiency in any building is of paramount importance, which pushes the architects, designers, and engineers to venture into research to find a better way that can improve the energy efficiency of the building. This results from the challenges faced nowadays concerning the limited energy sources. It is therefore imperative to find solutions to the problems, and this could be achieved through proper choice of glass and construction techniques adjunctively. [7]

1.2 MATERIALS AND METHODS

In order to assess the performance of glass facades in commercial buildings, this paper has combined use of two methods, design analysis and user perception survey. The choice of the methods was selected based on literature review [9] (p 60). The analysis parameters are derived from an extensive literature survey. Design analysis is carried out based on a detailed reconnaissance of the site and analysis of various documents, plans, designs, effects of climatic factors, site layout, buildings orientation, glass façade percentages of concentration, interior impacts, and comfort analysis. Qualitative and quantitative data were collected from the three selected case studies which were used to analyze the users’ perceptions for the adoption and performance of glass façade in three commercial buildings of Greater Noida. The buildings are identified through a random sampling method and representing the generic typology of the local region. A hard copy of 96 questionnaires was designed and administered to the users where 91 were returned valid, the valid ones were taken into account recording the users’ perceptions regarding the performance of glass façade in terms of the benefits and challenges based on the seven identified determinants. The questionnaire is divided into two segments; a demographic part that explains the respondents’ details such as name, type (staff or tenants), age, and gender. The second part is glass façade related questions which enable the users to showcase their experiences on the glass façade performances based on the parameters listed below. The questionnaire incorporated 7-point Likert scale, hard copy was presented to the users which give them sufficient time to look at the options for proper choice-making, unlike in a situation whereby the

questionnaire is administered over the phone [8] (p. 10). The results and conclusions are derived based on the analysis of data using excel and SPSS software for the user perception survey and qualitative techniques for the design analysis. The use of more than one method has enabled to obtain a comparative analysis, thereby increasing the reliability of the results.

2. CONCEPTUAL FRAMEWORK

Twenty-one reputable works of literature related to this paper were obtained from research papers, journals, articles, government regulatory bodies, points of view from professionals’ websites, and reviewed. Based on this literature review, seven key parameters are identified to thoroughly analyze the glass façade performance of the three selected case studies. The parameters are elaborated below.

2.1 Solar control: Good glass façade engrosses the solar energy from the sun, reflect back the unwanted rays with the aid of the solar reflector and transmit some amount into the building for lighting, and maintenance of the indoor temperature in the winters [10] (See figure 1& 2). The protection of building from solar radiation is of paramount importance as it increases the energy consumption for cooling, this is described as one of the major challenges facing glass buildings in creating heat discomfort and sun glare to the indoor spaces. In these regards, most of the buildings with large glass façade suffer solar discomfort, and this originates from the design stage to the fixing of the building and the glass material. Years back only 29% of glass buildings were designed with solar protections such as vertical and horizontal fins, eaves projections, cantilevers, etc. and this is to adequately shield the building from direct solar radiation, [9] (p. 60).



Figure 1. Gallery of Solarban low emission glass Source: (Archdaily.com).

as relative humidity, temperature, sun path, pressure, etc. [12]. Thermal insulation in a large glass façade can be accessed through careful consideration of the following "air temperature, air movement, long waves radiation, and solar load" [13]. Solar energy is a leading factor that causes overheating of the interior spaces, although it depends on the type of glass façade used. Each glass façade has a unique way of responding to energy efficiency in buildings. This can be achieved through climate-based analysis to technically analyze the building orientation at the design stage before installation, [14].

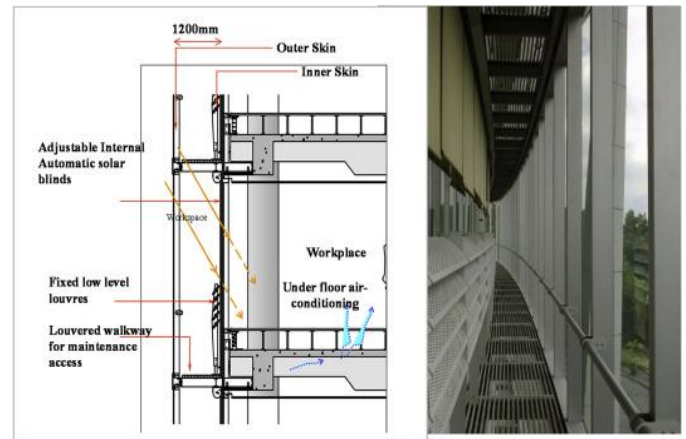


Figure 3. Thermal performance Double skin glass façade. Source: [15].

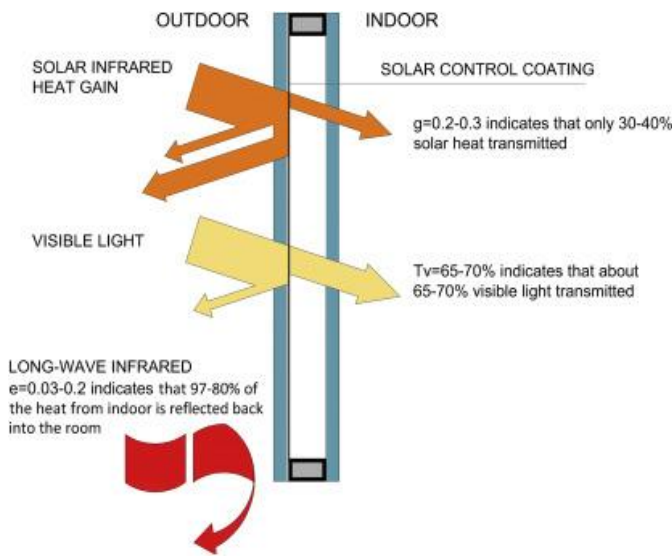


Figure 2. Solar control in glass façade.

Source: [11].

2.2 Thermal insulation: This expresses the control of the amount of heat transmitted into the buildings through the glass, thermal insulation is effectively achieved in double skin glass facade which has to do with the coefficient of U-Value and solar blind, (See figure 3). The degree of thermal insulation is achieved through proper considerations of artificial factors such as building form, orientation, setbacks, etc. It also relies on natural climatic factors such

2.3 Aesthetic: One of the primary reasons behind the use of glass façade is beautification, different types of glass give a different aesthetical view. The reflections of light and the neutrality of color are examined in defining the beauty of the glass façade as they come in different colors. [10] (p. 1066). The glass façade is described as a transparent architecture that gives an exquisite and indefinite morphology to the internal and external parts of the building. This architecture provides chances where light can maneuver to the internal environment as well as creating a reflective façade thereby contributing to the architecture of the building, [16].

2.4 Acoustic: Sound insulation is vital to the indoors and the glass façade provides a noise barrier from the outside to the inside spaces. Researches have been made on the effectiveness of double-skin glass façade and single skin glass façade on acoustics, and findings have revealed that double-skin glass façade is 24.68% better than single skin glass façade. [17]. One of the obstacles faced by the building professionals is the sound control in glass façade buildings although this problem seems abstract at the design stage, the architects and the building users get to

notice this after the completion of the project. The sound from outside diffuses to the indoor spaces to alter the users' comfort of living. This is why researches have been conducted to help the professionals with the knowledge of the glass type to be recommended for glass buildings to serve optimum sound control, [18].

2.5 Structural functions: "The term structural glass refers to a frameless assembly of glass where a portion of the structural load is taken by the glass itself rather than by a supporting frame", [19]. The glass façade is designed to withstand the mounted load on it and equally shielding the indoor spaces from the rain, wind, and even solar penetration in some cases. All the loads subjected on the glass façade are transferred to the building and finally to the foundation through the structural interface from which the transom and the mullion are attached to the building as in (figure 4), which is design for either dead load or wind load. [6]. Glass is used in different positions in building serving as a structural element or load-bearing element but its brittle behavior is what makes it scaring. This material is liable to failure mostly at tensile stress level where the degree of measuring compressive stress generates tensile stresses thereby making the precise allowable compressive stress tedious to find, [20].

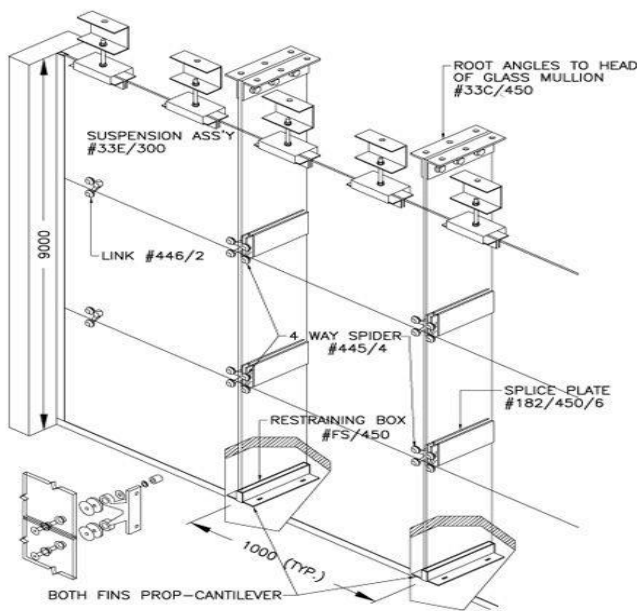


Figure 4. Structural details of the glass façade. Source: [21].

2.6 Safety and security: Some injuries in buildings are actually due to a lack of safety precautions. Safety and precautions in the glass façade buildings are very

essentials. Most people treat glass with extra care, however, an ability to understand this risk varies from individual. Glass façade used for security is considered imperative in public buildings such as commercial and office buildings. Safety precautions in any glass building need to be cogently adhered to, because of the risk and the injuries caused as a result of safety precautions negligence. Most designers, facility managers, and building users take this into account to abstain or minimize the level of glass failures for its continuous use. [22] (p. 13).

2.7 Natural Ventilation: Natural ventilation is dependent on stack effects, for air movements and pressure differences created by wind, natural ventilation does not need any mechanical supports to enhance the movements of air, the rate of ventilation receives is controlled by the climate and the temperature of the air in the cavity [23], (See figure 5). Passive ventilation is induced by wind force that makes the fresh air penetrate the building through the opening provided and cool the indoor space to improve health and the comfort of living to the users, this ventilation is achieved through careful planning/orientation of the building to expose the opening for adequate ventilation, [24] (p. 395). Natural ventilation has to do with the thermal buoyancy of air, and this takes cognizance with the internal and external temperature differences for air substitution. The external building shape and the internal arrangement determine how well the air circulates and the effectiveness of the driving forces. A well-designed naturally ventilated building contributes immensely to the achievement of sustainable buildings that are resistant to external factors and provide effective comfort to the occupants, [25].

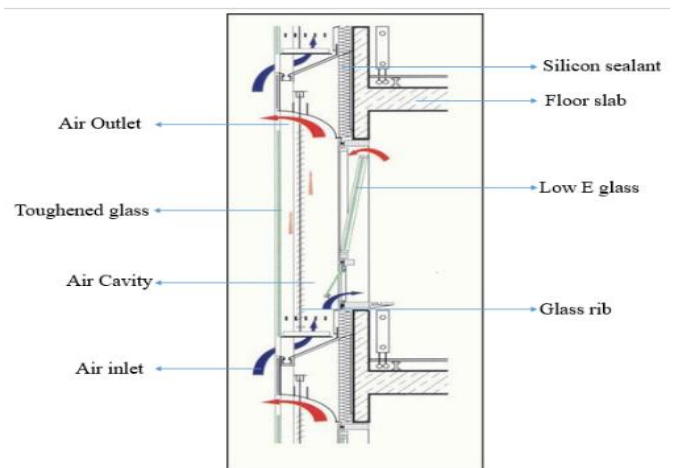


Figure 5. Ventilation strategy in glass façade. Source: {(Detailed: Author) (Image: [26],)}.

3. ASSESSMENT OF THE BUILDINGS (DESIGN ANALYSIS)

Three landmark commercial buildings of local importance, representative of the generic commercial architectural style of the region, and built between the years 2007-to-2019, are identified in Greater Noida, India. (See Figure 6) for the design and users' perceptions analysis. These are glass façade commercial buildings that are analyzed and assessed based on the seven identified determinants. Each building has its peculiar problems and success which contributes to the comfort of the internal spaces to the users. The buildings are:

1. MSX Tower 2, Alpha 1, Greater Noida.
2. Ansal plaza, Pari chowk Knowledge Park I, Greater Noida.
3. Solitarian City Center, Knowledge Park III, Greater Noida.



Figure 7. MSX Tower 2 Alpha 1 Greater Noida (2007), (Source: Author).



Figure 8. Covered atrium (Source: Author).

Figure 6. Satellite image showing the location of the three buildings in Greater Noida.

3.1 MSX Tower 2 Building

MSX Tower 2 is a mixed-use commercial development completed in 2007 which offers retail shops and office spaces. The building is one of the well-known commercial blocks in Alpha 1 with a total number of 222 shops spread across the 9 floors, the shops and offices are of different sizes such as 72sqft, 216sqft, 306sqft, 468sqft, etc. This structure has a covered central atrium where the two lifts are located but the center of the building is usually dark because there is no light coming from the sky through the central atrium (Figure 8). Due to this most of the shops use glass sliding door to admit natural light from outside to light up the central atrium as in (figure 9).

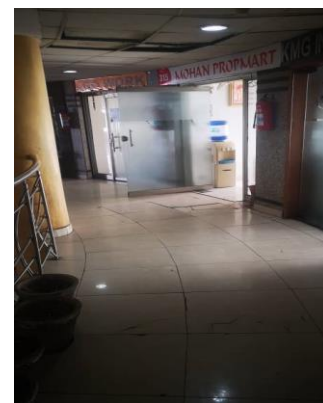


Figure 9. Glass sliding doors (Source: Author).

3.1.1 Solar control

The façade of MSX Tower faces south, and it receives an optimum radiation intensity at noon, (figure 10). Based on this, the building is protected from direct solar radiation as the sun rises from the east. Analytically all the shops located in the northern part of the building are in total

shading throughout the day because the sun sets at the west. So basically the movement is between east-south and south-west. Looking at (figure 11), the southern part of the tower covers about 70% of the glazing in the overall four sides and it receives maximum amounts of radiation intensity which creates overheating to the indoors during summers. Although the architect designed a slab projection on the first floor shading the ground floor, that is not enough as other floors suffer heat discomfort because of this dilemma that originated from the building design, orientation, and choice of the glass facade.



Figure 10. Satellite image of MSX Tower 2.



Figure 11. Building's facade, (Source: Author).

3.1.2 Aesthetic

MSX Tower 2 is fully glazed at the facade (figure 11), which makes the building attractive. The glass facade used at the building edges creates a reflective function of views that gives a sign of a gigantic commercial building. The tinted laminated glass facade used gives welcome adverts to the

southern side which corresponds to the metro line for the activities happening in the building. From the commercial perspective, the aesthetic reflection of the buildings with a large glass facade attracts more customers and tenants because of the beauty of the building.

3.1.3 Acoustic

In this building, two different types of glasses are used laminated and annealed glass installed at the facade (glass facade) and the windows respectively (See figure 7). From an analytical perspective, these glasses do not effectively control sound. This is especially at spaces located at the east and some parts of the south receive sound from the Alpha 1 main road and the metro lines that move to and fro throughout the day.

3.1.4 Structural function

Laminated glass is structurally good because of the PVB (Polyvinyl Butyral) contents that enhance the glass strength and prevent it from easy breakage, [27]. In this building, the glass facade is not supporting any structural member of the building, it is used to supplement the structural element from the exterior part of the tower.

3.1.5 Natural Ventilation

The architect did not consider ventilation strategy at the design stage, the circulation spaces around the atrium (figure 9) which is of utmost importance as a commercial building is completely out of ventilation. The glass facade is streamlined from the first floor to the ninth floor without any spot that allows natural air to penetrate. Windows are provided at the other sides of the building but because cross ventilation is not there, the building suffers a ventilation problem in which almost all the spaces use mechanical means of ventilation. The orientation of the wind pattern for ventilation in this building is elaborated below (Figure 12), and the figure shows where the glass facade is positioned.

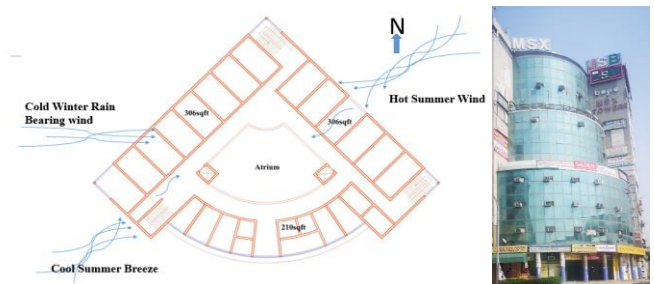


Figure 12. Wind Direction patterns for Passive ventilation (Source: Author).

3.1.6 Safety and Security

Although the glass is not intelligent enough but being installed at the approach of the building it gives the users an idea of whoever is approaching the building. This helps to have a glance at the outside for security reasons. This glass facade is supported by walls at either side to improve its reliability and safety, and the building's location and surrounding buildings make the users feel relaxed and secure. There is a provision of escape staircase for emergencies to improve the safety and security of the building as in (figure 13).

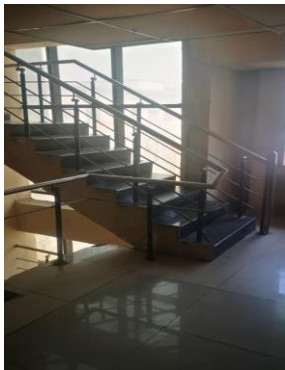


Figure 13. Escape Staircase. (Source: Author).

3.2 ANSAL PLAZA BUILDING

This is the First Mall of Greater Noida that has paid parking and shops. The building has 410 number of shops in total which ranges from 350sqft – 7871sqft. It's one of the oldest malls that is finished with a glass façade at the exterior parts to a certain percentage and is among the most active malls in Greater Noida (See figure 14). There are two operational floors- LG and UG. And the other five floors started from the Atrium floor to the third floor (cinema floor), where all the shops are located on the remaining floors.



Figure 14. Ansal Plaza Pari Chowk Greater Noida (2009) (Source: Author).

3.2.1 Solar Control

The architect recommended a toughened tinted glass which is good for solar control (See figure 16). From the analysis made concerning the design and building orientation, (Figure 15), the shops located at the façade receive more solar radiation intensity than the shops at the opposite side as the sun rises from the East and sets at West. The North Direction spaces are shopping complexes which accommodate people in large numbers, Furthermore, the southern part of the building receives optimum daylight which changes the conditions of the interior spaces. Therefore, the building can reflect solar radiation as it strikes the building thereby maintaining the comfort level of the building.



Figure 15. Satellite image of Ansal Plaza



Figure 16. The toughened tinted glass (Source: Author).

3.2.2 Aesthetics

The beauty of this building is contributing a lot to the attraction of the customers and tenants. The glass used in this building is aesthetically attractive and functionally reliable. The building location is easily accessible and exposed because of its proximity to the Pari chowk metro station, and its beauty is visible and captivating from all angles of the neighboring buildings. Ansal Plaza is regarded as one of the busiest malls in Greater Noida and aesthetic quality contributes to this achievement.

3.2.3 Acoustics

The shop chosen for the analysis is a rectangular shop measuring 3205sqft and the average reverberation time is 2.64 seconds at 6000 Hz (See figure 17). The rate of absorptions coefficient is in the use of mid-frequencies [28], the sound coming to the building is insulated to a reasonable amount, the glass façade used has the potential to repel the sound wave entering the building and this is applied to the other shops of the same sizes and materials.

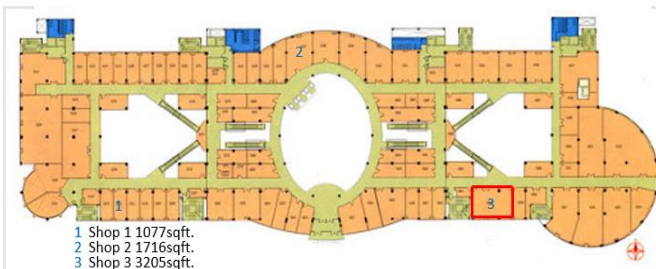


Figure 17. Floor plan of Ansal plaza Pari Chowk Greater Noida (2009). Source: [29].

3.2.4 Structural functions

Although the focus on this parameter is basically on the glass façade used as structural functions, researches have proven that glass can also be used in a staircase, roofs, etc.

[30] (p. 315). Therefore, the glass facade in this building supports some lightweight materials especially the steel fixed toward the northern side (See figure 14).

3.2.5 Natural Ventilation

As a commercial building, it is designed to have a free flow of air through the windows, corridors, and circulation spaces to enhance the social well-being and a healthy environment. The volume of air entering through the northeastern part is circulated within the enclosed spaces and the atrium, the building has tilted orientation as shown in (figure 18), to achieve effective natural ventilation to help in the control of energy efficiency and comfort of living.

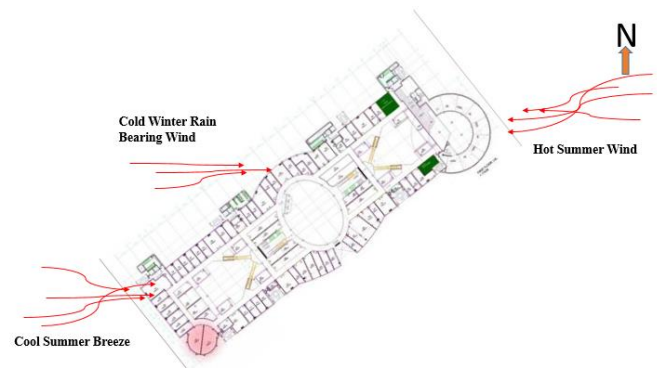


Figure 18. Wind Direction Patterns. (Source: Image [29] Detailed: Author).

3.2.6 Safety and Security

This type of glass has a high-grade polyacrylic combined with tempered or toughened glass which ranges in thickness from 5mm to 19mm. [31]. This composition can withstand an attack for a maximum period of 120 seconds such as hands, hammer, ax, etc. Toughened glass is secure and safe as it is one of the toughest glasses in the family of glass.

3.3 SOLITARIAN CITY CENTER

This is a commercial building located at knowledge park 3 Greater Noida. It provides different offices and shops space of different configurations, the building has four blocks (A, B, C, and D) where each block has eight floors which are replicas of each other (See figure 19). The building was established by the Solitarian Group Knowledge Park 3 to bridge the gap of the need for commercial and office spaces, considering Greater Noida as a thriving city. The site is designed with the ambition of future development

where hotels and clinics are proposed as an extension of the building.



Figure 19. Solitarian city center knowledge park 3 Greater Noida (2019). Source: [32].

3.3.1 Solar Control

The building uses toughened glass which is resistant to mechanical attack and climatic factors. It contains a solar reflector that protects the interior spaces from direct ultra-violet rays. From the building layout (Figure 20), it is positioned to abate the sun rising from the east where some offices and shops are shaded, similarly, the western part spaces are shielded from receiving direct solar radiation. The south normally receives much amount of Ultra-violet at noon in the northern hemisphere. This building is solar control repellent and heat malaise responsive thereby making the indoors affable.



Figure 20. Satellite image of a solitarian city center. Source: [32].

3.3.2 Aesthetic

This building is aesthetically cordial from the approach and the side views (figure 19). It is designed to capture the attention of the masses thereby encouraging building usage. Solitarian city center is positioned on a commissure road which makes the people passing-by appreciate its beauty and makes the building a central destination for different activities offered by the building in knowledge park 3 Greater Noida.

3.3.3 Acoustic

Sound control in the solitarian city center is duly observed from the choice of glass façade to the orientation of the buildings. This is because the building is vulnerable to sound disturbances from the east, south, and some parts of the west as the building is positioned at the road junction where the noise from the vehicular movement goes directly into the building side to create sound discomfort to the users. Because of this, the architect specifies the glass façade that responds to sound insulation so that the activities in the indoor spaces comfortably go on without any hindrance.

3.3.4 Structural function

The glass façade used is not load-bearing but it is structurally durable and reliable for use. The partitions walls are adjusted from the external walls in some locations and the glass façade is wrapped to the structural members of the building serving as a primary protective layer (barrier) to the internal environment, (Figure 21). The building is surrounded by beams and columns in an aligned order (Frame structure) to effectively bear the load of the building.

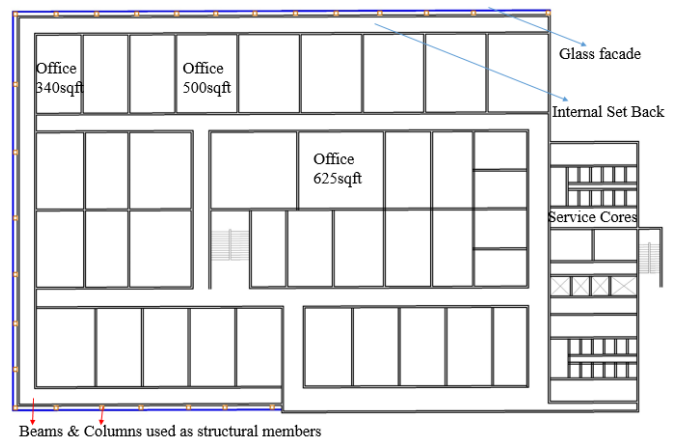


Figure 21. Glass façade as a non-structural member. {(Image [32] Detailed: Author)}.

3.3.5 Natural Ventilation

Critical analysis of this building shows that passive ventilation strategy is missing which reveals that 70-80% of the spaces rely solely on mechanical means. Glass façade with ventilation openings contribute to the interior cooling, but in the solitarian city center, only 10-20% spaces have the opportunity to benefit from the natural breeze (Figure 22), which is good to healthy environment.

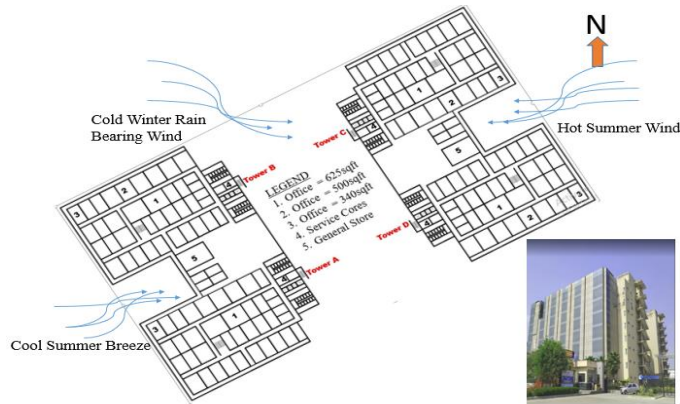


Figure 22. Wind Direction Pattern. Source: {[Images [32] Detailed: Author]}.

3.3.6 Safety and Security

Solitarian city center is not fully occupied, but from the site plan (figure 23) the whole site is carried along, activities are designed to make the whole site lively to solve the security issue. Similarly, toughened glass is four times stronger than annealed glass, [29], so the tendency for it to break is low, nowadays it is the glass recommended for skyscrapers glass buildings because of its resistance and durability.



Figure 23. Site plan of the solitarian city center. Source: [32].

4. USER PERCEPTIONS STUDY

It is part of this paper's objective to discover the users' perceptions of the Performance of the glass façade, and this was collected and analyzed through the medium of the questionnaire-based primary survey. The questions capture the perception of the building's performance against the seven parameters and also identifies how the buildings contribute to the comfort level of the users.

4.1 MSX Tower 2

Most of the respondents that were interviewed have stayed in this building for more than ten years the respondents have gathered much experience about the glass façade uses in this building, the insight of which is captured through the questionnaires (See Table 2). The seasonal electricity consumption of this building was collected to reckon the energy efficiency performance, (See Table 1). MSX Tower 2 has 222 shops/offices and their sizes are categorized into four as shown in Table 1. and replicated across the 9 floors in the building.

Table 1: Seasonal electricity consumption in MSX Tower 2.

S/N	Office/Shops Sizes (sqft)	Consumptions per month In Summer (₹)	Consumptions per month In Winter (₹)
1	726	7500	3000
2	516	5500	2200
3	306	3500	1400
4	210	2000	800

Table 2: Perception scores of respondents in MSX Tower 2

S / N	Parameters.	7 (%)	6 (%)	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)	Average
1	Solar Control	6.90	48.27	31.04	13.79	0.00	0.00	0.00	5.50
2	Thermal Insu	0.00	13.80	37.9	34.4	13.8	0.00	0.00	4.50

	lation			2	8	0			
3	Aesthetic	17.24	17.24	17.24	27.58	17.24	3.46	0.00	4.50
4	Acoustic	17.24	31.03	27.59	0.00	24.14	0.00	0.00	5.00
5	Structural Function	10.35	13.79	24.13	4.38	10.35	0.00	0.00	5.00
6	Natural Ventilation	0.00	0.00	0.00	34.48	5.17	10.35	0.00	3.00
7	Safety & Security	3.48	10.34	6.90	13.79	17.25	3.45	13.79	4.00

Furthermore, because of the magnitude of this building, only the range of the shops' sizes was collected together with the seasonal electricity consumption data (See Table 3). The building has 410 total number of shops distributed across the five floors of different sizes. Due to the immensity of this building, the electrical energy needed is high, therefore the building receives electrical energy from different sources such as Combining power Bodkub (CPB) ranges from 1010-1500KVA and Noida Power Company Limited (NPCL) 2222KVA.

S / N	Parameters.	7 (%)	6 (%)	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)	Average
1	Solar Control	31.04	34.48	17.24	17.24	0.00	0.00	0.00	5.50
2	Thermal Insulation	20.69	34.48	13.79	20.69	10.35	0.00	0.00	5.00
3	Aesthetic	20.69	34.48	31.03	13.80	0.00	0.00	0.00	5.50
4	Acoustic	24.14	20.69	27.59	24.13	3.45	0.00	0.00	5.00
5	Structural Function	34.49	17.24	27.58	17.72	3.45	0.00	0.00	5.00
6	Natural Ventilation	3.45	17.24	41.37	37.93	0.00	0.00	0.00	5.50
7	Safety & Security	37.93	27.59	13.79	10.34	6.90	3.45	0.00	4.50

Table 4: Perception scores of respondents in Ansal Plaza.

4.2 Ansal Plaza

The perceptions of people vary because of the individual differences, in terms of knowledge, religion, cultures, or socio-economic factors. The questionnaire was administered in this building and the respondents that filled this questionnaire are males and females which have 85% and 15% respectively. Respondents' feedbacks are tabulated below (See Table 4).

S/N	Office/Shops Sizes (sqft)	Consumptions per month In Summer (₹)	Consumptions per month In Winter (₹)
1	7871	2,73,818.65	1,84,799.36
2	350	2,140.55	2,076.06

Table 3: Seasonal Electricity Consumption in Ansal Plaza.

4.3 Solitarian City Center

The questionnaire was administered in the Solitarian City Center and 97% of the respondents in this building are male and 3% female, the overall scores are computed below (See Table 6). Seasonal electricity data was collected for this building too, to assess energy efficiency. (See Table 5).

Table 5: Seasonal Electricity Consumption in Solitarian City Center

S/N	Office/Shops Sizes (sqft)	Consumptions per month	
		In Summer (₹)	In Winter (₹)
1	621	5500	3300
2	500	4200	2520
3	340	3000	1800

Table 5 shows the sizes of the building spaces range from 340sqft - 621sqft. And just like the previous seasonal electricity consumption, the consumption differs seasonally. It consumes a lot in summers because of the demand for mechanical cooling and requires less in winters as solar heat utilized to adjust the temperature of the internal spaces.

Table 6: Perception scores of respondents in Solitarian City Center.

S / N	Parameters	7 (%)	6 (%)	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)	Average
1	Solar Control	20.00	39.99	33.34	3.33	3.34	0.00	0.00	5.00
2	Thermal Insulation	10.00	33.33	36.67	16.66	3.34	0.00	0.00	5.00
3	Aesthetic	3.33	40.00	33.34	0.00	3.33	0.00	0.00	5.25
4	Acous	6.66	33.33	36.66	16.66	6.66	0.00	0.00	5.00

	tic	7	33	66	67	7	0	0	
5	Structural Function	10.00	33.34	43.33	6.66	6.67	0.00	0.00	5.00
6	Natural Ventilation	0.00	3.33	26.66	20.00	43.33	6.68	0.00	4.00
7	Safety & Security	20.00	16.67	26.67	6.67	20.00	6.67	3.33	4.00

In the percentage scores for the three tables (2, 4, and 6), in MSX Tower 2, Ansal Plaza, and Solitarian city center respectively. The users of these buildings score each building through the medium of the questionnaire based on their experience with the performance of the glass façade in their respective buildings. The percentage Performance of each determinant is calculated from the inferences of the questionnaires administered to them. And the seven vital parameters listed in the tables are gauged based on the 7-point Likert scale, ranging from the highest choice (7. Strongly agree) to the lowest (1. Strongly disagree). The highest percentage scorings are represented in bold in each table for easy computation and study, also the comparative analysis of the parameters is graphically represented in the bar chart (See figure 25). Where the overall result is reckoned and conclusively summarized.

5. RESULTS AND DISCUSSION

The three case study buildings are analyzed in two different ways to improve the reliability of the results. 5-point Likert scale was employed to summarize the comparative analysis of the design analysis of the case study buildings. The six parameters are marked between 0-100% with subdivision as 0-20 (poor), 20-40 (fair), 40-60 (Good), 60-80 (V. Good), and 80-100 (Excellent). Ansal Plaza and Solitarian City Centre perform comparatively well in terms of solar control aesthetics and acoustics. Ansal Plaza also performs well on the other two parameters. MSX Tower 2 performs low on most of the parameters (See figure 24). Overall, it is identified from the design analysis that the parameters that buildings are performing well in terms of Aesthetics, Safety/Security, and Acoustics with 65%, 90%, and 84% scores

respectively in MSX Tower 2, Ansal Plaza, and Solitarian city center. Also, the parameters where the buildings score substantially low are fundamental aspects like Solar Control, Structural function, and Natural Ventilation with 15%, 45%, and 17% respectively.

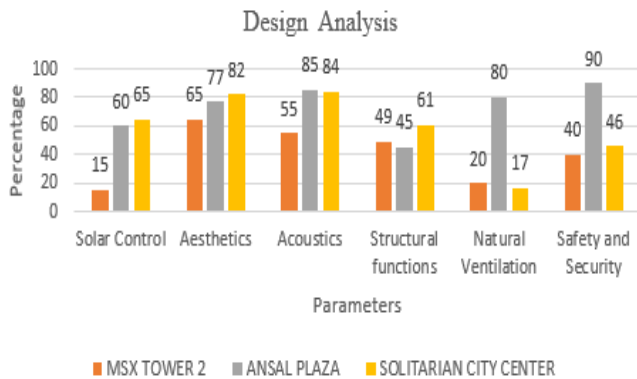


Figure 24. Design Analysis result for the performance of the glass façade.

The users’ perceptions survey record was analyzed from the questionnaire administered to them based on the 7-point Likert scale. The seven parameters are assessed thoroughly by the users according to their practical experiences on the glass façade performance in their respective buildings, based on the following scale. 7. Strongly agree, 6. Agree, 5. Slightly agree, 4. Neutral, 3. Slightly disagree, 2. Disagree, 1. Strongly disagree. Taking the percentage scores into account, both the three buildings perform relatively well in Solar Control and Acoustic. Ansal Plaza and Solitarian City Center seem to perform well in the remaining parameters, leaving behind MSX Tower 2. (See figure 25). However, in MSX Tower 2, Ansal Plaza, and Solitarian City Center the parameters that perform the most are solar control, aesthetic and solar control with 86%, 86%, and 93% respectively according to the respondents. Furthermore, the result shows that the parameter that the buildings majorly perform low is the prominent parameter which is natural ventilation with 0%, 62%, and 30% respectively according to the users’ responses.

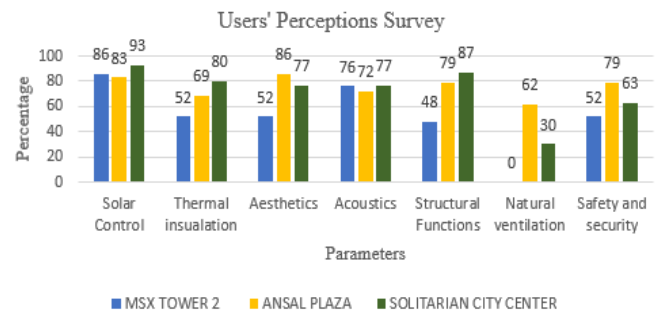


Figure 25. Users' Perceptions Survey results for the performance of the glass façade.

The datasets for this paper were analyzed using SPSS and Excel software for the computation and analysis of the ninety-six administered questionnaires distributed across the three buildings. However, the normality of the data was checked in SPSS using Kolmogorov-Smirnov and Shapiro Wilk test, and the result revealed the data are not normally distributed. Taking this result into account, the Mann-Whitney u test of non-parametric was conducted building wise to statistically test the difference between the two groups (Staff & Tenant) and (Male & Female). And it is discovered there is a statistically significant difference of opinion between the 4 groups of stakeholders, hence the results vary. The possible reason for this variation between the staff and the tenant is that the staff do not stay all the time in these buildings so their perceptions differ from the tenants that stay throughout the day inside the buildings. For the case of males and females, the numbers of females interviewed are not more than 22% and most of them are office clerks and secretaries, and their portion offices are partitioned with the board. The way they perceive glass façade differs from the males that are majorly the bosses that live in the offices and the shops. This might be the reason for their variation of opinion. The design/survey analysis conducted is to technically justify these buildings based on the performance of the identified parameters. This analysis was taken to the scaling level which was statistically represented and compare the outputs with the users’ perceptions survey.

6. DISCUSSION

Certainly, the aesthetical appeal of glass façades in commercial buildings is what keeps it popular among all other cladding materials. However, the analysis of the case study buildings brings out some design lacunae. Lack of creative thought on the internal quality of natural light and ventilation are the major parameters affecting the use, comfort, and environmental quality in commercial

buildings with large glass facades. The design analysis has identified that such buildings rely heavily on mechanical cooling. Hence, there is a need for integration of natural ventilation methods in the design of these buildings taking cognizance of aspects like energy efficiency and energy emergencies that might come up in the future. It is understood that all the seven parameters have a different dynamic impact on the interior space and the implication of not considering them appropriately in the building design is detrimental to the comfort, health, and value of money for the users. Taking the results of both the analysis conclusively, it is inferred that all the identified parameters are vital, however, solar control and natural ventilation strategy are the core determinants that need to be improved greatly in the design of commercial buildings in Greater Noida.

7. CONCLUSION

The scope of glass façade usage is increasing day by day in commercial buildings, as the nature of the material and technology persuade the designers and architects to continue employing this material in our contemporary buildings. Originally the concept of glass façade buildings is in a positive response to the natural environment. However, this study has inferred that glass façade use has performed positively and negatively to the building envelope. It is identified that solar control and natural ventilation as the prominent parameters that perform the most to the use of glass façade in commercial buildings. The paper inferred that glass façade performance in MSX Tower is poor in terms of the influence on the comfort of living to the occupants, and this was discovered from the design analysis and user's perceptions.

The Solitarian city center which is considered to be an average building, which has been able to achieve solar control to an extent as per design analysis as well as users' perceptions. Passive ventilation is the major issue identified that affects the comfort level of the building. Such buildings without effective natural ventilation access do not contribute to minimizing the energy consumptions of the building as there is a demand for mechanical ventilation. Generally, there is a problem regarding the prioritization of Natural Ventilation right from the design stage which is one of the key elements that facilitate the comfort of living and the healthy environment as insufficient of it cause Sick Building Syndrome (SBS), [33] (p. 517).

Ansal Plaza is identified as the best glass façade design amongst the three from the study findings. It responds positively to many prominent parameters in contributing

to the comfort, health, and social well-being of the users. Although solar control is not very effective, the natural breeze that circulates insulates the heat in summers to a good level.

Based on these findings, this paper has two contributions to the academic literature and researchers in the field of architecture. First, it is discovered that glass façade buildings with no ventilation strategy are more likely to be in an acute heat discomfort especially in spaces with no access to mechanical means or situations of emergency. Second, the design analysis discovered that proper building orientation and consideration of the sun path are always the keys to achieving good solar control in a glass façade with no solar reflector (solar control coating). This research looks forward to seeing how to promote the use of glass façade in Greater Noida through the Knowledge of achieving good glass facade designs that respond to the seven listed parameters, in enhancing the comfort of the living spaces. Greater Noida is still in the development phase, investors are now constructing plazas, offices, and hotels, etc. Therefore, the use of a glass façade is not only popular but also promoted to develop buildings with optimum energy efficiency control and a healthy environment. As a result of the increase in population growth, the demand for commercial buildings also increases to cater to the need of the public. This paper recommends the following measures to improve the performance of the glass façade and increase social well-being and provide a healthy environment in Greater Noida for the benefit of all.

- Architects should take careful consideration of the sun movement, building orientation, morphology and appropriate glass type to be used in a particular building right from the design stage. This helps to achieve comfort and sound glass façade buildings that enhance the social well-being and life of the users.
- Consistency in supervisions is essential to ensure the adherence to the specifications mentioned by the professionals and proper implementation of them.
- Architects should include the idea of a ventilated glass façade or serrated glass façade with ventilation access to aid the interior cooling, promotes a healthy environment, and reduces the energy consumptions needed for mechanical ventilation.
- Policies should be enacted by building professional bodies and Government agencies on the glass façade building designs and recommended glass type for commercial

buildings, taking cognizance of the building functions, location, orientation, and many more. This helps in controlling the improper use of the material to protect the lives and properties of the masses.

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