ELECTRICITY CONSUMPTION FOR ENERGY CONSERVATION IN OFFICE BUILDINGS IN LAHORE-PAKISTAN

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ABSTRACT: It has become a popular practice to design highly glazed high rise office buildings in Lahore. The electricity consumption in these buildings is becoming a severe problem in the absence of climatic considerations. Therefore, simulations become a need to evaluate such type of buildings for energy conservation. This paper presents analysis of electricity consumption for typical highly glazed office building in Lahore through simulations process. The parameters selected for simulation were the orientation, shape of building, elements of façade such as windows, their size and the type of glazing. The paper concludes that highly glazed buildings require huge electricity than the buildings designed with climatic considerations.

Key words: Office buildings, Simulations, Electricity, Lahore, Glazing.

INTRODUCTION

Offices are a basic unit for work buildings. Most of the energy for service sector is used in various kinds of offices for heating, cooling, lighting, computing and hot water. Therefore, energy consumption in office buildings is one of the research areas which have significant importance (Zhang, 2011) and (Rijal, 2007). The office buildings with huge glazing have been built in Lahore during the last few decades. Such buildings consume more electricity to maintain comfortable indoor conditions, as their facades are more sensitive to outdoor climatic conditions (Reinhart, 2002) and (Saeed, 2010). There is not enough information available to consider for the electricity conservation in context of outside climatic conditions of Lahore. This paper is an attempt to give an overview of the thermal performance and total electricity consumption office buildings with high glazing in Lahore (Drury, 2005). For this study, a typical glazed office building located in Lahore was selected for detailed analysis. The whole building energy analysis software, 'e-Quest 3', was used to study electricity consumption in the selected building. The results analysis can be recommended for different electricity management strategies and solve practical office electricity consumption problems.

METHODOLOGY

A virtual model of the case study building was created with the necessary input data needed for the simulation of electricity used in the building, such as orientation, the building's shape, size of window and type of glazing, building construction, HVAC system, the occupancy and schedules, were collected and described in great detail. The 'e-Quest 3', software which is generally known as quick energy simulation tool for advanced energy and indoor climate analysis is used for analysis. Thermal comfort and electricity consumption was simulated at zone level and building level. The results achieved by this tool are validated. It has been shown that the program gives reasonable results applicable to detailed building physics and HVAC simulations.

Modeling and Simulation: The selected building known as Bank of Punjab (BOP Tower) as shown in Figure 1, was completed in the year 2002. The total area of the plot is 9000 Sft. The building is designed with two basements for car parking each having covered area of 9000 Sft. It has a lower ground floor with an area of 4143 Sft and ground floor with an area of 4229 Sft. Next ten floors are typical each having a floor area of 5197 Sft. The top floor is partially covered having a floor area of 1537 Sft. Hence the total covered area of the building is 79,885 sft. (Figure 2).

Ceiling height from first floor Level to soffit of slab is 8'-8" in two basements & Lower Ground floor. The Upper Ground floor has a ceiling height of 11'-8" from FFL to soffit of slab. The typical floor heights from 1st floor to 10th floor are 8'-11" from FFL to soffit of slab. Finally the top floor clear ceiling height is 7'-0" only, so the total height of the building from road level to top of parapet is 130'-0", and it is going -22'-6" down from road level for basements & lower Ground floor.

In order to calculate the total electricity consumption in the selected building, each zone (a typical floor) was multiplied with the number of the identical zones. The ground and top floor were simulated separately since their boundary conditions (floor and ceiling correspondently) differ from the typical floors. It is also assumed that there is no heat exchange between internal building elements. Thermal Properties of Building Elements were calculated with respect to the four facades. Percentage of glazed areas, their shading coefficients and the U- Values of facades were calculated.

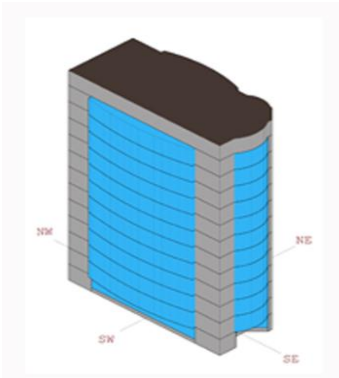

Fig. 1: Virtual model of the office building created using e-Quest 3.0 software

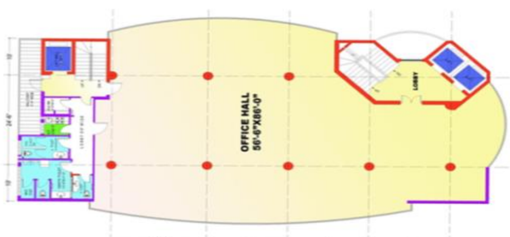

Fig 2: Typical Floor Plan

Occupancy: The occupancy assumed is 85% from 08:00 to 12:00 h and 13:00 to 17:00 h .The activity level was assumed 70 W per occupant for occupants sitting and working. Finally the occupant's clothing was assumed to be 1 clo (Light business suit) during winter and 0.6 clo during summer.

Lights and Equipment: All the necessary data used for the design of general lighting and task lighting is collected and provided in Table 1.

Table 1: Lighting and Equipment Loads

Space Type	General Lighting w/sq.ft.	Task Lighting w/sq.ft.	Equipments Plug Load w/sq.ft.
Office-General	3.0	3.5	2.5
Office (Executive/Private)	2.75	3.0	1.5
Conference/Meeting Rooms	3.0	3.0	1.0
Corridors	0.30	0.10	0.20
Lobbies, Staircases & Lifts	0.5	0.15	0.5
Kitchens/Food Preparation	1.75	0.1	0.2
Toilets	1.0	0.15	0.2
Mechanical/Electrical Room	0.7	0	0.2
Parking Areas	0.3	0.1	0.1
Storage Spaces	0.7	0	0.15

RESULTS AND DISCUSSION

Electricity consumed by various systems in BOP building for each month of the complete year is shown in Figure 3. Electricity demands appear to be fluctuating with the change in outside temperature from summer to winter months. The Fig. 3 indicates that the major consumer of electricity in the office building are the area lighting and task lighting, consuming 53% of the total electricity consumed in the building. While space cooling consumed 29% of the total electricity used in the building.

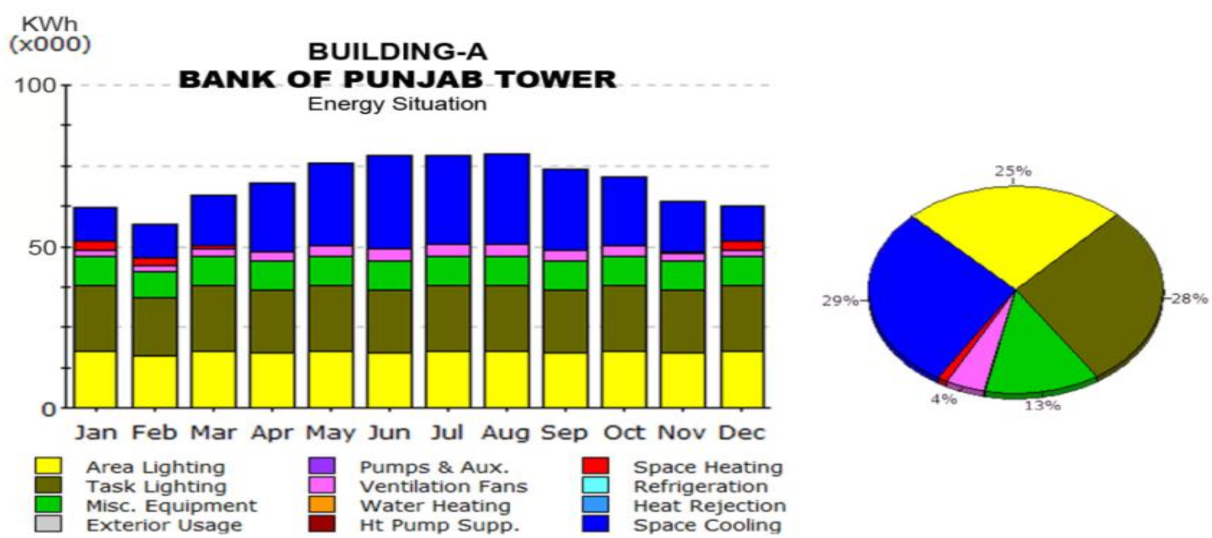

Fig 3: Monthly / Annual Energy Consumption

Table 2: Electric Consumption (KWhx1000)

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	10.5	10.6	15.9	21.3	25.6	28.8	27.5	27.9	25.2	21.6	15.7	10.7	241.35
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.77	2.02	0.70	-	-	-	-	-	-	-	0.63	2.70	8.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.95	1.90	2.00	3.10	3.50	4.02	3.85	3.87	3.47	3.08	2.42	1.95	35.62
Pumps & Aux.	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.175
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	8.95	8.07	8.95	8.65	8.95	8.65	8.95	8.95	8.65	8.95	8.65	8.95	105.27
Task Lights	20.3	18.3	20.3	19.6	20.3	19.6	20.3	20.3	19.6	20.3	19.6	20.3	238.87
Area Lights	17.6	15.9	17.6	17.1	17.6	17.1	17.6	17.6	17.1	17.6	17.1	17.6	207.3
Total	62.17	56.9	66.0	69.8	76.1	78.3	78.2	78.8	74.1	71.6	64.1	62.3	838.45

The following systems appear to be the main consumer of energy in the BOP building.

General Lighting and Task Lighting: The lighting loads include general lighting and task lighting and are constant throughout the year consuming average electricity (16.25 KWh for space lighting, 18.75 KWh for task lighting) about 53% of the total electricity consumed in the office building. It is a very high rate of consumption of electricity (3 W/Sft) for illumination purposes in an office building when compared with other countries. The major reason appears to be the excessive use of glazing without consideration of orientation. In order to control direct Sun light and glare venetian blinds have been used inside the fixed glazed panels. These blinds completely blocked the daylight; however, allow the solar radiation which results in the heating of indoor space. Therefore only artificial light is used for illumination in the office space, which is also responsible for additional heat gains and thus increasing the cooling loads substantially.

Space Cooling & Heating: The cooling loads are varying with the climatic conditions throughout the year in Lahore. The maximum cooling load of 28.83 KWh is observed during the month of June due to maximum outside temperature between 46 Cº to 48 Cº. On the other hand in January the cooling load is comparatively low 10.5 KWh. The space heating loads (red color) having maximum value of 2.77 KWh is observed during the month of January (Table 2). The minimum heating loads are observed in the month of November 0.625 KWh. The space cooling and heating loads are directly associated with the envelope. As has been discussed earlier the use of excessive glazing, 46.5 % of the wall area and without consideration of orientation and absence of shading devices, coupled with excessive use of artificial lighting for illumination purposes appears to be responsible for high cooling loads.

Cost of Energy Consumed: In order to validate the simulated results, actual utility bills of the case study building for the whole year were collected and compared with simulated results as shown in Fig 4. The analysis shows that the difference between actual and simulated energy cost is about 8.6% being under acceptable limits.

Potential for Electricity Savings: In order to assess the potential for electricity saving in the selected office building, the design standards used for different components and services in the selected office building were compared with those recommended in the International Energy Conservation Code (IECC) 2009. It is a model code and recommends energy conservation standards to be applicable in all climatic regions. In addition, it also recommends minimum requirements for exterior envelope insulation, window and door U-factors and SHGC ratings, duct insulation, lighting and power efficiency.

It is evident from the above comparison that interior lighting, including both area lighting and task lighting, is consuming 53% of the total electricity used in the building. The reasons for this significantly high consumption have already been explained. A major reason is the use of lighting load of 3.0 W/sft for area lighting and 3.5 W/sft for task lighting. While, the "IEC Code 2009" recommends that the maximum allowable lighting load should not be more than 1.0 W/Sft. for both space lighting and task lighting. It is clearly evident that at least 70% of the electricity consumed for interior lighting could be saved if lighting loads as recommended in IEC Code 2009 are followed. In addition the proper use of day light may have resulted in further reduction of artificial lighting and hence electricity consumption. Such a reduction in the use of artificial lighting would also resulted in space cooling loads needed to maintain comfortable indoor conditions.

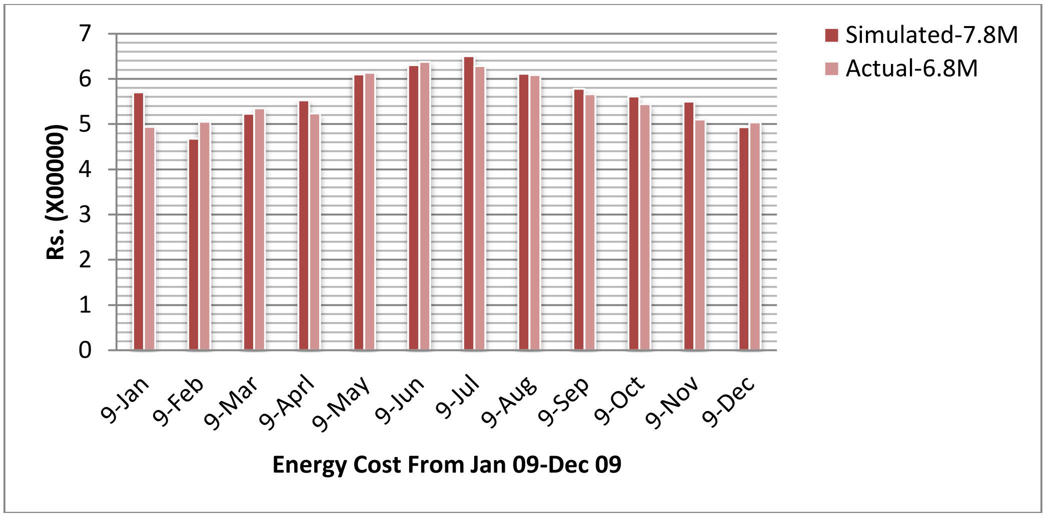

Fig 4: Comparison of Simulated and Actual Energy

Cost in BOP: In the selected building glazed surface (fenestration) is about 46.5% of the total façade surface of the building and with a U-value of 4.8 W/m²K. In addition maximum of these glazed surfaces are oriented towards North east, south east and south west, thus exposing the building to maximum direct solar heat gains, increasing the cooling loads. The Solar Heat Gain coefficient (SHGC) for the glazing used in the selected building is 0.75, which means the amount of solar heat gain passing through the glazing is 75%. The IEC Code 2009 recommends glazing with SHGC of 0.35%. If such a glazing had been used in the selected building it would have resulted in 50% reduction in the direct solar heat gain and hence space cooling loads. In addition, consideration of orientation and use of shading devices would have resulted in further reduction in direct solar heat gains. It is safe to assume that 60% of the electricity consumed for cooling of indoor spaces could have been easily saved by adopting above mentioned measures.

From the above discussion it is clear that by careful planning, adopting climate responsive design strategies and standards and recommendations as provided in the International energy Conservation Codes 2009, almost 50% of the total electricity consumed in the selected building can easily be saved.

Conclusion: In Pakistan most of the high rise buildings are not designed keeping in view the local climatic conditions. Rapid construction of high rise commercial buildings and rising living standards are considered to be the causes of increased energy demand by the building sector in the country. A considerable amount of energy is being used for the HVAC and interior lighting of commercial building to maintain its thermal and visual comfort. After detail analysis of the electricity consumption by different systems and services in selected building, it has been identified that because of the current construction trends, the energy is being wasted in increased lighting levels and comfort conditions. The fact is that interior lighting (task and area lighting) is not being properly designed keeping in view the activity of that space. The envelope of a building plays an important role in reducing / increasing HVAC loads. These loads can be minimized by using construction materials having high R-value or lower U-value. At the same time the air conditioning units with new technologies not yet introduced in the country due to increased initial cost of the equipment.

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