Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Designing a thermally efficient building envelope of Rotary Plaza of Kathmandu

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Abstract

Nepal is a developing south Asian country with high electricity generation potential and almost negligible production rate. The maximum load consumption is in the domestic sectors and very less in the commercial and industrial sectors. This will provide specific methodologies and information, for energy efficiency improvements in commercial cum office building at Kathmandu Valley, to help designers and managers in getting started on an energy managing program and creating some “energy winnings” in order to save more energy for other purpose. A building in Kathmandu has been chosen as a case study for the commercial building considered as huge energy is consumed due to the regular requirement of the lighting, air conditioning and official equipment. The modelling is done in Ecotect-2010 for the building. Glass envelope with different specifications are taken and the energy simulation is done. An efficient energy saving modelling is done to decrease the energy consumption and reduce the heating, cooling and lighting requirements in buildings was developed. Solar PV Panels has also been designed and obtained the significant grid energy optimization for heating and cooling energy consumption. The research also demonstrates that the proper use of facade envelope with proper shading can make the significant optimization of energy efficiency. The energy consumption of the building, after the application of energy efficient measures for the simulation results in decrease in the energy consumption per year by the use of infill walls than the glass façade envelope though the proper orientation of building is its limitation due to the land constraints.

Keywords

Commercial Buildings, Thermal load, Efficiency, Glass Facade, Infill Wall, Energy Optimization

1. Introduction

Construction materials has been dynamic component in the global prospective. ‘Buildings have long been constructed with the exterior walls of the building supporting the load of the entire structure. The exterior walls could be non-load bearing and thus much lighter and more open than the masonry load-bearing walls of the past [1]. This gave way to increased use of glass as an exterior façade, and the modern-day curtain wall was born. Glass has high transmittance value which results in high amount of energy consumption for maintaining thermal comfort. Different systems are used for installations like the traditional Stick System and Ladder System and the Unitized system. Stick System and Ladder System are those in which more activities are done in Site and less time is spent in Workshop. In the Unitized system, more time is spent in Workshop than in Site[2]. The Infill wall use fibre-cement board in both the outer surface and thermocol-cement-sand mix in between as a sandwich panel. As the façade envelope is chosen without thermal analysis in Nepal, high energy consumption is inevitable.

For making the building energy efficient, the imported components and features with mentioned energy efficiency percentage is incorporated during construction without gaining idea of what actual performance would be best for the climate of different parts of Nepal. Glass panels with random thickness has been trending as envelope. Single glazing to triple glazing containing infills of air, vacuum, argon, etc. has been used randomly. This research is intended to compare and recommend the energy efficiency requirement in glass façade in complete envelope versus glass façade covering the South-West portion as per the climatic condition of Kathmandu.

As buildings has been constructed using imported construction materials, the research would be helpful for choosing the better non-structural envelope which would optimize the heating and cooling load when the material is used towards the direction of direct solar radiance. Also, achieving passive thermal performance in the present construction practice with enhanced aesthetic property, the research will help practitioners, Engineers and Architects to select the most suitable energy efficient construction material. The research intends to help the designers who would choose to incorporate the glass façade curtain wall as the prime envelope for the climate of Kathmandu Valley.

The review findings confirm that building energy efficient design optimization is a promising technique to design buildings with higher energy efficiency and better overall performance [3]. Different countries have been adopting the building regulations including the energy parameters for the construction materials used. But, in Nepal, energy efficiency has only been the trending topic limited to discussion for the building. Most buildings in Nepal has been constructed using traditional methodology and traditional building materials. Thermal performance of those traditional residential building, adapted in various ways to the changing thermal regime for thermal comfort inside Kathmandu Valley is better than that of contemporary buildings [4]. The change in façade trend is more rapid for the commercial complex to recognize it as a landmark of the location and eye-catching spot. This research has compared different thermal performance of the building that would depend on the façade elements and recommend the better alternative.

The main objective of this paper is to compare and analyze the thermal behavior of Glass Facade Curtain wall panels and drywall system. Further, this research aims to investigate the results from analytic method and compare the results from Ecotect-2010. Thus, this research work has following objectives.

1. To enlist the thermal conductivity of building envelope materials
2. To calculate and compare the thermal parameters of both the sample panels
3. To design a structure based on the case study

The overall heat transfer coefficient along with thermal properties of different envelope materials has been enlisted. Calculations has been carried out for the Glass façade and infill wall structure and the parameters has been compared to each other. For the efficient façade design, designing has been split in different cases. The building has been designing the building for the dry infill wall towards the South, the West and both the directions. The first case of designing has been for the glass façade taken on all the direction. For the Second case, the complete building has been remodeled for the infill envelope in the South and the West portion and the third has been for both South and West directions. The solar azimuth is measured from due south in the northern hemisphere and is positive towards the west [5]. The calculation has also been focused for measuring the shading angle required, and shading device to be proposed. Also, designing of the solar panel for the basic heating and cooling requirement has been calculated to replace the active grid electricity replacement for the Heating and cooling purpose.

Energy efficiency is a mandatory requirement and integral part of green and sustainable buildings [3]. Energy efficient design optimization is both a design philosophy and a practical technique that has been proposed and used by architects and other professionals for several decades, especially in the past few years [3]. Since the building envelope is the most crucial components determining a building's thermal and energy performance, it is worthwhile for larger-scale building with complex façade systems to have building envelope commissioning, to safeguard its workmanship, durability and other environmental performance. In places where high performance building façade systems are not used or are unfamiliar, carrying out research and development to determine material availability and types of façade systems is useful which are appropriate to the local context, including the climatic conditions, patterns and norms of building occupants' behavior defined by local culture and social values, etc. The findings also serves as baselines for further research and development on designs and the implementation of innovative façade systems. Capacity building is implemented to upgrade the professional's knowledge and train a workforce with skills for designing, installing, operating and maintaining high performance building façade systems.

2. Simulation Scenario

The building of Rotary Plaza of Kathmandu is taken as the case study for the designing of the thermally efficient envelope. The building is located in Thapathali and is the building in which structure is on the phase of its completion. As this building is under construction and material for the architecture of the building envelope can be wisely selected, this building is found the most suitable for the case study. As the roadway access for the building is towards the East, the orientation of the building is the limitation. The building stands on the area of 3 Ropani 4 Aana. The length of the building is 40 sqm and the width is 30 sqm.

This thesis, thus, emphases on the designing of the envelope for a structure with the orientation towards East. As this building is aimed to be operating as the office complex, the design parameters for the designing requirement of an office would be standardized.

2.1 Comfort Temperature

The meteorological data are taken from the Department of Meteorology. From the Meteorological data, the bioclimatic chart is generated as per the figure 1. Using the Climate Consultant, the comfort range of the temperature obtained is in-between 18 degree to 25 degree Celsius. The same temperature is used for the Ecotect Analysis.

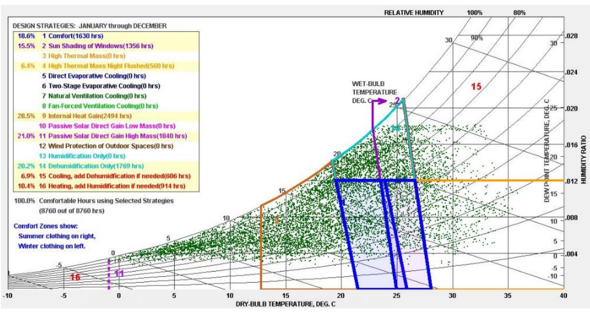

Figure 1: Bioclimatic Chart of Kathmandu Valley

The Annual Solar Chart in June results in high intensity of solar incidence and shorter shadow formation. The sunlight enters the room at the South-West after 4 pm. Different types of glasses are used in the market. The specification of glasses are the table in table 1.

For the designing, the building's façade is separated into two types. In the first type, the glass envelope is placed in all the direction. For the second case, the glass envelope of the South is replaced by light weight dry wall structure with 15% openings. The architectural plans and elevations of the building as shown in Figure 2.

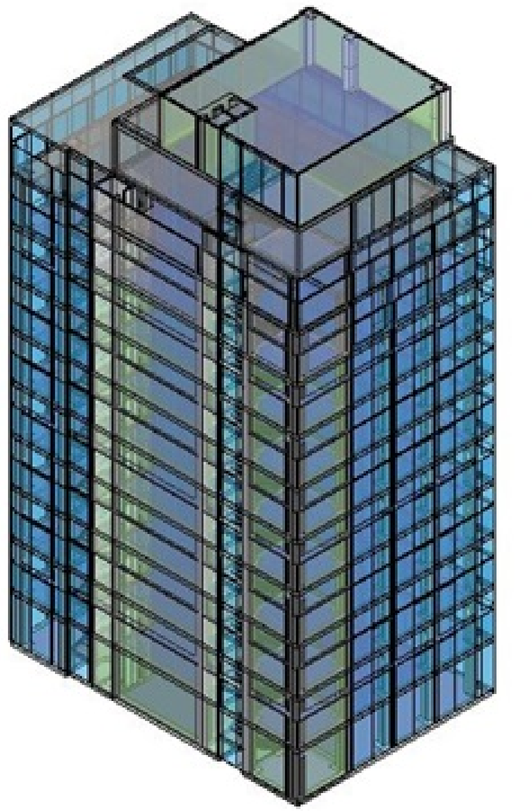

Figure 2: Elevation of Building

Using Glass of the specification as per the table 1 , three cases are developed comparing the Transmittance, Outer Reflection and Absorption value for the glass of same U-Value. For the First case, the SN 70/35 Neutral Blue Shaded glass with 12mm air space and 6mm clear glass with lower Absorption value of Glass for Facade was used. For the second case, the SN 70/37 Neutral Shaded glass with 12mm air space and 6mm clear glass with lower Outer Reflection value for Facade was used and for the third case, the SN 40/23 Neutral Blue Shaded glass with 12mm air space and 6mm clear glass and lower Transmission value was used.

For the second model, the dry infill wall of thickness 100 mm was used towards the South face of the building in the first case and the dry infill wall of thickness 100mm was used towards the West side of the Building for the second case.

Combining all the cases above, the building with dry

	Visible Light				Summer	Winter	
Glass Products / Colour Appearance	Transmission %	Reflection Outside %	Absorption	Relative Heat Gain W/m3	U-Value Day time W/m2K	U-Value Day time W/m2K	U-Value Day Time W/m2K
SN 40/23 Neutral Blue	39	16	45	174	1.5	1.6	1.3
SN 70/35 Neutral Blue	69	14	17	246	1.5	1.6	1.3
SN 70/37 Neutral	69	11	20	258	1.5	1.6	1.3

Table 1: Specification of Glass used in Facade Envelope with minimum U-Value

infill wall in the South and West direction and Glass façade of lowest energy consumption for heating and cooling load was used in the building for simulation for creating the third scenario of the consumption.

3. Simulation Result and Discussion

The cost of the envelope construction is computed as table 2.

Table 2: Cost of Installation of Envelope

Case	Description	Cost
1	Glass in All Direction	18,309,554.66
2.1	Wall in South Portion,	16,219,747.59
2.2	Wall in West Portion,	15,523,145.23
3	Wall in South and West	13,433,338.16

The observation of energy consumption shows that the Neutral Shaded glass has least energy consumption for the glass façade. For the model of infill wall, the wall in the South portion results in the least energy consumption. The Table 2 also illustrates that the envelope cost is maximum when glass facade is used. The cost becomes minimal if the infill wall facade is used in the envelope. The cost of the building envelope decreases by 27% when the infill wall is used in the South and West portion of the building replacing the glass facade of these directions.

Table 3: Energy Consumption in different cases

		Energy Consumption		
		Losses	Gains	Total Wh
1.1	SN70/35	28928	65145	94073
1.2	SN70/37	2023	88420	90443
1.3	SN40/23	3843	43711	47554
2.1	Infill in South	4252	34051	38303
2.2	Infill in West	28903	65159	94062
3	Infill in South and West	28899	65163	94062

The result of the observation is represented in 4 for all cases and Comparison of Comfort Hours as well as Comfort Percentage.

Figure 3: Comparison of Comfort Hours and Comfort Percentage

The Chart 3 illustrates that the comfort level is more when the glass facade of neutral blue shading and with lower value of transmission is used. The comfort level is also high if the infill wall envelope is used in the South direction.

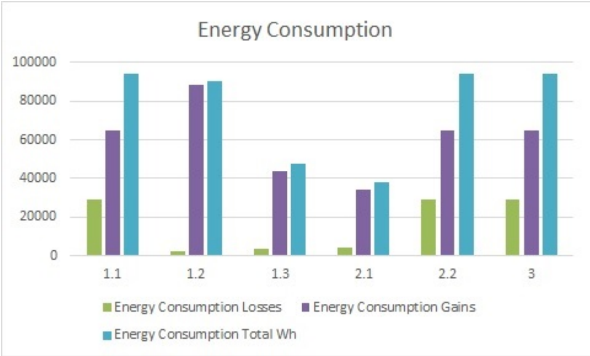

Figure 4: Comparison of Energy Consumption

The figure 4 represents the graphical representation for the energy consumption for the different envelope alternatives. The chart illustrates that the energy consumption is least when the glass facade of neutral blue shading and with lower value of transmission is used. And, for the infill wall envelope, the heating and cooling energy consumption is minimum for the infill wall envelope used in the South direction.

Regarding the shading, the building is to be protected from the direct sunlight for direct heating during March to September from 12 Noon to 3:30 PM as the temperature at this time is maximum. The horizontal shading obtained is of 1.59 meter. For the minimum energy consumption obtained from the simulation model, the design load for panel to be operated for the heating and cooling load needs to be 3,06,424 Wh. 406 nos of PV panel of Imp 8.08 A, Isc 8.72 A, Vmp 37.15 V and Voc 44.5 V is obtained with 258 nos of 130Ah battery of 12V. Charge Regulator of Imax greater than 532 A; 218 nos of Inverter of size 47879 VA and Wires of size greater than 15cm, 8cm and 11.3 cm is designed. As the size of solar panel is 1.954*.990*.45, the length of solar panel can be used as the shading length.

Length	=	1954	
Width	=	990	
Height	=	45	
Area of total PV Panel	=	785.4	sqm
PV module in each floor	=	58	
Total Floors for Shading	=	7	

Table 4: Area occupied by Solar PV panels replacing Shading devices

With the cost of NRs. 1.76 Crore, the solar panel can be used which replaces the grid energy costing 10.49 Lakhs per annum resulting in the payback period of 16.79 years.

As per the observation for Energy Consumption as per Table 3, it can be seen that the energy consumption is least in the Neutral Blue Shaded glass with least value of transmission coefficient. But, the cost of construction is higher as the glass envelope is to be imported. The cost of construction lowers with the use of infill wall envelope. The cost of construction of façade envelope is maximum (1.83 crore) when the complete building is enclosed by Glass façade. As the infill wall is cast-in-situ, the construction cost decreases to 1.35 Crore. Also, use of Wall envelope at South can also reduce the solar consumption and increase the comfort upto 65%.For the shading towards the south, solar PV panel can be used. The requirement of shading is 1.59m projection. If the solar panel is used as the shading device for the horizontal shading, as per table 4, the area occupied by Solar PV Panel would be 785.4 sqm and 58 panels in each floor for 7 floors could be used. By this, the cost of installation of PV Panel would replace the cost of construction of shading and the cost of energy consumption could also be decreased reducing the payback period of the construction. It can be said that an energy efficient modeling is done to decrease the energy consumption and reduce the heating, cooling and lighting requirement is hence developed [6].

4. Conclusion and Recommendation

From this research, it can be concluded that the cost of the construction is least when infill wall envelope is used rather than the glass facade. But, the infill wall envelope in the West portion results in the lowered comfort for the building occupants. So, for the land-marking commercial structures, the use of glass facade is most feasible in the East and the North portion avoiding the Southern sunlight enter the building as the insolation is towards South is maximum. Also, if the solar photovoltaic panel is to be used, the Southern portion of the building would be the most efficient. Also, as the shading requirement is maximum in the South portion, replacing the shading device by Solar PV panels would be most effective to reduce the separate space to be allocated for the solar panel as well as to decrease the separate cost for shading. This pattern of using the solar photovoltaic panel to replace the shading device is wide in the western developed countries.

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