DESIGN APPROACH OF ENERGY EFFICIENT READY MADE GARMENTS FACTORY IN VIEW OF THERMAL COMFORT

Sajal Chowdhury* and Md. Rabiul Alam

Department of Architecture, Chittagong University of Engineering and Technology, Chittagong, Bangladesh
** Corresponding author (sajal_c@yahoo.com)*

ABSTRACT: In Bangladesh Garments Factories are playing a vital role in the field of economical development but over the last 32 years these factories have been highly criticized for the hazardous working environment in the production floor in which high thermal gains from the artificial lighting, poor natural lighting system, excessive heat from the upper metal roofing system are common phenomenon. Most of our Garments Factories do not consider building depth, building height, volume, equipments and number of storey which factors are very essential to make factory energy efficient. This paper identifies the cause of poor and unhealthy working condition of Garments Factories in Dhaka and detail analysis in view of Thermal Comfort level to make garment factory energy efficient by a design approach with the help of building simulation tools such as Radiance, Eco-tech, Dia-Lux etc.

Keywords: *Thermal Comfort, Energy Efficient Design Approach, Ready Made Garments Factory*

1. INTRODUCTION

The Ready-Made Garment (RMG) industry of Bangladesh started in the late 1970s and became a prominent player in the economy within a short period of time. The industry has contributed to export earnings, foreign exchange earnings, employment creation, poverty alleviation and the empowerment of women. But Like many other developing countries, occupational health is still a neglected area in Bangladesh. Very little industrial management is concerned to the work place environment and health of the workers. As a result, the industrial management does not provide any attention to the work place injuries, sickness and environment.

The workers bear the sole responsibility to their health and safety. But to ensure sustainable economic and social development, the industry owners and management must take responsibility. Any development will be meaningless if the poor workers do not have any share of it.

The objective of this work is to investigate the energy efficient strategies that can be employed within RMG factories and demonstrate the role of modeling and simulation in the designing of low energy RMG sector in Bangladesh.

The purpose of evaluating these case studies is to demonstrate that energy reduction can be achieved in Garments Factory Buildings in view of Thermal Comfort. Design approach, building envelope, planning and building services are all considered with respect to comfort level in RMG sectors. The key factors associated with the successful achievement of low energy RMG factory design have been identified and formulated into a methodology to provide a guide for designers.

2. CLIMATE OF DHAKA CITY

Dhaka city has mainly three different seasons. These are:

1. The hot dry season (March-May)
2. The hot humid season (June- November)
3. The cool dry season (December- February)

April is considered as hottest month and is considered average temperature is available as 30.3 – 34.8 deg c

January is considered as coldest month and is considered average temperature is available as 9 – 15.2 deg c

Type of Sky	Hot Dry	Warm Humid		Cool Dry	Total Day
	Pre-	Monsoon	Post-	Dec-Feb	

	Monson March-May	June-Sept	Monsoon Oct-Nov		
Clear Sky	62	38	39	77	215
Overcast Sky	30	84	22	14	150
Total Days	92	122	61	90	365

Table: 1 Sky condition with respect to cloud cover for year (Joarder, AR, 2007.)

Sky condition with respect to cloud cover for year is shown in Table 1. It is seen that April is the hottest month with average temperature of 32 deg C and January is the coldest month having temperature 15 deg C.

3. METHODOLOGY OF ANALYSIS

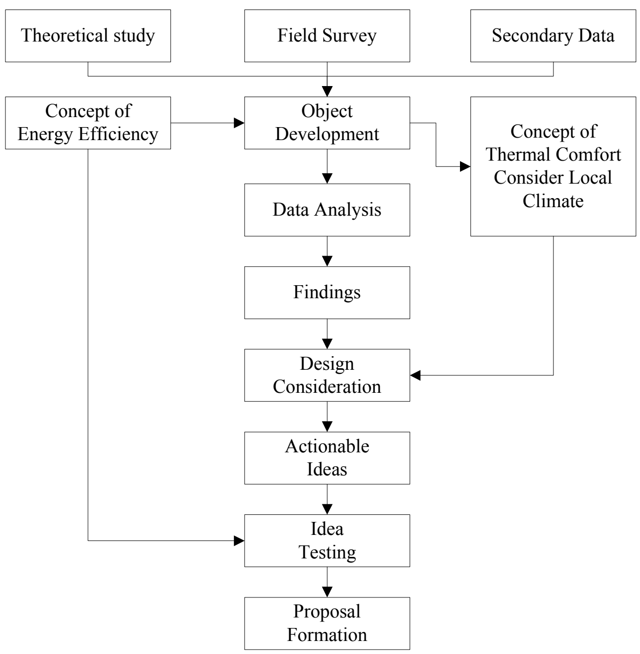


Fig. 1 Structure of the Research

From Fig. 1 it is seen that there are difference strategies and steps to identify the design approach of energy efficient Garments Factory in view of Thermal Comfort level under the consideration of Dhaka Local Climate, Bangladesh to make sure of energy demand and generation in all the RMG sectors. In this paper after gathering the National and International theoretical Knowledge about the RMG sectors, data have been collected from practical field survey. After the data analysis, with the help of energy efficient design considerations and building energy simulation software was used to get the final design criteria considering thermal comfort level for the Ready Made Garments Factory in Bangladesh.

4. ENERGY EFFICIENCY AND THERMAL COMFORT

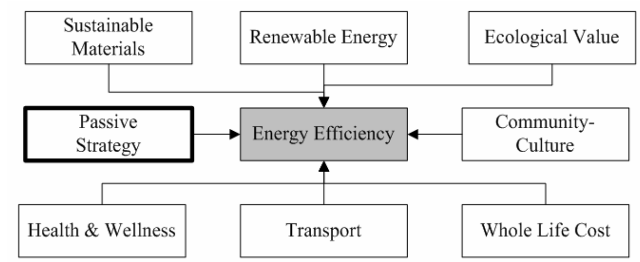


Fig. 2 Components of Energy Efficiency

From Fig. 2 it is shown that eight components are co-related with the Energy Efficiency, among them passive design features are discussed to achieve thermal comfort level in this paper. Thermal comfort is one of the main elements of passive design features. Standard Thermal comfort level has not been yet introduce for the working (production) area of the Ready Made Garments Factory in Bangladesh which is very important to make a factory green and energy efficient. Thermal comfort is affected by heat conduction, convection, radiation and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate thus maintaining thermal equilibrium with the surroundings. Any heat gain or loss beyond this generates a sensation of discomfort. It has been long recognized that the sensation of feeling hot or cold is not just dependent on air temperature alone. Factors determining thermal comfort include: (i) Air temperature (ii) Mean radiant temperature (iii) Air movement / velocity (iv) Relative humidity (v) Isolative clothing (vi) Activity levels. The concept of thermal comfort is closely related to thermal stress.

4. FINDINGS FROM FIELD SURVEY

From the field survey it is seen that the following gaps are generally occurred in local RMG factory, Bangladesh which has the great impact of thermal comfort level in the production space.

Most of our RMG factories are constructed by steel structure in the upper portion and brick plaster in the lower portion which is found from field survey. RMG factories have no consideration about protect or restore open habitat and pest management, erosion control and landscape management plan in Bangladesh. From the physical survey it is noticed that most of Ready Made Garments factories have no reflection about the ratio of open space and built space. Many of the factories have less than 30-40% open green space and no consideration about the future expansion. There no found of non-fossil fueling facility for vehicles and lack of green consideration about soft paving. According to field survey it is noticed that most of Ready Made Garments factories have less reflection about the water conservation and water efficiency strategy. Most of the factories have no efficient indoor plumbing fixture and water harvesting system. There is less use of water that comes from ETP and no consideration about water efficient landscaping. 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. In Bangladesh even now there is no consideration about sustainable ventilation, lighting, building envelope etc. From the field survey, we have noticed that most of the occupants who sit beside the evaporative cooler often suffer from various healths hazardous. In many factories are using LED in sewing section for effective lighting. But here some problems are created. This machine LED light generally creates contrast between work plane and surroundings to occupants and this happen serious problem in eye in future.

Workers Percentage (%)	General Diseases	Average Duration of Sufferings (in days) per Month
57	Headache	14.4
21.9	Muscular-skeleton pain	21.8
42.4	Weakness	19.8
20.3	Eye pain	10.7
3.2	Ear pain	12.8
18.3	Cold/Cough	15.6
11.3	Chest pain	12.2
9.9	Diarrhea/stomach Dysentery	5.5

Table: 2 Type of diseases or illness of workers for bad working environment (Paul, Majumder, 2003)

In finishing and sewing section thermal level is high and perfect monitoring system is not found most of factories. Noise level control is another problem. Most of factories want to maintain 22-26 degree Celsius temperature for indoor environment but for our climatic consideration what is the standard temperature, we don't know even now. Heat generate from machine in the dyeing section of RMG factory. Now days many of our factories take the initiatives against Environmental tobacco Smoke and dust Control by using sensor and highly performance machineries. The single largest operating cost of industrial buildings in the Bangladesh is lighting. Lighting systems represent one-third or more of the total electrical energy costs of a commercial building. They also introduce heat into the space and increase building cooling loads. Because lighting systems significantly impact a building's operating cost and energy performance, evaluate options for the lighting systems before considering strategies for a low-energy HVAC system. Also, take advantage of day lighting opportunities whenever possible. Most of our RMG factories use artificial lighting for whole day long. But they have a lot of opportunities to use natural day light. And final result is they have to need provide more electricity which is our main problem. The sustainable placement of exhaust fan and evaporative cooler are not considered while designing a factory. As a result thermal comfort level is high at the middle part of the factory.

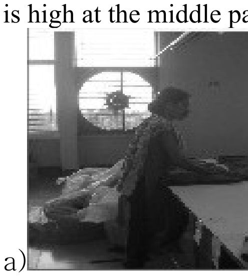
a)  b) 

Fig. 3 a) Worker besides the Evaporative cooler; b) artificial lighting during day time

From Fig. 3 it is shown the internal hazardous condition of a local RMG factory. From the field investigation it is noticed that there are many water bodies besides the factories. But no more consideration and proper design initiatives about natural disasters and risk management. Geographically specific environmental priorities may cause flood and serious problem at any time because lack of management consideration about efficient water treatment. Sustainable orientation is another key point for the factory building. Many of our factories should not compromise about sustainable orientation. As a result excessive heat and light come through windows from outer environment.
Density is one of the vital issues for poor indoor air quality. In maximum RMG factories have no adequate movement place for worker and production space. Therefore, it creates lack of fresh air in production area. As a result indoor air temperature becomes high.

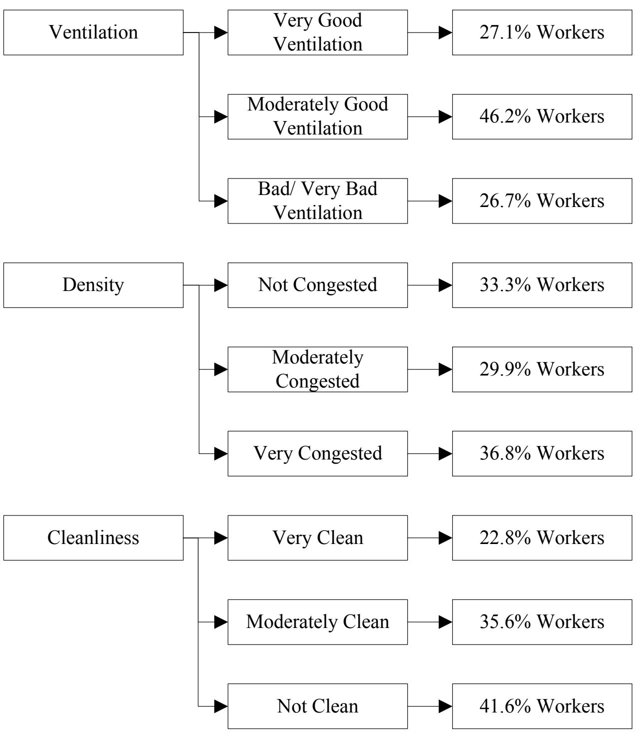


Fig. 5 Nature of physical working condition and health condition of the RMG factories

From 15 factory buildings survey it is shown about 50 percent garments workers have moderate ventilation system. As a result mechanical ventilation system is required to improve the indoor air temperature and it costs extra energy per month. From the field survey it can also be seen that many of the factory buildings have no observation about the wall and window area ratio. It is observed that for 550 sqm floor areas, it has only average 21% opening which is not sufficient for natural cross ventilation system.

5. SIMULATION MODELING PROCEDURE

The study is performed in a simple rectangular shape for the benefit of comparison of thermal condition and comfort level of the workers. Factory size is considered as 80m by 25m (depth) and ceiling height is considered as 3.00m to 12m and windows area is considered as 15% to 80% (total wall openings). Room is considered to be constructed by brick, metal, concrete and cleared glass construction (average U value for cleared glass construction 5.100 w/m2k). In all cases all windows are located .76m above the floor level and are made with 25.4mm aluminum frame. Impact of exterior surface has not considered on the interior surface. It is assumed that 150-200 workers work in this single production space model from 9.0 AM to 7.0PM in a day. All analysis is based on the local climate of Dhaka, Bangladesh. Eco-Tect and Radiance building environmental simulation software are used to predict the circumstances.

5. DESIGN CONSIDERATION

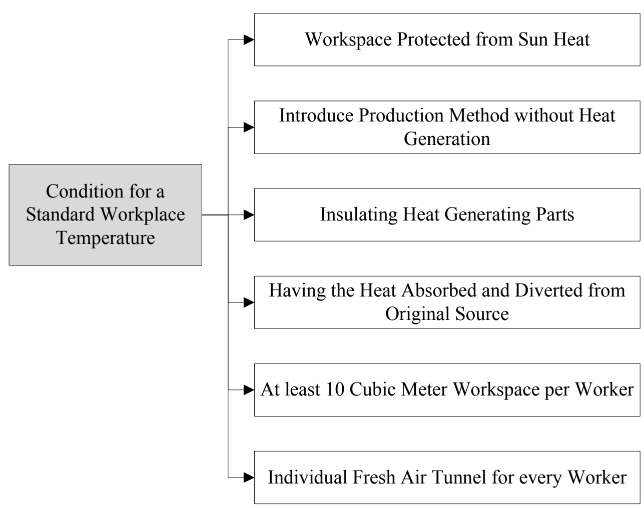


Fig. 6 Condition for standard workplace temperature

According to the international labor law and WHO Fig. 6 is shown that six requirements are very essential for a factory building to achieve the good working environment and indoor air quality.

Area Name	Space Ratio	Suggested Design Temperature	Hours/Day Occupied
Sewing-S	S=X	26-28 deg C	12
Cutting-C	S:1=X:2X	26-28 deg C	12
Irining-I	S:1=X:2X	26-28 deg C	12

Table: 3 Space ratios of production areas

From Table: 3 it can be shown that sewing section is two times longer than the cutting and ironing section to achieve the great impact from the environment.

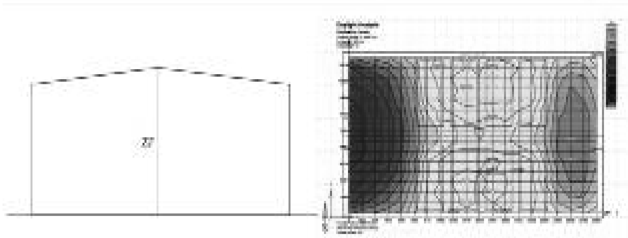


Fig. 7 Factory height analysis by Eco Tect and Radiance

The floor plates and height of a RMG factory can be varied depending on the thermal levels required, occupancy and activity requirements. Based on the internal heat gain, space layout can be adjusted. From Fig. 6 it can be seen that if the height of the factory building is 6m to 8m, it will give the maximum comfort level for the production area in which 150-200 workers work at a time in a single space from 9.0 AM to 7.0PM.

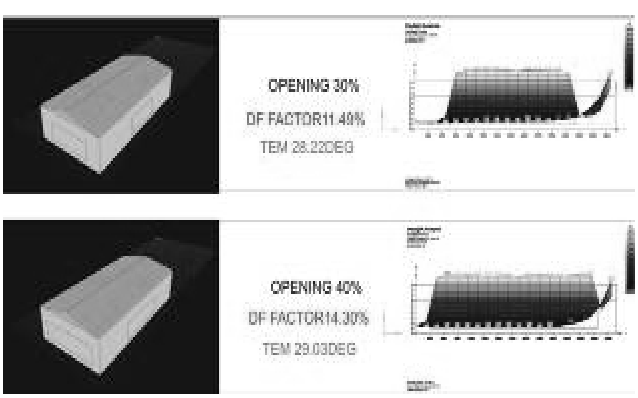


Fig. 8 Windows opening analysis by Eco-Tect and Radiance

According to the thermal comfort factors, production space temperature and comfort level are calculated with the help of Eco-Tect and Radiance software (Building Performance Software) for all types of windows openings. From the simulation result it is seen horizontal window with the shading device has achieved the good quality comfort range of temperature and the minimum percentage of openings should be 25-35% to achieve the standard thermal comfort level for production space. The floor plate of a factory building should be no longer deeper than 25-30m to assist cross ventilation opportunities. It is measured that production floor area should be come from the following equation: 15 x no of production line x no of machine x sft per machine + circulation. This equation gives the optimum comfort level for the production area.

In Bangladesh, most of the RMG factories have no consideration about the building finishes and external-internal color scheme which is very important to make a factory green and cost effectives.

Option	Elements	Materials	degC
Model 1	Roof Wall Floor	Corrugated metal sheet Brick plaster Concrete slab	29.21
Model 2	Roof Wall Floor	Corrugated metal sheet Concrete block plaster Concrete slab	25.81
Model 3	Roof Wall Floor	Corrugated metal sheet Double brick cavity plaster Concrete slab	25.32
Model 4	Roof Wall Floor	Corrugated metal sheet Double brick solid plaster Concrete slab	24.8
Model 5	Roof Wall Floor	Corrugated metal sheet Brick concrete block plaster Concrete slab	24.75

Table: 4 Factory building materials analysis

From this Table it can be shown from the analysis, if the factory wall is constructed by brick plaster only, it creates high temperature for the indoor space than others. Standard comfort level can be achieved when the factory building's wall is constructed by cavity or solid block because it creates heat barrier from outdoor to indoor.

Fig. 9 Opening shape and window patterns analysis by Eco-Tect and Radiance

From Fig. 9 it is shown that windows with horizontal and vertical blind cannot penetrate daylight properly but it creates more comfort inside the indoors and makes the direct sunlight diffuse which is good for work efficiency. It is also seen that when day light penetrates high level into the inner side of the production space, it creates more discomfort level. As a result the temperature becomes high and work efficiency goes down lower gradually.

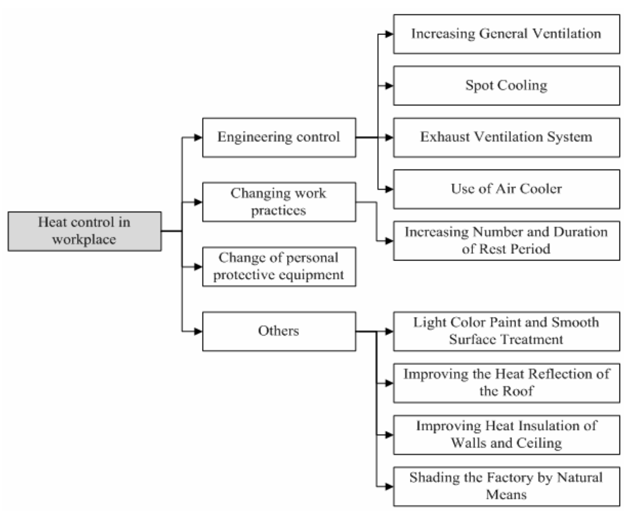


Fig. 10 Heat control strategies in workplace

Finally it can be stated that for the heat control in a production space of RMG factory four techniques can be taken which is indicated in Fig. 10.

7. CONCLUSION

In this study, it has been observed that enhanced daylight, color, building height and depth, material selection windows performance have often resulted in reduced thermal performance in a production space. Effective design solutions will require supervisory level control algorithms by which designers would be able to balance the visual and thermal aspects to accomplish energy efficiency. A methodology has been developed for the combined thermal and human comfort of RMG factory buildings and applied to existing RMG factory in support of design guidelines in Bangladesh under the consideration of local climate.

REFERENCES

[1] Marsh, A., Eco-Tect, (2010), *conceptual design analysis tool*, San Rafael, USA.

[2] Majumder, Pratima Paul and Begum Anwara,(January 2006), *Engendering Garment Industry : The Bangladesh Context*, The University, Press Limited, Dhaka Bangladesh.

[3] Mauritius, C. Bhurtun, N. Kistamah and J. Chummun : *Energy Saving Strategies In Textile Industry*

[4] Auliciems A and S Szokolay (1997) Thermal Comfort, PLEA Note 2, *Passive and Low Energy Architecture*