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ENVIRONMENTAL AND ENERGY ANALYSIS OF TALL BUILDINGS IN BANGLADESH

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Abstract- *Now a day, the energy crisis is a burning issue in our domestic and nation life. For this reason, optimized design strategy can be implemented into appropriate building and façade design. As most of the analyses in this paper demonstrate strongly, there is a need to consider energy efficiency before the impact of renewable technologies can be maximized. There are signs that energy efficiency and renewable energy are now being more appreciated and considered by the public. Therefore buildings should be designed to optimize energy in use and without compromising performance in terms of, air quality and comfort conditions. There is also a great potential to use passive and active renewable energy technologies in buildings. In order to maximize energy efficiency within a building, heat losses within the building envelope must be kept to a minimum. This is achievable via insulation to the roof, walls, windows and floors. Insulation can be improved via joining of units to increase thermal massing and minimize heat loss through exposed walls. Meanwhile on the other hand adequate ventilation without draughts is essential to avoid condensation problems. All these issues can be done by the* ***Environmental and Energy Analysis*** *of Buildings and this is very important for Bangladesh in context of contemporary energy crisis.*

Keywords: Energy use, tall building, microclimate (Bangladesh)

1. INTRODUCTION

The use of energy in buildings has increased in recent years due to the growing demand in energy used for heating and cooling in buildings. Without energy buildings could not be operated or inhabited. Improvements have been made in insulation, plant, lighting and controls and these are significant features that help towards achieving an energy efficient building. At this stage it is important to know what is meant by “Energy Efficiency”.

2. PROBLEM DEFINITION

The aims of this paper are as follows:
i) To identify the use of energy and energy analysis according to building’s microclimate. ii) To identify the integration process of climate and energy in building.
iii) Considering renewable energy and combined heat and power in buildings with environment.

3. ENERGY EFFICIENCY

Energy efficiency means utilizing the minimum amount of energy for heating, cooling, equipments and lighting that is required to maintain comfort conditions in a building. An important factor impacting on energy efficiency is the building envelope. This includes all of the building elements between the interior and the exterior of the building such as: walls, windows, doors, roof and foundations. All of these components must work together in order to keep the building warm in the winter and cool in the summer. The amount of energy consumed varies depending on the design of the fabric of the building and its systems and how they are operated. The heating and cooling systems consume the most energy in a building; however controls such as programmable thermostats and building energy management systems can significantly reduce the energy use of these systems. Some buildings also use zone heating and cooling systems, which can reduce heating and cooling in the unused areas of a building. In commercial buildings, integrated space and water heating systems can provide the best approach to energy-efficient heating.
In the past huge dependence on energy was not available, due to higher cost of production. Energy audits can be conducted as a useful way of determining how energy efficient the building is and what improvements can be made to enhance efficiency. Tests should be undertaken to ensure that the heating, cooling, equipment and lighting all work together effectively and efficiently.
Buildings also produce Carbon Dioxide (CO_2) emissions, but this sector receives less attention compared to other pollution contributors such as the transportation and

industry sectors. In addition to energy conservation and energy efficiency measures introducing renewable energy would be an advantage to the building sector as it will reduce the carbon dioxide emissions, and the energy generated from the renewable energy could be used for heating, cooling, ventilating or lighting.

4.1 DESCRIPTION of BUILDING MODULES

The building modules are built at Chittagong in an open location with uninterrupted solar access. The 0ne module is shown in the background of Figure 1. The module containing the window (brick with plaster and clear glass) is shown in the foreground and door. The modules have a rectangular floor plan of 190 feet x 48 feet (approx) and are spaced 10 inches shading and minimize wind obstruction. With the exception of the walls, the buildings are of equal construction, being built on a concrete slab and aligned in a manner so that the north wall of the buildings is perpendicular to astronomical north. The building has a ceiling height of 10’. The ceiling consists of 6” RCC (thermal resistance or R-value = 2.560 m2.K.W-1). Entry to the building is via a standard lobby with glass & aluminum glass door located on the eastern face of the building. The room door is well fitting and normally kept shut. It is only opened only to allow necessary access, making the building as air-tight as possible. No carpet or other floor covering has been placed over the concrete slab. In summer, a high thermal mass wall (10” brick wall in some façade but basically 5” brick wall) can reduce the transfer of heat by absorbing the heat energy flowing in from the outside. This process is slow and results in a delay. As a result it takes several times to make it cool. Windows are normally recessed and constructed by 2 mm colored glass not tempered. In the inner zone of the building, the capacity to absorb large quantities of heat energy for a small rise in temperature combined with the thermal lag effectively increases the R-value performance over the complete day-night cycle. Maximum external air temperature is usually reached between noon and 2pm-4pm.
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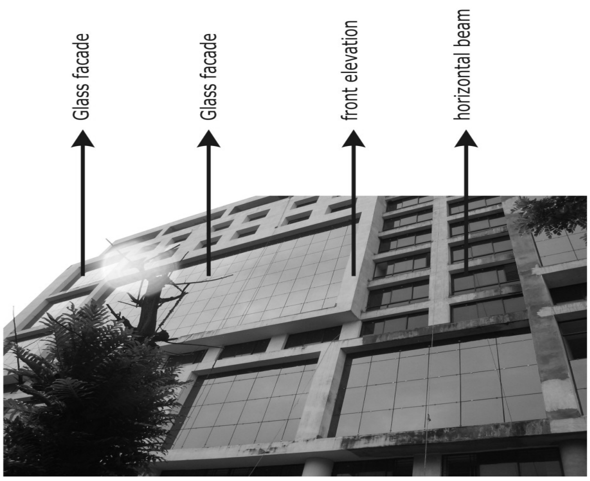


Fig.1: Front elevation of high rise building at Chittagong; CNF Tower

From the daily experience and filed survey, it is noticed that a lag of four hours, which is typical for brick construction, the maximum heat flow would not reach the interior until four hours later. By then external air temperature will usually have dropped and thermal flow will reverse, allowing the building to cool for the following day. The study found that a large portion of the heat is reflected and radiated back to the external environment by the exterior surface of the brick plaster and glass materials. It’s also show that significant amounts of the heat stored in the wall are released back to the exterior environment at night. This indicates the brick walls allow heat flow in and out of the building. It is also noticed that maximum Heat flow through the west wall of the brick plaster building

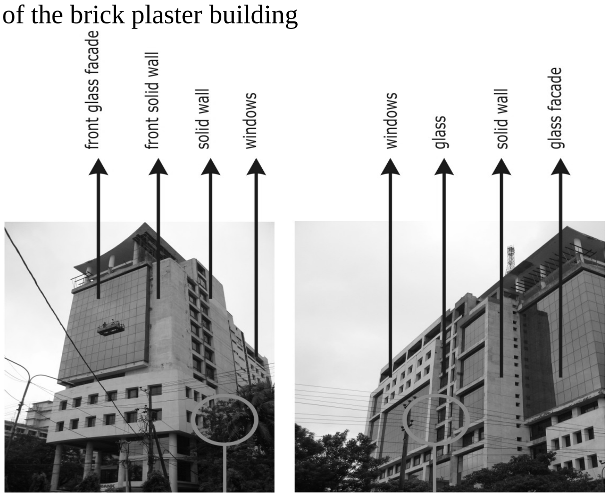


Fig.2: Perspective view of high rise building at Chittagong; CNF Tower

4.2 BUILDING FORM

From an integrated building perspective the architect must balance and reconcile the functional, programmatic, contextual, and economic drivers of the building form; and at the same time investigate passive solar, day lighting, sun shading, landscaping, and natural ventilation strategies to optimize use of the natural features of the site to maximize energy efficiency of the building form. The following building is rectangular shape and maximum surface is in north south face. Entry is situated in eastern side. Building form consideration is given bellow:

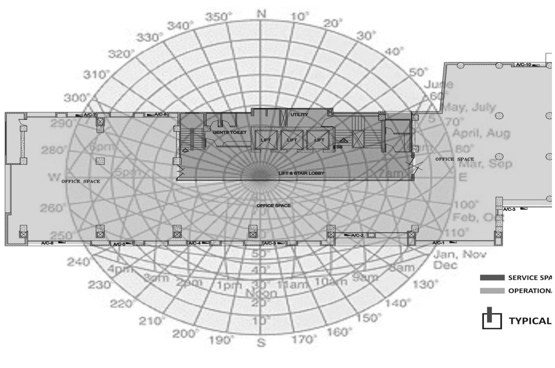


Fig.3: Building orientation

i) Orient the building on a north/south axis to allow for the highest wind flow and the lowest summer solar gains and to maximize beneficial day lighting to occupied spaces. But from field survey it is found that maximum window or glass surface is fixed and they have no contribution of wind flow. For cooling system AC is used for daytime (9.00 am to 5.00 pm).

ii) Less consideration about to regional climate and site microclimates because from the figure 1 we can see that maximum west façade is made by glass surface no consideration about sun shading and these surface is fixed by blue colored glass.

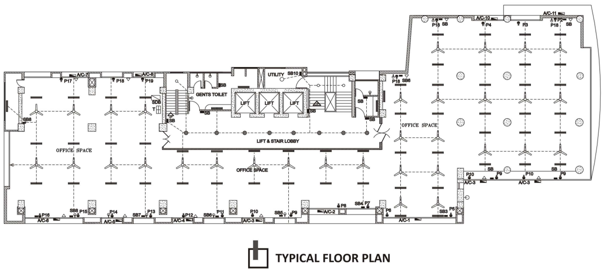


Fig.4: Building typical floor plan

iii) No consideration about minimize exterior surface complexity to reduce chance of leaks and energy loss. And no use roof overhangs to shelter facades and exterior walkways from harsh sun and weather.

iv) Considered the use of porches and pergolas to shelter exterior spaces and activities.

v) No use of landscaping features to channel and direct natural breezes and deflect harsh winds.

vi) Carefully site the building to take advantage of natural site features such as topography, sunlight, shade, and breezes to develop the most energy-efficient and cost-effective building design.

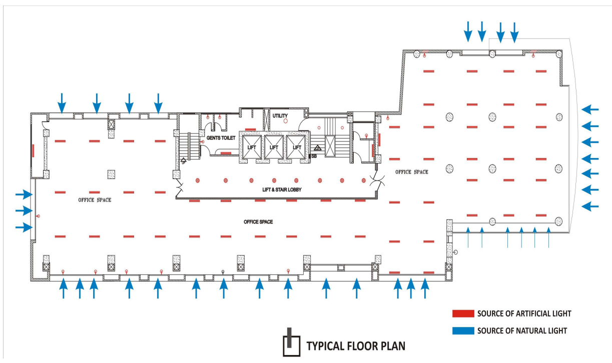


Fig.5: Wind flow and artificial lighting system

4.3 BUILDING MATERIALS

From the field survey the following materials and their cross section are found.

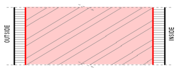
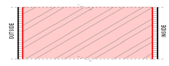
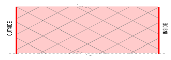
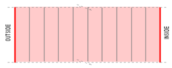
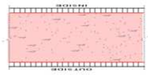
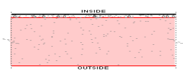
Name	Materials	Sectional Quality
Outer wall	10 " brick plaster	Normal 
Internal wall	5 " brick plaster	Normal 
Door	Wood/plastic	Well varnished (3'x7') 
Window	Clear glass with aluminum frame	Slit & normal (1.5'x4.5') 
Roof	Concrete slab	6" cc 
False ceiling	no	no
Floor	Concrete slab (cc)	Normal 
Grill	MS and aluminum frame	Normal
Color	White /ash	Distemper

Table 1: Building materials & sectional quality

4.4 ENERGY USE IN BUILDING

Object	Unit energy demand	Unit no	Total energy demand Per floor (watt)	Total energy demand (watt)
Ceiling fan	65 watt	32	2080	29120
Tube light	40 watt	54	2160	30240
Energy saving light	35 watt	40	1400	19600
Normal light	60 – 100 watt	-	-	-
HVAC	1 ton 2 KW	-	110000	660000
Lift core	6 person 1 KW	3	15000 for 6 persons	45000
Power socket	500 watt	40	20000	250000
Normal socket	60 – 70 watt	60	3600	50400

Table 2: Per day energy use in building

Total need: 1084360 watt, Use 70 % = 759052 watt =759.052 KW, Electricity cost per day: 4240.80 taka, (unit price 5.58 BDT)

Source of energy	**% of total energy**	**Per day need**	**Per month need**	**Total energy need per year**	**Total energy cost per year**
environment	16	1130 KW	33900 KW	406800 KW	2269944 TK
Energy source from region	64	4518 KW	135540 KW	1626480 KW	9019958.4 TK
Renewable energy	0	0	0	0	0
Generator	20	1412 KW	42360 KW	508320 KW	2836425.6 TK

Table 3: Per day energy demand of CNF building, Chittagong

5.1 THERMAL ANALYSIS

From the field survey it also noticed that the heat flux entering the building through the window is significantly smaller than the heat flux entering through the walls because of small square size windows. The performance of the building was influenced by the heat entering the window. The incoming solar radiation via the window becomes the dominant driver for the internal temperature. The heat exchange occurs through the window for both winter and summer. In winters the peak incident solar radiation falling on the north facing window. In summer due to the higher solar altitude no direct solar radiation is observed on the north face of the building, but the reflected and diffuse radiation still enters the building. The diffuse radiation enters the building throughout the day, from 6.30am until 5.30pm, and peaks in the order of at 12.30-2.00pm. (Field observation) Approximately 75 % of heat enters into building through ordinary clear colored glass windows. The amount of solar radiation entering through the window is beneficial in winter when this heat energy can be stored by the thermal mass of internal brick walls and the concrete slab (roof and floor).

Direct solar radiation falls on the white wall surface during the day time and increases the temperature of the room because of the small size zone height but at the middle portion of the building, temperature is less than the other zone of the building.
Commercial buildings have a significant impact on energy use and the environment. They account for approximately 18% (17.9 quads) of the total primary energy consumption in our country. The energy used by the building sector continues to increase, primarily because new buildings are added to the national building stock faster than old buildings are retired. Energy consumption by commercial buildings will continue to increase until buildings can be designed to produce more energy than they consume.

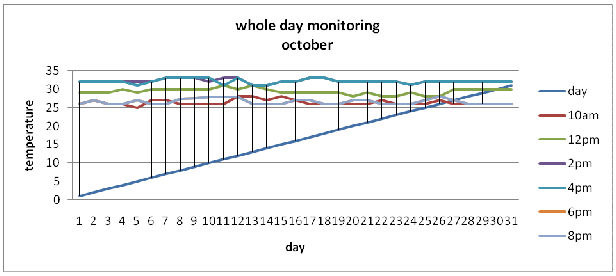


Fig 6: Whole day monitoring result by simulation

In case of commercial buildings we studied has a unique purpose and function, but all have commonalities. Each building must provide visual, acoustic, and thermal comfort for the occupants. All must stand up to climatic conditions, and all must meet or exceed the programmatic requirements for their spaces. The building in this study is not fully successful in these respects, and is all not good energy performers.

5.2 BUILDING FABRICATIONS

An important aspect of building materials is the building fabrication. Fabrication consists of materials that minimize the flow of energy through the surfaces of buildings. This includes materials to reduce both conduction and radiation of energy. Without insulation, the energy flow in buildings would be too immense to preserve comfortable conditions via passive means. i.e. without the use of mechanical techniques for heating and cooling.
In this building brick, glass and concrete are mainly used. These materials are values are the followings:
Brick: 0.8, concrete: 1.8 and glass: .14, gypsum board: .6 (for interior use) and wood: 1.01-1.4

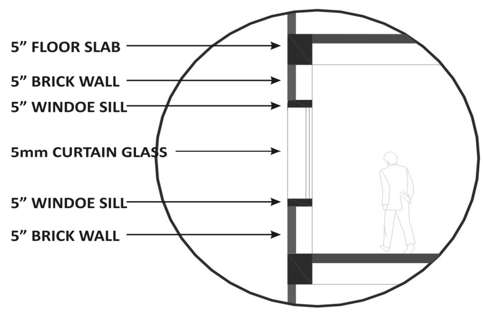


Fig 7: Wall & window section of the building

Thermal resistance (R) is a measure of the effectiveness of the insulating material, the larger the "R - value" of a material, the better. For the purpose of calculation of total energy transfer, the reciprocal of the thermal resistance is the "U - value", and is measured in W/oC/m. The smaller the U - value the larger the thermal resistance.

In this building thermal Conduction is the process of heat transfer through a material medium in which kinetic energy is transmitted through the material from particle to particle without displacement of the particles.

Building surface	Total Area
Window	2000 sqm
Glass	1525 sqm
Solid wall	3800 sqm

Table 4: Building surface area of various components

5.3 SITE PLANNING AND LANDSCAPE

Lack of Careful building sitting and no consideration about preserve native vegetation, agriculture, recreation, and wildlife habitat while providing a serene and healthy setting for this building. There is always a gap between Building exterior and landscape Management plan. During Site Development and construction period most of the built site has no consideration about protect or restore open habitat and Pest Management, erosion Control and landscape Management plan From the physical field survey it is noticed that the building has no consideration about the ratio of open space and built space. The building has less than 40% open green space and no consideration about the future expansion. It creates tremendous problem in future. There are also some lacks findings are given below:

- i) Contaminated Site Remediation
- ii) Storm water Quantity Control and management
- iii) Heat island reduction
- iv) Compliance with Local Regulations
- v) Soil Erosion Prevention & Control

5.4 WATER CONSUMPTION

From the physical field survey it is noticed that the building has less consideration about the water conservation and water efficiency strategy. This has less efficient indoor plumbing fixture and water harvesting system. There is no use of water that comes from rain and no consideration about water efficient landscaping.
There are also some findings from the field survey are given below:

- i) Lack of Minimum indoor plumbing fixture and fitting efficiency
- ii) Water performance Measurement is rarely found
- iii) Lack of consideration about Water use reduction
- iv) Lack of water efficient landscaping
- v) No consideration about Rainwater Harvesting

5.5 INDOOR ENERGY AND ATMOSPHERE

Achieving a sustainable production building requires a commitment from developing the initial energy conservation and atmosphere documents through detailing and commissioning.

- i) Lack of Components of the energy conservation and atmosphere in this building are given bellow:
- ii) lack of opportunity about performance Measurement—Building automation System
- iii) Lack of on-site and off-site renewable energy

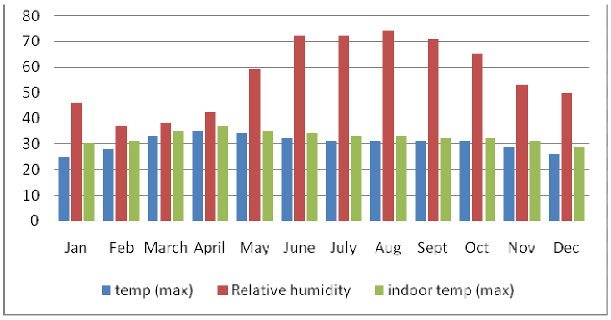


Fig 8: Whole year indoor environment analysis by simulations

5.6 BUILDING ENVELOP

By now, the building envelope serves multiple roles. It protects the occupants from changing weather conditions and it plays a key part in meeting the occupants' comfort needs. The heating, ventilating, air-conditioning, and lighting (HVAC&L) systems complement the architectural design, govern the building's operation and maintenance costs, and shape the building's long-term environmental impact. But in our country even now there is no consideration about sustainable ventilation, lighting, building envelope etc. From the field survey, we noticed that most of the occupants who sit beside the AC often suffer from various health's hazardous. In working section thermal level is high and no perfect monitoring system is found in the building. Noise level control is another problem. Maximum building floors maintain 24-28 degree Celsius temperature for indoor environment by mechanical ventilation system but it cost excessive cost for whole month and whole year and need extra energy. On the other hand the east/west axis, wall providing excessive solar heating and day light, and no horizontal architectural elements shading the window in summer. Heat generates from machine in the office section of the building.

5.7 LIGHTING

Most of the floor there is no consideration about the diffuse day lighting. From the field survey it is noticed that most glass surface is fixed and ventilation system is poor. And the ratio of floor height and floor width is not proper for day lighting. So artificial light is used for the maximum working time and it need extra energy load. It costs almost 5,000 take per floor for just artificial lighting system. When the time of load shading – generator is used for power (electricity).lighting level is not considered. So they are not able to know the actual value of lighting level that they need. According to energy analysis it's a big matter of consideration.

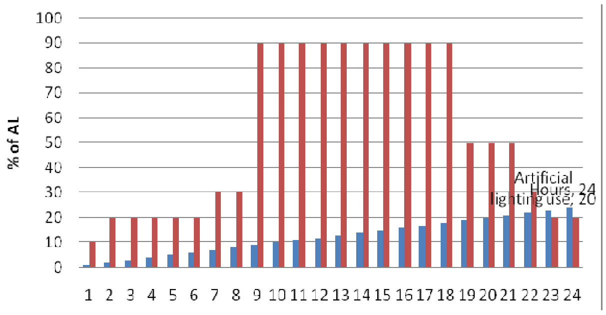
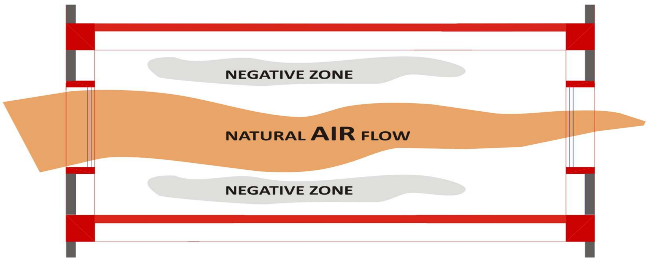


Fig 9: Artificial lighting analysis by simulations

5.8 NATURAL VENTILATION

Natural ventilation techniques of this building are poor because of fixed window and fixed glass. Most of the time maximum windows are closed and as a result natural air flow movement is being hampered.



The potential for reducing the cooling load by the use of natural ventilation is not considerable and depends on the location. The maximum reaches 50% which means that the other 50% have to be cooled mechanically. Taking this into consideration there remains the problem of a hybrid ventilation strategy to ensure that buildings are naturally cooled when possible and the annual electricity potential is used additionally. From the field survey it is noticed that

Object	Unit energy demand	Unit no	Total energy demand Per floor (watt)	Total energy demand (watt)
HVAC	1 ton 2 KW	-	110000	660000

For 1 month: 660000x8=5280000x30=158400 KW and for 1 year 158400x12=1900800 KW
Total unit price: 1900800X5.58 (Per Unit Cost) =10606464 taka
And the electric bill is very high for the year and month just for lack of natural ventilation system.

6. CONCLUSION REMARK

The data presented here represents only a small portion of the overall volume of data collected to date. The thermal behavior of the buildings surface is influenced by the day-to-day and seasonal variations. The thermal behavior of the modules also represents upper and lower extremes as there is no direct entry of solar radiation, to provide solar passive heating in winter, or night-time ventilation during summer to cool the building's interior. The response of the modules is also affected by several other parameters related to the geometry of the building including wall/floor area ratio and the lack of internal partitions. the data provides a useful understanding of the energy used in a commercial building under Bangladesh climatic conditions. This can be observed by comparing the internal/external mean temperatures. These temperatures are similar, with the internal temperatures generally being slightly higher. The higher mean internal air temperature in the buildings is likely to be due to the absorption and conduction of solar radiation by the masonry walls. The presence of cloud cover significantly reduces the maximum temperatures observed on the surface of the external masonry walls. The building shows the ability of masonry walls to attenuate the day-night temperature variation. The internal air variations were in the order of 2.5–3.5ºC for the cavity brick module and 3–5ºC for the brick veneer for external air variations up to 22ºC. The cavity brick module showed a smaller variation despite this walling system having only approximately half the R-value of brick veneer construction. According the whole building energy analysis it is noticed that for being of lack of natural ventilation, façade design and materials, building height and depth ratio, window and glass pattern, the energy cost of this building is very high. It should be reduced by the proper energy efficiency design methods.

REFERENCES

[1] Marsh, A., Eco-Tect, (2010), *conceptual design analysis tool*, San Rafael, USA.
[2] Auliciems A and S Szokolay (1997) Thermal Comfort, PLEA Note 2, *Passive and Low Energy Architecture*
[3] Electric Power Research Institute (EPRI) EM-4195, Energy Management Systems for Commercial Buildings
[4] Energy Efficiency and Renewable Energy Network (EREN),http://www.environmental-expert.com/articles/article193/article193.htm