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To Evaluate the Feasibility and Efficiency of using Photovoltaic Solar Panels on High- Rise Office Building Facades in Navi Mumbai, Thereby Reducing Cooling Load Inside the Building

Rupali A.Vaidya, Prof. Sudhanshu Pathak, Prof Avadhoot Kulkarni

Rupali A. Vaidya, Dept. of Construction Management D.Y.Patil college of Architecture, Akurdi.
Prof. Sudhanshu Pathak , Dept. of Engineering , D.Y.Patil college of Engineering, Akurdi.
Prof. Avadhoot.Kulkarni , Dept. of Engineering, D.Y.Patil college of Engineering, Akurdi.

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Abstract

Till recently glass was considered as the ultimate exterior cladding material for High rise buildings worldwide. Photovoltaic facades does give an alternative cladding material which is been adapted worldwide with magnificent results. Navi Mumbai which has become the latest hub for office buildings does have a tremendous potential for the application of Photo voltaic in facades due to its warm climate. Moreover the demerits of glass are beginning to be experienced by the occupants inside as well as the people outside. In spite of this, the builders and Architects are reluctant to use Photovoltaic in the upcoming buildings. This paper tries to discuss and evaluate the application of Photo voltaics on facades in Mumbai. My study focuses on stressing on the fact that replacing glass with Building Integrated Photovoltaic (BIPV) systems on facades can solve major environmental problems, reduce cooling loads which in turn affects the productivity of employees. Simulations are carried out on a Base case Glass Façade Building and cooling load for different temperatures is simulated and compared with BIPV panels on facades. The results so obtained give a clear picture how BIPV reduces heat gain inside the building thereby reducing cooling load in the interiors and in addition generating power. The study shows that in spite of considerably higher capital investments for BIPV, the benefits it will continue to yield over the years, to the occupants inside the building are remarkable.

Keywords: glass, façade, photovoltaic, cooling loads, solar energy.

1. Introduction

In the recent times, Glass facades have become symbolic of Modern Architecture and are supposed to impart Character and Status to High Rise Office buildings. The IT Sector boom has been continuously giving rise to many Glass façade buildings which after engulfing Mumbai has now moved on to Navi Mumbai, which has become the latest hub for such buildings. It is observed that every newly constructed Office Building has a Glass Facade and it becomes the USP of the building and a cost deciding factor. Millenium Park, Mahape Village, Navi Mumbai which is the biggest Software Park in India houses numerous such glass facade Buildings and is the busiest work hub today. Unfortunately, these glass façade buildings have become a source of many problems eventually disturbing the thermal comfort conditions inside the building. These grave consequences are the result of the stubbornness shown in the replication of Western Architecture without giving a thought to the adaptability of glass in a warm and humid Climatic zone like Navi Mumbai.

Ironically, glass is technically the least favorable construction material to be used in Mumbai with its Hot and humid climate. Glass generates a high level of solar radiation that in turn traps heat and raises the temperature inside and around the building and also leading to higher air conditioning and soaring power bills. All these factors point to the fact there is an immediate need to incorporate sustainable and energy-efficient techniques to diminish the energy demand, tap renewable sources of energy, to meet the energy demand of office buildings and work towards providing better indoor environments within buildings.This can be achieved by replacing glass with an alternative material without compromising on the Aesthetics it offers, that being considered its USP.

If we can accept a glass which controls the harsh sun rays from entering the building interiors, we might as

well implement BIPV on facades and work towards tapping renewable energy which is the need of the hour. Also, it is seen that globally BIPV Facades are being implemented in buildings worldwide with favorable and proved results. But, we in India are still quite conservative about using the same. The cost involved in installing the system along with the fear of using a new material along with availability of the same being the areas of concern. But the probability of replacing glass with Building Integrated Photovoltaic (BIPV) systems on facades needs to be evaluated as the later offers an added advantage of minimizing the problems caused by glass facades and at the same time generate Electricity.

2. Methodology

The study focuses on the possibility of replacing Glass facades with BIPV Panels.. Data was collected by means of Literature views (Research papers, Articles and Standard codes). An analytical approach was adopted where there could be comparisons done between different materials (Glass and BIPV) & Building components (Roof, Facades, horizontal solar farms). Standards were referred for the purpose and data was extracted through Case studies. Simulations were run in Equest Software for a Base Case Building with glazed façade to analyze the effect of materials with different thermal properties on the inside of the building. Analysis was conducted on the basis of effect in cooling loads inside the building for range of temperatures. Conclusions were made after a comparative study based on the data accumulated through literature reviews, simulations and standards (ASHRAE).

3. Literature Review

Facades, are instrumental in affecting the indoor Environment of a building. Lightweight and thin film PV panels have been proposed for facades which suffices the needs of a sustainable solution thereby producing electricity. Although these facade systems receive less irradiation than rooftop and ground installations, they offer lower diurnal and seasonal variations, thus can continue to be a viable solution. Simulations were done and it was observed that the total energy savings of 25%.was achieved.[Zoltan Nagi.(2016),et.al(i)]. In one paper the feasibility of using Solar cooling facades on buildings in different regions with a warm climate was discussed. Through this paper the performance of vertical facades was analysed and based on a built up model the four best directions for orientation of solar facades was deduced.[Alejandro Prieto, (2018),et.al (ii)]. A paper on different shading systems discussed how External shading devices are more effective than internal shading devices since they are more efficient in decreasing the cooling loads of buildings in hot climate regions .The cost factor which may be a challenge for BIPV to be a façade material to be implemented.[Joud Al Dakheel and Kheira Tabet Aoul(2018)(iii)] PV integrated south facing facades in Indonesia produced electricity to be used for lighting while achieving 12% efficiency and 3 degrees decrease in indoor temperature. Fixed Sun breakers or Brise Soleli systems and Solar collectors were applied on building facades in and was found to be effective for electricity production as well as cooling the interiors. [Mandalaki et al. (2014)(iv)] The Solar tracking system discussed in the paper for Roof top systems can be implemented for building facades too by applying these solar trackers on the façade BIPV panels to increase power productivity. [Suneetha Racharla ,et.al(2015) (v)].

Ashrae Standards 5517

These are standards set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers is an organization devoted to the advancement of indoor-environment-control technology in the heating, ventilation and air conditioning (HVAC) industry. These temperatures are as per the Fixed Temperature Approach. As per the table the acceptable comfortable indoor temperature is considered as 24deg -26 deg .

4. Data Collection/Analysis

The Data to be collected is split into three sections :

i. The Climate of Navi Mumbai.
ii. Simulations on a base case glazed building to analyse cooling load repurcations due to DGU and BIPV.

Climate Analysis of Navi Mumbai (Source :National Oceanic Atmospheric Administration)

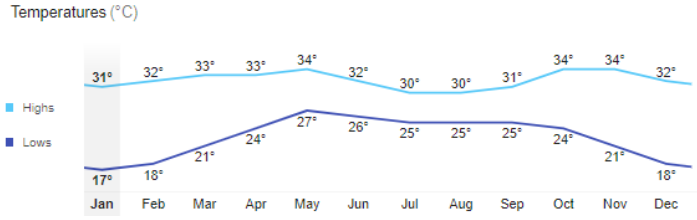

Fig 1 . Monthly Temperature Variations

The following observations can be made from the climate overview of Navi Mumbai:

- Being a coastal region variations in temperature are not large. After February, temperatures progressively increase till May which is the hottest month.
- With the onset of the south-west monthly temperature decreases a little but with the withdrawal of the south-west monsoon,day temperatures increase again and in October and November, days are nearly as hot as in summer.
- Relative humidity is about 60% throughout the year.
- Navi Mumbai has a warm climate all the whole year round which makes it a potential location for Solar Power generation.

Base Case Study for Existing Glass façade buildings

Rupa Solitaire – High rise Office building in Mahape (Navi Mumbai)

Fig 2 North west Facade

Fig 3 Building Orientation

The building is part of a business park in Navi Mumbai with Glass Façade on all the four sides of the building. It is a 17 storey Office building which houses approximately 300 offices and an occupancy of close to 3000-4000 people at a given time. Most of the offices are call centers, centrally air conditioned and operate on a 24x7 basis. The orientation of the building is such that the South-West, South-East & North-West receive the solar rays for most of the year. The shorter sides the building are majorly dead walls. The existing façade is made of Unitized 65.2 mm DGU façade with reflective films. Roof Top PV Solar System is already functional since the building is constructed ,though the users do not find it efficient enough. It was observed that The HVAC system is designed for a temperature of 24 deg. The offices have a DX coiled HVAC system and face a problem of increased Air Conditioner electricity bills. A study was carried out where a few offices on floors above the fifth floor level in each orientation of the building were considered.The following were the observations:

- Offices on the South, South east and South west side have an intense problem of heat glare.
- The Air Conditioning temperature has to be maintained at 18-22 degrees Celsius throughout the day which becomes uncomfortable to the employees working there.
- The glass facades need to be covered all throughout the day with blinds resulting in consuming 100% artificial lights.
- A large quantity of DX systems for Air Conditioning is used in offices which consume considerable electricity.
- Overall a very high electricity consumption is observed in the offices facing South , east and West .

5. Findings

A study of the building was conducted to measure temperatures (indoor& outdoor), the relative humidity, check for heat glare and Air conditioning temperatures to understand the existing cooling loads in different offices. The readings were taken for three days each in January, February & March whereas projected readings for the month of April and May were considered.
The base case has existing Double Glazed Unit System for the façade and the proposed System is the BIPV façade system. The parameters are compared to analyze the performance of the two materials based on the parameters or properties.

Simulations and Results

The main aim of performing simulations was to analyse how the solar radiations would behave when incident on building facades incase of i) Glass, ii)

BIPV panels. As the focus of study was the indoor air environment, the Simulation needed to be done majorly to study the Cooling load inside the building which would be resulting due to a range of temperatures throughout the year. After exploring few energy related softwares, Equest is the software which I selected to get an Energy model on a Base Case Building.

Note : The Building under consideration is representative of the many Glass façade buildings in Navi Mumbai and is worked upon to check feasibility of replacing glass with BIPV facades.

The Simulations were run for two cases Double Glazed Unit and BIPV façade panels. The total Cooling load in both cases was modeled for a range of external temperatures. The comfort temperature range considered for the interiors of the building was from 24 deg-26 deg. The comparison is then done on the basis of how much reduction in cooling load is achieved by replacing glass panels with BIPV panels. This will also prove that the solar heat gain in case of glass is much more than of BIPV panels.

Energy Modelling for Rupa Solitaire

Name of Project	Rupa Solitaire	
Location	Navi Mumbai, Maharashtra	
Type of project	Commercial-Office	
Project Report for	Energy Simulation	
Energy Simulation Software	eQuest 3.65	
Software Inputs		
	Base case	**Proposed Case**
Weather file	Mumbai Weather file, ASHRAE IWEC, Station 430030	Same as base case
HVAC Details		
a) Type of System	DX coils (Cooling only)	Same as base case
b) COP	4.3 (Daikin VRV IVassumed)	Same as base case
c) Cooling set point Temperature	75.2°F (24°C)	Same as base case
Roof U Value considered	1.09 W/m2.K (10 mm tiles + 15 mm cement screed + 5 mm Bitumen + 125 mm brick + 75 mm insulation + 35 mm screed +150 mm RCC)	Same as base case
Lighting	Lighting Power Density (W/sq.ft) as per LEED NC' baseline	Same as base case
Glass		
a) Type	DGU	BIPV
b) U value	2.1 W/m².K	1.1 W/m².K
c) Shading Coefficient	0.66	0.40
d) VLT	0.75	0.34

Table 1: Base case Energy Simulation Results(Annual Energy consumption in MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.47	0.44	0.51	0.55	0.62	0.56	0.54	0.52	0.5	0.56	0.48	0.48	**6.22**
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	**0**
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Vent. Fans	0.11	0.09	0.09	0.08	0.09	0.08	0.07	0.07	0.07	0.09	0.09	0.11	**1.01**
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Misc. Equip.	0.7	0.64	0.71	0.72	0.71	0.7	0.73	0.71	0.7	0.73	0.63	0.73	**8.41**
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Area Lights	0.47	0.43	0.48	0.49	0.48	0.47	0.49	0.48	0.47	0.49	0.42	0.49	**5.67**
Total	1.75	1.6	1.79	1.84	1.89	1.81	1.83	1.77	1.74	1.86	1.62	1.8	**21.31**

Table 2: Proposed case Energy Simulation Results(Annual Energy consumption in MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.4	0.38	0.45	0.49	0.54	0.5	0.49	0.47	0.45	0.49	0.42	0.41	**5.49**
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	**0**
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Vent. Fans	0.09	0.08	0.08	0.07	0.08	0.07	0.06	0.06	0.06	0.08	0.07	0.09	**0.89**
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Misc. Equip.	0.7	0.64	0.71	0.72	0.71	0.7	0.73	0.71	0.7	0.73	0.63	0.73	**8.41**
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Area Lights	0.47	0.43	0.48	0.49	0.48	0.47	0.49	0.48	0.47	0.49	0.42	0.49	**5.67**
Total	1.67	1.52	1.72	1.77	1.81	1.74	1.78	1.72	1.69	1.79	1.54	1.72	**20.47**

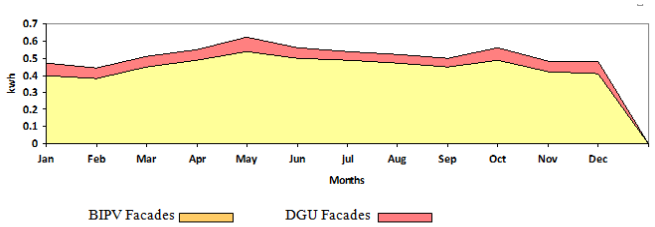

Fig4 Graph showing comparative cooling loads

The Thus the simulations show that the annual energy consumption with proposed glass (BIPV) is 5.58 MWh while with the existing glass (DGU) is 6.33. Hence, approximately 0.75 MWh of energy (11.8%) will be saved annually if the project shifts from DGU to BIPV.

5. Conclusions & Recommendations

It is clear from the graph, that in case of glass facades, the cooling load is comparatively higher than as compared to in case of BIPV facades. This means that the annual power consumption of the building can be reduced with the use of BIPV facades.

Moreover the BIPV panels will also act as power generators. Thus the total grid electricity consumption will definitely reduce as the power generated from the facades will also be used for the electricity consumption.

Looking at the advantages offered by BIPV Panels have been proved to be an alternative to glass, which reduce the negative effects of glass on the building interiors

which have been studied and analysed in the paper. As we have already switched to High performance Solar Control Glass which is available in the market, we can definitely move further to BIPV Facades where in we actually get to utilise the solar radiations rather than merely controlling them. With a Warm and Humid Climate of Mumbai, Solar Energy generation on Facades need to be explored upon, which could also be beneficial along with Roof Top solar Systems ,to tap renewable energy.

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